How to manage and improve inventory control

A study at AB Ph Nederman & Co for products with different demand patterns

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Preface

This master thesis is the final part of our education, Master of Science in Industrial Management and Engineering at Lund University, Faculty of Engineering. It has been conducted in cooperation with the employees at AB Ph Nederman & Co under the supervision of Professor Jan Olhager via Lund University, Faculty of Engineering, Department of Industrial Management and Logistics, during the spring of 2012.

We would give a special thanks to our supervisor, Fredrik Arborelius at Nederman who have helped and guided us throughout the entire master thesis by always being there and helping us with different tasks and it would never have been what it is without his help. We would also like to thank Maria Waidele and Erik Blix at Nederman for their directions and guidance that have kept us in the right direction and the rest of the employees for answering our questions and thereby contributed to the result.

Finally we would like to thank our supervisor Professor Jan Olhager at Lund University, Faculty of Engineering, Department of Industrial Management and Logistics, who have helped us and guided us with valuable comments and thoughts throughout the master thesis.

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Abstract

Title:	How to manage and improve inventory control – A study at AB Ph Nederman & Co for products with different demand patterns
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Background:	Nederman has a long term goal of improving their supply unit in Helsingborg. One step of this is to investigate if there are any improvements to be made in the inventory control in terms of stock levels and service level. This since the employees at Nederman believes that the existing methods are too blunt as a tool for the product range and that their methods can be improved by adding a new dimension on the existing system in terms of demand pattern.
Purpose	The purpose of this master thesis is to improve the inventory control at Nederman by lowering the stock level given the goal of the service level.
Method:	This master thesis has been performed with a systems approach. An abductive research method has been used and the authors have been moving back and forth between theory and practice. A huge amount of numerical data from different sources has been used throughout the master thesis why most of the analysis has been quantitative, but it has been supported with more qualitative analysis in terms of interviews.
Theory:	The theory used in the master thesis is a mixture from different authors and time periods. But since most of the traditional theory for inventory control has been consistent the last decade it could therefore be summarized from a few well known authors and then supported with more recent theory.
Conclusions:	The conclusions of this master thesis are divided in a few different steps. It was concluded from the current state analysis that the product range was pretty complex and that the existing system had potentials for improvement. Further analysis showed four distinct types of demand pattern and by dividing the products according to this the authors found a way to apply this to the existing system. The implementation showed that improvements were possible in terms of a lower safety stock value with a maintained service level. But that it in order to make further improvements on the service level was needed an even more sophisticated system.
Keywords:	Inventory control, demand pattern, coefficient of variance, reordering point, safety stock.

Sammanfattning

Titel: Att styra och förbättra lagerehantering – En studie hos AB Ph Nederman & Co för produkter med olika efterfrågemönster.

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Projektbeställare: Erik Blix, Fabrikschef, Nederman.
Maria Waidele, logistikchef, Nederman.

Backgrund: Nederman har ett långsiktigt mål att förbättra enheten i Helsingborg. Ett steg i detta är att se om det finns några förbättringar att genomföra i lagerstyrningen i form av lager- och servicenivåer. Detta då de anställda upplever dagens verktyg som ganska trubbiga för det nuvarande produktsortimenetet och att detta kanske kan förbättras genom ytterliggare en dimension på det befintliga systemet i form av efterfrågemönster.

Syfte Syftet med examensarbetet är att förbättra lagerhanteringen genom att sänka lagernivåerna givet målet på servicenivån.

Metod: Detta examensarbete har utförts med ett systemsynsätt. Det abduktiva metodsättet har applicerats på detta och författarna har rört sig fram och tillbaka mellan teori och praktik. Mycket numerisk data från många olika källor har använts under projektet vilket lett till en kvantitativ analys som har stöttats med kvalitativ analys i form av intervjuer.

Teori: Teorin som använts i detta examensarbete är en blandning från olika länder och tidsepoker. Men eftersom mycket av den klassiska teorin för lagerhantering inte förändrats mycket under detta århundradе kan den därför bli sammanfattad från ett fåtal välkända författare som sedan stödjs av nyare teori.

Slutsatser: Slutsatserna i detta examensarbete är uppdelade i några steg. Först och främst fastställdes det genom nulägesanalysen att produktsortimentet var ganska komplext och att det nuvarande systemet hade potential för förbättringar. En vidare analys visade att det fanns fyra tydliga efterfrågemönster och genom att dela upp produkterna efter dessa mönster så fann projektgruppen ett sätt att applicera detta på det befintliga systemet. Implementationen visade att förbättringar var möjliga i form av lagersänkningar med upprätthållen servicenivå, men att det för att lyckas med ytterligare förbättringar av servicenivån behövs ett mer sofistikerat system.

Nyckelord: Lagerhantering, efterfrågemönster, variationskoefficient, beställnings-punkt, säkerhetslager.

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1. Introduction

This chapter aims to give an introduction to the subject of inventory control and the entire report by discussing the background followed by the problem statement and the purpose. Focus and delimitations of the master thesis are described and the target group is identified. The chapter ends with an outline to make it easier for the reader to follow the rest of the report.

1.1 Background

AB Ph Nederman & Co is a company that develops, produces and sells systems for improving the safety and working conditions in factories and other facilities. Their global headquarter and main distribution center for Europe is located in Helsingborg, Sweden. The variety of different parts and products are increasing continuously and to be able to control the flow of goods and optimize the inventory cost Nederman is putting more and more effort on their inventory control system.

The distribution of material and goods are also essential for a company´s development and without the capability to transport, deliver and store products at the right time and place, the development will grind to a halt[1]. More and more companies realize today the importance of inventory management, and that an effective inventory control could be a competitive advantage.

Inventory management is an old concept that was first used in the beginning the 20th century. Many of the theories and statistical system that the industry uses today were developed nearly 100 years ago. Even if the theories are the same, modern computer systems have changed the inventory management the last decades. Nowadays warehouses and inventory systems can be controlled with precisely performance which has changed the conditions for inventory management. The opportunity to be able to optimize the inventory system fully, by controlling every item individually down to product level, has been possible to do the last decades. [2]

In a sophisticated computer system, all types of functions could be optimized and completely automatically updated. Everything from the analysis to support functions and maintenance could be controlled automatically and the focus for the supply chain unit could instead be put on future development and optimization. Today many companies are in the situation of changing the system and implementing new and better systems, but even if the benefits are large the systems are not free of complications. The downside is that these systems are expensive and companies needs to be able to use the system fully to reach all the benefits of it. The price of a system could hardly be justified if only parts of the functions are used, and before implementing a new system a company needs to ensure that they have the competence and knowledge to use these functions. This is a situation Nederman and many other businesses are facing now and in the near future.

Many companies, like Nederman, see their future sales figures, for on stock articles, as unpredictable and store the products in large batches to cover for future demand. Even if the product range is wide and storing everything in large batches has very negative effect on the stock level, there is still a common "knowledge" that the future demand is impossible to predict and storing everything is the

[1] S Axsäter, Inventory Control*,* 2006, p. 1
[2] Ibid.

only option. Earlier research has showed that there is often the possible to analyze old sales data and classified the article range into different demand pattern and therefore be able to better predict the future sales. On example of this is the study that was made on the German company Rohm and Haas in 2000, where the stock level and service level was drastically improved after sorting and controlling the products after demand pattern.[3] This is something that Nederman also wants to investigate to see if there are any possible improvements in n their system by looking at the demand pattern.

1.2 Problem statement

The tools and methods used for the inventory control at Nederman are among the staff perceived as quite blunt. The major reason for this is that all products are controlled likewise when setting a proper safety stock based on the same two parameters, frequency and product value. All products that are stock items are divided in two different groups, manufactured and purchased goods. All the products from each group are distributed in a matrix, one for each group and this is the tool used for controlling the safety stock. The matrices are based on the value and frequency where every combination is assigned a certain amount of safety days that serve as the base for every products safety stock. These matrices are called SS-bas matrices and the value (amount of safety days) is called SS-bas. The amount of days has earlier been controlled and adjusted by the plant manager Erik Blix, based on his experience and how the service level for each segment has developed over time[4].

There is a belief that it is possible to divide the products in different classifications based on their demand pattern and control the identified subclasses differently. These classifications will add a new dimension to the existing system with SS-bas matrices and create a more adopted tool that may result in more accurate stock levels that still meets the stated service level and therefore improves the overall inventory control.

This creates the following quite clear problem statement:

"Find a way to divide the products into different classifications based on their demand pattern in order to improve the inventory control."

And in order to make improvements the second focus will be:

"Finding ways to control the different classifications that will lead to improvements on stock levels given a certain service level."

[3] A D'Alessandro, A Baveja, Divide and Conquer: Rohm and Haas´ Response to a changing Speciality Chemicals Market, *Interfaces,* p. 4.

[4] Erik Blix, plant manager, interview 2012, 01 19

1.3 Purpose

The purpose of this master thesis is to improve the inventory control at Nederman by lowering the stock level given the goal of the service level.

1.4 Approach

In order to reach the purpose the first task is to classify products with different demand patterns and properties that can be controlled differently. The aim is to find a number of products that will represent each classification and then implement new controlling tools for those in the existing system. The products will then be tested in reality and compared towards reference groups with similar properties and then evaluated. The result will in the end be fully evaluated and compared with two other proposals but this is not within the scope of this master thesis.

The deliverables in the master thesis can be summarized in the following bullets.

- Define a set of groups with different demand patterns among the products.
- Provide information of how this classification is done and how it can be repeated.
- New start matrices for SS-bas.
- Which effect would this give on the stock level given an overall service level at 94%. (Nederman´s goal for 2012)
- An academic report describing the master thesis and its results.

1.5 Focus and delimitations

The master thesis is limited to the two warehouses in Helsingborg. It will consider both the component warehouse and the warehouse for finished goods. When analyzing the demand pattern the authors will consider all active products that had any transactions the last two years, with exception for new products. This considers all purchased and manufactured products whether or not they are stock items today.

When different classifications are identified a narrower amount of products representing the product range will be further analyzed for finding the right control parameters. To be able to compare the products in a good way the amount of products will be limited to products that had transactions in 2011, was created before 2011 and are both on stock currently and according to this analysis.

When the right parameters are identified 20 % of all products will be randomly selected to serve as a test group to be supervised during the implementation phase.

The authors are bound to use the existing system with SS-bas and the formulas connected to this matrix system. This is resulting in limited possibilities to develop the system for finding the right safety stock levels and to operate under a theoretical service level, but it will still respond to the goal of finding improvements within the existing system.

1.6 Target group

This master thesis is aimed for the warehouse management group at Nederman. It is also directed towards engineering students within the fields of logistics and supply chain management and teachers and professors at Lund University, Faculty of Engineering, Department of Industrial Management and Logistics. These groups are assumed to have a certain level of knowledge in this area and the content and level has therefore been adapted to this.

1.7 Disposition

Chapter 1 – Introduction

This chapter will give an introduction to inventory control and describe the problems at Nederman and what they want to achieve. It will describe the problem statement and the purpose of the master thesis. It will also identify the target group and the delimitations of the study.

Chapter 2 – Presentation of Nederman

This chapter will describe Nederman with its history and today's focus. The products and the customer will be discussed along with how they are operating. There will also be a description of the organization at Nederman on different levels.

Chapter 3 – Methodology

This chapter will give the reader a deep understanding of the overall methodology and also different methods that can be used in similar reports or projects. Areas discussed are research approach, research method, qualitative and quantitative approach, data, analysis model and credibility. Every section will be followed by a clarification of the specific approach taken in this master thesis.

Chapter 4 – Theoretical framework

This chapter will give a base to the reader by describing the theory of all the frameworks used, or in other ways, relevant in this master thesis.

Chapter 5 – Empirical study

This chapter describes all the data that have been collected and used during the entire master thesis. It describes what type of data that are used and how it is handled and sorted before the analysis.

Chapter 6 – Analysis

This chapter will describe how the analysis is done. It will describe how the different demand patterns are identified and how these will stand as the base for dividing the matrices into several matrices with this new dimension. It will also describe how the new start values for SS-bas will be determined, how the updating model is done and show the analysis of the implementation. The results of the different parts will also be presented throughout this chapter.

Chapter 7 – Conclusions and Recommendations

This chapter will summarize the master thesis and describe the conclusion from the result. It will also, based on the implementation phase and the overall analysis, provide Nederman with recommendations of how these improvements could be done in the most optimal way.

2. Presentation of Nederman

This chapter will give an introduction to Nederman for a better understanding of the company throughout the report. It will describe the background and the history, form foundation until today. The products and their customers will be discussed followed by how the organization is structured.

2.1 Background

Nederman was founded in Helsingborg 1944. Philip Nederman, the founder, was quick to see the health risk in the manufacturing industry and started therefore the company. He started to produce ventilation fans and sold them to the construction industry. The business was good and Nederman continued to develop products for a better and safer working environment and stayed specialized on ventilation system. Today the company offers full solutions for all kinds of businesses that need to protect the health of their workers and improving their workplace environment. The customers are in the range from small fire stations to large production facilities.[5]

In 2010 Nederman acquired Dantherm Filtration, and thereby became the world leading company in industrial air filtration and has the markets most complete range of products for extracting hazardous air-borne particles. Nederman's offering covers everything from the design stage to installation, and servicing. The headquarters is still located in Helsingborg, but is indeed a multi-national company which operates in over 30 countries today, see figure 1 for the global presence.[6]

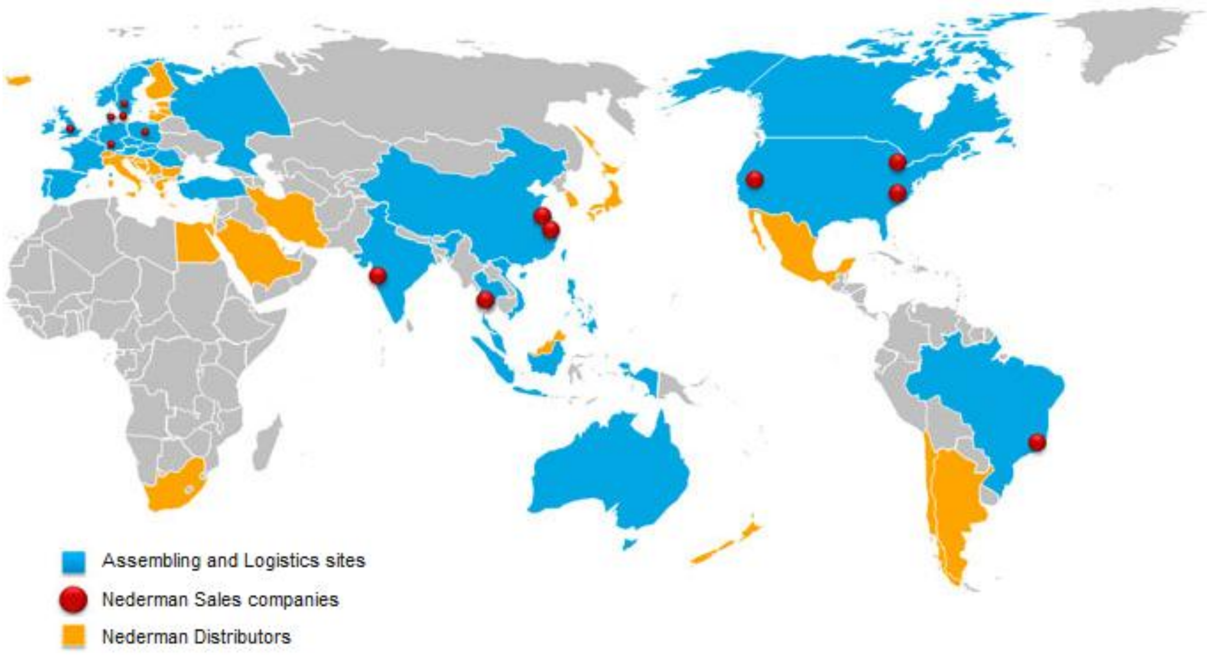

Figure 1 - Nederman´s Global Presence.[7]

[5] Nederman Company History, 2010.
[6] Nederman, 2012, *Nedermans Homepage.*
[7] Ibid.

2.2 Products and customers

Nederman has a large range of products to be able to fully cover the range of safety equipment and to be able to offer complete customized solutions. Nederman develops and assembles products themselves, but a large part is purchased from a number of different suppliers. The products are mainly for air filtration system, developed to absorb products from welding fumes and exhaust gas from different vehicles. But the product catalog includes many other products like safety curtains for handling dangerous liquids or working benches to improve the workplace. The huge range is to be able to fully improve the safety conditions and environment for the workers of the customer's.

The largest markets today is northern Europe, follow by North America and the largest growing market is China, where Nederman sees good future potential.[8]

2.3 Organizational structure

The organization is based around Helsingborg and all important strategic units are based here. The different sales, support, production and logistic units are all located in Helsingborg, which can be seen in the organization map in appendix A.

The operation unit is divided in different supply units, located all over the world. The largest one is the Supply Unit in Helsingborg and it is operated by Erik Blix. The different supply units are quite independent and they are operating individually except for a few examples, like shipping of components between the different units. The structure of how the different supply units are connected is illustrated in figure 2.[9]

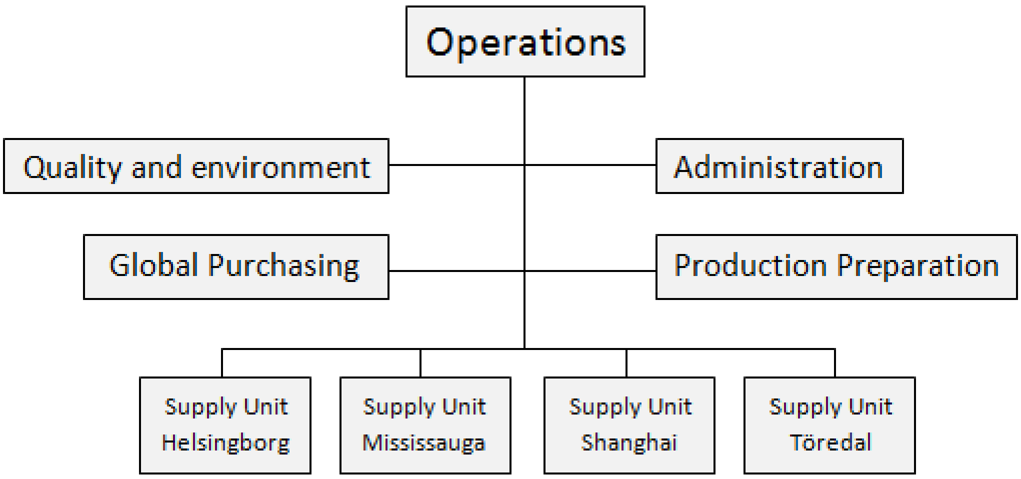

Figure 2 - Production and Operation units globally.[10]

[8] Nederman, 2012, *Nedermans Homepage.*
[9] Nederman, 2010, *Nedermans Homepage.*
[10] Ibid.

3. Methodology

This chapter provides information for the reader regarding choice of methodology. It describes general methodology followed by the strategy chosen by the authors. It will also describe different methods and different data sources followed by the credibility of the report.

3.1 Research approach

In all scientific projects the choice of research and method approach is very important and will affect the outcome of the project in several ways. The overall perception or fundamental assumptions of the world will affect how we as a human perceive data and results. The scientists have developed a "language" to describe the relationship between the fundamental assumptions and the methodology where the concept "paradigm" plays an essential role as a tool. The paradigm acts like a bridge between the fundamental assumptions and the methodology, see figure 3.[11]

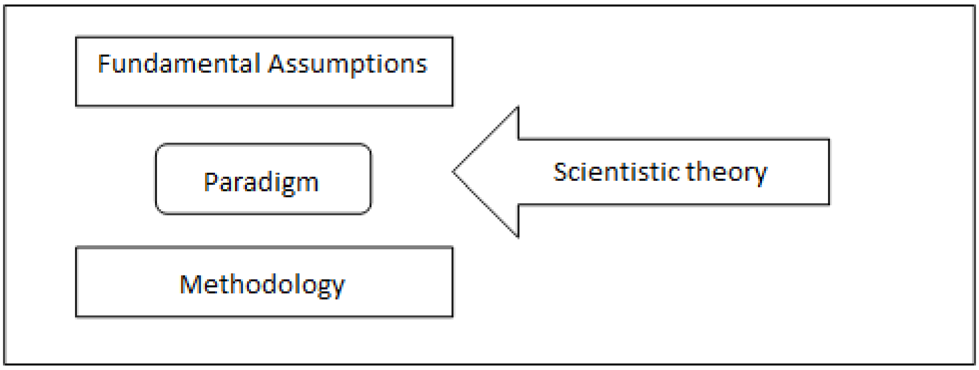

Figure 3 - How fundamental assumptions and the methodology is linked together by the paradigm.[12]

There is a close relationship between paradigm and methodology and multiple methodological approaches can exist within the same paradigm. It is also possible that one methodological approach can find inspiration in several paradigms. There are three different research approaches within the area of methodology in business economics that are stated below.[13]

- Analytical approach
- Systems approach
- Actors approach

The three approaches will be further elaborated in the chapter 3.1.1-3.1.3 and how they are interconnected to each other are explained by figure 4.

[11] I Arbnor & B Bjerke, *Företagsekonomisk metodlära,* 1994, p. 19-37.
[12] Ibid., p. 29.
[13] Ibid., p. 19-37.

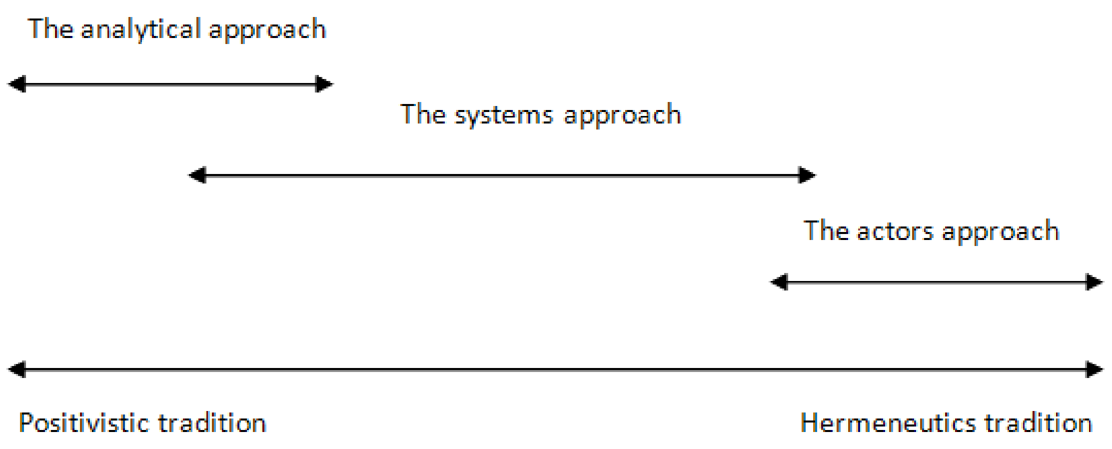

Figure 4 - Connections between the different research approaches.[14]

As can be seen in the figure 4 the analytical approach is in line with the positivistic tradition and the actors approach with the hermeneutics tradition. The approach linking them together is the systems approach that acts like a bridge between them.

The positivistic tradition is closely linked to natural science and the quantitative methods. And to understand what it contains and stands for the following bullets summarizes the tradition.[15]

- It is possible to use natural science to explain the social science even though the fact that human has characteristics that cannot be explained by the nature science.
- It is only events that are possible to observe that can be called valid knowledge and human feelings are not such a thing.
- Scientific knowledge is established via cumulative verified fact and is often called laws.
- The scientist is disconnected from all values that can cloud the objectivity and affect the conclusions.
- There is a strict difference between scientific inquiry and normative inquiry.

The hermeneutics tradition can be associated with the philosophy of interpretation and many things in this tradition are about how to interpret the meaning of different things. It is important for the interpreter to have a pre-understanding and to switch between a total perspective and a partly perspective. It is also important that the interpretations are in a relation to a context. The hermeneutics can also be seen as a general science of communication and understanding.[16]

3.1.1 Analytical approach

The analytical approach is the oldest of the three approaches and has deep roots in the western society. It originates from the analytical philosophy and the main object is that the totality is equal to the sum of the separate parts, see figure 5.[17] This approach describes the world as an objective reality where causal relations can be identified. This means that the reality can be decomposed into

[14] I Arbnor & B Bjerke, *Företagsekonomisk metodlära,* 1994, p. 62.
[15] A Bryman, Kvantitet och kvalitet I sammhällsvetenskaplig forskning, 1997, p. 23-25.
[16] G Wallén, *Veteskapsteori och forskningsmetodik,* 1996, p.33-35.
[17] I Arbnor & B Bjerke, op.cit., p.65-95.

small parts and studied separately and from there draw conclusions from the exposed cause-effect relations that separately can describe the reality.[18]

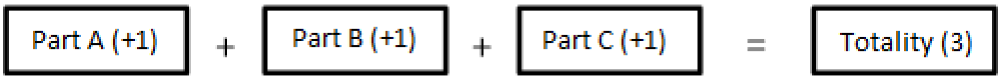

Figure 5 - Relationship between the parts and the totality in the analytical approach.[19]

3.1.2 Systems approach

The systems approach is the next approach in the history and it came as a reaction towards the analytical thinking of an additive reality. The system approach states that the totality is separated from the sum of the parts as can be seen in figure 6. The relationship between the different parts can give both positive and negative effects to the totality and is therefore a synergy. According to this approach the knowledge is dependent on the system. Individuals can be part of a system and their acting is following the principles of a system. This implies that the parts can be explained from the properties of the totality.[20]

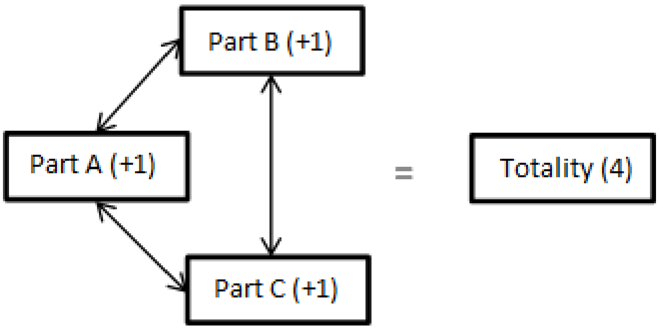

Figure 6 - Relationship between the parts and the totality in the systems approach[21]

3.1.3 Actors approach

This is the youngest of the three approaches and it implies that the totality could be understood from the properties of the parts. This approach has no interest in being explanatory and is focused on understanding the social totality. This is done from perspective of the individual actor and the reality assumes to be a social construction. The reason for this is that the approach maps the implication and meaning of the different actions and the environment and thereby creates this social construction in structural levels of meaning.[22]

3.1.4 Explorative, descriptive, explanative and normative

Apart from the different approaches according to Arbnor & Bjerke, there are different approaches that can be taken depending on the amount of existing knowledge in the area of study. If the

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[18] B Gammelgaard, 'Schools in logistics research? A methodological framework for analysis of the dicipline', *International journal of Physical Distribution & Logistic Management,* vol 34, No 6, 2004, pp 479-491.
[19] I Arbnor & B Bjerke, *Företagsekonomisk metodlära,* 1994, p.66.
[20] Ibid., p.65-95.
[21] Ibid., p.67.
[22] Ibid., p.65-95.

knowledge in the area is very low the best approach is *explorative* and the object is to create a basic understanding in the subject. When there is existing basic knowledge, understanding in the subject and the goal is to describe without explaining relations, the approach is called *descriptive*. The third approach is *explanative* and this is an approach used when there is knowledge in the area and the purpose is to find a deep understanding for both description and explanation. The last approach, *normative,* has the goal to provide guiding information and propose actions in an area where knowledge and understanding are quite good.[23]

3.1.5 Research approach used in this master thesis

Many logistic problems have been and are often described by the systems approach.[24] It has, after studying the different approaches in the context of the problem and purpose of this master thesis, become clear for the authors that the systems approach is the best approach for this master thesis.

In order to understand and describe the inventory control at Nederman and from there find improvements, the whole system has to be taken into consideration. It is not possible to just study every separate part and analyze them separately without interference from connected activities. Therefore the authors find the pure analytical approach not suitable for this master thesis.

Neither can the authors find the actors approach suitable for this master thesis. How individuals act and behave, within the different parts of the inventory control, is interesting and will affect how the inventory control is managed and the results. But the purpose of this master thesis is not to investigate how their acting affects the result of the chosen inventory control nor the social construction created by those.

Therefore the most suitable approach for this master thesis is the systems approach since many different parts and activities are analyzed both separately and as a system. The relationship between the activities is important and taken into consideration during the master thesis and the totality of the chosen inventory control is based on the total system and not on the best separate parts.

The research area of Inventory control holds a huge amount of knowledge and earlier research. This taken into consideration along with the purpose of using existing information in finding a better way to control the inventory in terms of safety stock at Nederman makes the normative approach the best suitable approach for this master thesis.

3.2 Research method

To choose the proper research method is, like the research approach, very important for the authors and the master thesis. The chosen methods will also affect the result and the outcome of the analysis and it is therefore essential to use a research method that fits the problem and will answer to the problem in a satisfying way.

3.2.1 Induction, Deduction, Abduction

Where to start and how to balance between the theory and the empirical data can be described by the concepts of induction, deduction and abduction. Induction is the way to create theory from the empirical data and deduction has the aim to explain the empirical data by using the theory. The third

[23] M Björklund & U Paulsson, *Seminarieboken – att skriva, presentera och opponera,* 2003, p. 58.
[24] B Gammelgaard, 'Schools in logistics research? A methodological framework for analysis of the dicipline', *International journal of Physical Distribution & Logistic Management,* vol 34, No 6, 2004, pp 479-491.

concept, abduction is a combination of them both where the authors move back and forth between the theory and the empirical study.[25]

Induction means that the authors have a start point in the empirical data and from there creates general and theoretical conclusions. Even though it starts from the empirical data, it is often done with already existing theoretical knowledge in mind, see figure 7.[26] It is stressed that the data collection should be done without predictions, and the approach has been criticized because of this. Both for the fact that the theory does not contain anything else than the empirical material but also that the author in every selection and examination has some kind of predictions, which implies that there is no such thing as "without predictions".[27]

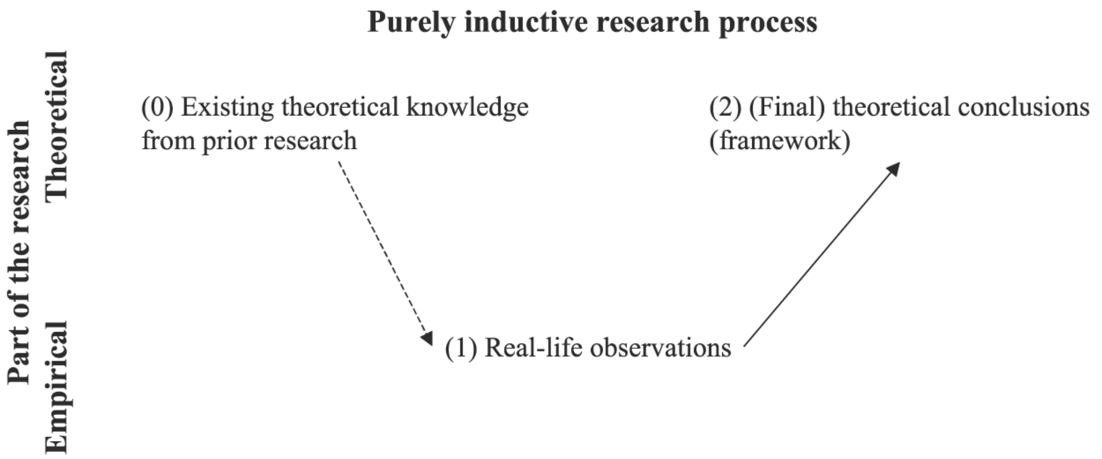

Figure 7 - Process between theory and empirical studying in the inductive approach.[28]

Deduction has a much greater focus in the existing theory and the theory is used to create conclusions. These conclusions are then to be tested by the use of the empirical data and from there final conclusions will be drawn whether the theory is correct or if new or additional theory should be established, see figure 8.[29] A theory is never fully completed and this is a reason why this approach often is used. This means that there are always areas in the existing theory that can be developed and by executing empirical studies in those areas, development of existing theories, can be made.[30]

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[25] M Björklund & U Paulsson, *Seminarieboken – att skriva, presentera och opponera,* 2003, p. 62.
[26] G Kovács & K Spens, (2005),"Abductive reasoning in logistics research", *International Journal of Physical Distribution & Logistics Management*, Vol. 35 Iss: 2 pp. 132 – 144.
[27] G Wallén, *Veteskapsteori och forskningsmetodik,* 1996, p.47.
[28] G Kovács & K Spens, loc.cit.
[29] G Kovács & K Spens, (2005),"Abductive reasoning in logistics research", *International Journal of Physical Distribution & Logistics Management*, Vol. 35 Iss: 2 pp. 132 – 144.
[30] I, M Holme & B, K Solvang, *Forskningsmetodik – Om kvalitativa och kvantitativa metoder*, 1997, p. 51.

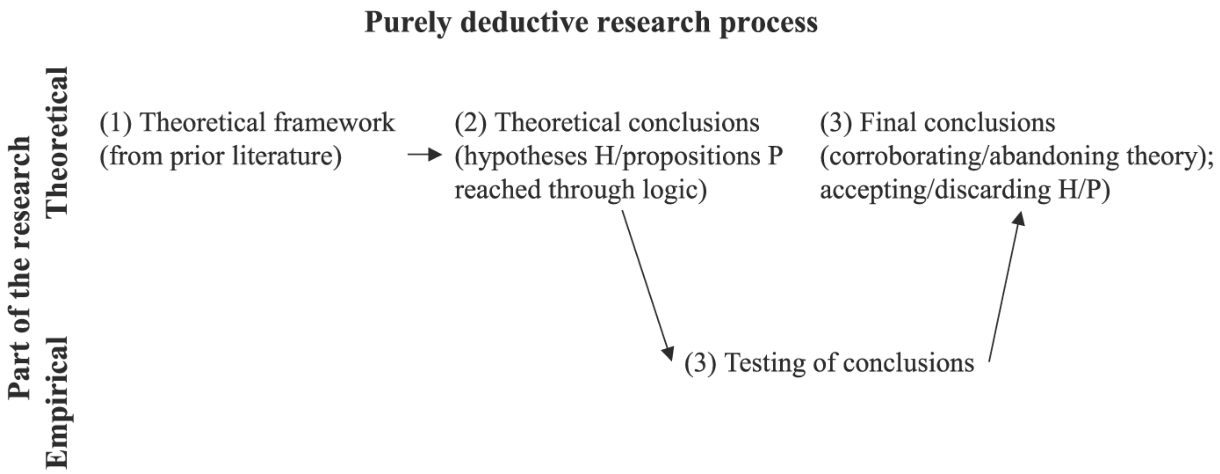

Figure 8 - Process between theory and empirical studying in the deductive approach.[31]

Abduction is a combination between induction and deduction and it has risen from the fact that many of the great insights in science neither follow a pure inductive nor deductive approach. The process starts like the inductive approach with some theoretical knowledge and are thereafter moving between empirical data and theory for matching and validating theories before reaching final conclusions and if possible apply the concluded results, see figure 9

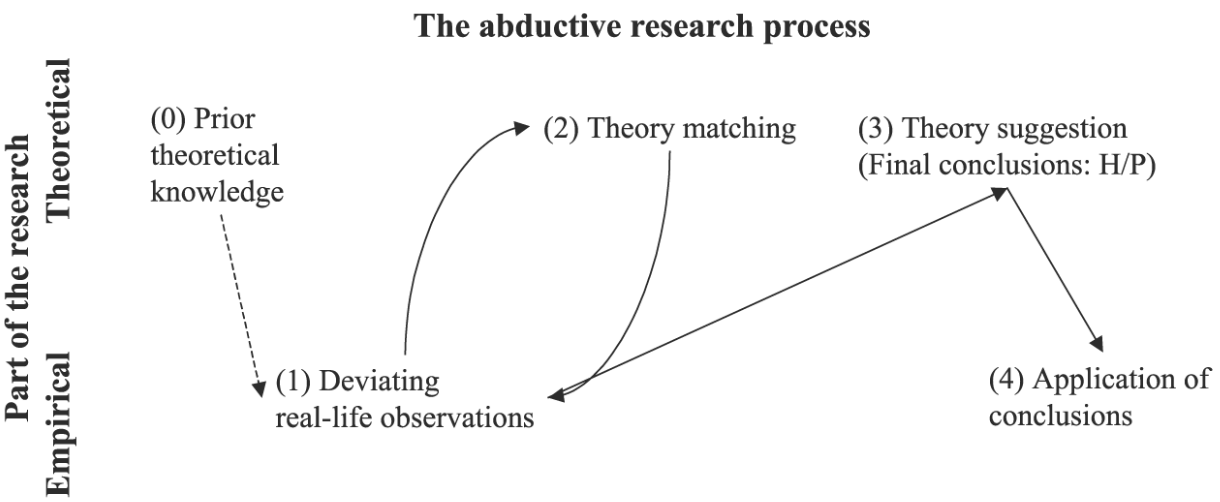

Figure 9 - Process between theory and empirical studying in the abductive approach.[32]

3.2.2 Qualitative and Quantitative approach

There are two general approaches used in scientific research methods, qualitative and quantitative methods. Quantitative methods are all methods where information and data can be measured and analyzed numerical. Qualitative methods are used where a deep understanding in a specific subject

[31] G Kovács & K Spens, (2005),"Abductive reasoning in logistics research", *International Journal of Physical Distribution & Logistics Management*, Vol. 35 Iss: 2 pp. 132 – 144.
[32] Ibid.

or situation is the goal.[33] There is also one fundamental similarity between them and that is that their goal is to create a better understanding of the society.[34]

Qualitative approach has for a long time been used by social scientist and a main character is participating observations. Unstructured interviews are another method where the interviewer is looking for more deep information from the interviewee by letting him or her wander away from the subject. A scientist using the qualitative approach always has a desire to express events, actions and norms from the view of the studied object.[35]

Quantitative approach is very similar to the approach of natural science. Examples of different quantitative research methods are surveys, structured observations and content analysis and all those are ways to collect large amount of data for analysis. Quantitative research can be seen as a part of a special language which contains many expressions used by scientists when observing the nature. Some of them are *variables, control, measuring* and *experiments* and it implies that the quantitative approach is a way to create models based on science of nature.[36]

Table 1 below describes some of the more distinct characters of the two approaches and especially how they differ from each other.

Table 1 - Characters and differences between qualitative and quantitative approach.[37]

Quantitative methods	Qualitative methods
Precision: The scientist aims for a maximal mirroring of the quantitative variation.	Adaptability: The scientist aims for best possible reflection of the quantitative variation.
Broad approach.	Narrow approach.
Systematic and structured observations.	Unsystematic and unstructured observations.
Interest in common, intermediate or representative.	Interest in the peculiar, unique or deviating.
Distance to the living, collection of information is made under circumstances that differ from the reality.	Closeness to the living, collection of information is made under circumstances that are very close to the reality.
Interest in separate variables.	Interest in contexts and structures.
Description and explanations.	Description and understanding.
Acts like an observer and examines the phenomena from the outside.	Acts like an actor and observes from the inside. Can affect the result by his presence.
I-it relation between scientist and the object.	I-you relation between scientist and the object.

3.2.3 Research method used in this master thesis

In this master thesis the choice of research method is quite obvious. The authors are approaching an area where there is a lot of existing theoretical knowledge. The theory frame contains theory that is collected over many hundred years and is widely accepted. The purpose of this master thesis is to use the theory and then compare the conducted empirical data with the theory in order to find the best optimal solution for the company based on their specific data in the context of existing theory.

[33] M Björklund & U Paulsson, *Seminarieboken – att skriva, presentera och opponera,* 2003, p. 63.
[34] I, M Holme & B, K Solvang, *Forskningsmetodik – Om kvalitativa och kvantitativa metoder*, 1997, p. 76.
[35] A Bryman, *Kvantitet och kvalitet I sammhällsvetenskaplig forskning*, 1997, p. 58-88.
[36] Ibid., p. 20-23.
[37] I, M Holme & B, K Solvang, op.cit., p. 78.

This makes abduction the best fitted approach for this problem and is therefore guiding the authors throughout the master thesis.

This master thesis is based on a combination between quantitative and qualitative research. Data in terms of numbers is very important in the analysis and is standing as the base. But to support the quantitative analysis the authors uses qualitative methods to reach a deeper understanding in desired fields.

3.3 Data

Collection of data and other information can be researched and found in many different ways and methods. Some of these methods are interviews, observations, literature studies and data collected from databases. Different methods are suitable for different purposes, but they can all be divided in two different main groups, primary and secondary data.

3.3.1 Primary and secondary data

Primary data are all types of new data that has been collected to a specific project. It could be interviews, test or observations that directly could be associated to the project. Primary data could always be adapted for the purpose since the research is done for the specific project.[38]

Secondary data is based on historical data and the information has not been collected to the specific project and it is information collected by another person than the investigator.[39]

3.3.2 Different data sources

3.3.2.1 Interviews

Interviews are a type of data collection that is directly relevant for a specific project. It is a well working method to get a deeper understanding and also be able to adjust the questions to different persons. Interviews are a typically primary data. [40]

Interviews are in one point of view a very simple method of collecting data. The method does not require any technical or expensive equipment and have a lot of similarities to a normal conversation. From another point of view it is not that simple. There are a lot of differences between normal conversations and an interview, for example it is arranged and controlled in a pre-set way, which makes it more difficult. Interviews could also be very time consuming both to perform and to summarize the outcome of the interview.[41]

Interviews can be divided in three different types, structured, semi-structured and unstructured. A structured interview means that the interviewer has a lot of control over the questions and the form of the answers. During a semi-structured interview, the interviewer still has a list of subjects that should be discussed and questions that should be answered, but is more flexible for changing the order of the question and allows the answers to be more detailed than they were planned to be.

[38] M Björklund, U Paulsson, *Seminarieboken*, 2012, p. 68.
[39] Ibid., p. 67.
[40] Ibid., p. 70.
[41] M Denscombe, *Forskningshandboken*, 1998, p. 130.

Unstructured interviews are more of a conversation where the interviewer just starts the conversation and let the answers be more like reasoning.[42]

3.3.2.2 Observation

Another typical primary data is information taken from observations. This is called observation study, and occurs when specific event or other process is being analyzed. An observation is done when new information is collected through technical equipment or own senses. The observation method could be divided in four different stages, depending on how much the person that process the observation is involved. The scale is from being just an observer to fully take part in the process.[43]

3.3.2.3 Databases

Information from databases is also a primary data since it is taken from the database especially for the project. Databases is a digital form of organized data and today more or less all companies have a database system to organize large numbers of transactions, information and other kind of data.

3.3.2.4 Literature studies

Literature is a typical secondary data, and it is a fast and simple way to get information and knowledge of a specific subject. Literature is all forms of written material and it can be everything from books and journals to newspapers. An important aspect during literature studies is to be critical to the sources and make sure that the information in the texts is accurate and written by an objective person. Another aspect for the reader is to check the date of the literature so the information is up to date.[44]

3.3.2.5 Data from existing projects and tests

Old data from previous test is also classed as secondary data. This could be quantities measurement of performance, preexisting tests or other type of analysis that another investigator has done.

3.3.3 Data used in this master thesis

During this master thesis several different methods of data collection has been used. This was done to have a wide range of data, from several different sources and with focus on combining academic sources with data and knowledge from the company. The largest part of the data has been taken from databases, and then been further analyzed. This data has been downloaded from the different databases used at the company.

Interviews have also been essential for the understanding of the company, current situation and methods of working. Interviews has been done in several ways and methods, both structured, semi-structured and unstructured interviews has been used. In some cases the interviews has been controlled by a specific guide, and at other times the interviews has been more as a conversation. Throughout the entire master thesis there have been ongoing conversations with the supervisor, Fredrik Arborelius, about how things are working and the information obtained from those conversations acts like an additional source for the current state analysis after a more structured interview. Those conversations also stand as the major source for how the databases are used and how the gathering of that data has been performed.

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[42] M Denscombe, *Forskningshandboken*, 1998, p. 134-135.
[43] M Björklund, U Paulsson, *Seminarieboken*, 2012, p. 69.
[44] Ibid., p. 69-70.

In the second half of the master thesis, the focus of the data collection switched to a combination between experiments and observations. The experiment took place over a longer time period and was based on the results of the analysis. This resulted in numerous observations that where compared to the existing database.

During the entire master thesis literature studies has been carried out on the side of the other methods of data collection. This was done to complement and support the other data and give a more solid and theoretical background to be able to develop the analysis.

3.4 Analysis model

To choose an analysis model for a project is a very important step and it is important to find a model that will respond to the purpose in a good way. The analysis model can be seen from two angels. The first is the overall model for the entire project taking in all steps for consideration. And then of course how the analysis of data is made in order to obtain the expected result.

The information and data that has been collected can be analyzed in many different ways since the purpose of a study can be different. Some examples could be to compare improvement suggestions, find connections between different variables or show changes over time.[45]

3.4.1 Statistical processing

The information that is collected can be analyzed statistical to get new information. This is done through statistical measurements, tables or charts, depending on the purpose of the study to compile and present the data that was collected. This could be done through advanced computer programs or manually, depending on the amount of data. Historically, manual handling of data has been used, which have been both time consuming and inefficient.

Nowadays there exist very advanced computers which are more and more used in statistical processing. These new tools have really change the efficiency and outcome of the statistical process the last decades.[46]

3.4.2 Modeling and simulation

The collected information can also be simulated in different forms, which is a very common method to use during an analysis or a project. Through this method, which is more or less always done via advanced computers, different scenarios can be simulated and possible future outcomes can be seen and predicted.

This method is used to be able to forecast and actually see how an implementation or a theory would work in reality. By testing the data under the same circumstances as in reality, parameters that affects the results that would be hard to predict, can be noted and seen before the real testing or implementation.[47]

[45] M Björklund, U Paulsson, *Seminarieboken*, 2012, p. 71.
[46] Ibid., p. 73.
[47] Ibid.

3.4.3 Analysis model used in this master thesis

The analysis model of this master thesis starts in the practice by determining the problem and from there the purpose of the study. When the scope was defined, theory was used to find a methodology that was suitable for this master thesis on every level. When the proper methodology was chosen the knowledge of the theory for the subject among the authors were established and served as a base in the decision of the collection of important empirical data. The master thesis moved here into a phase of practice when the data was collected and the major analysis of the data was performed to reach the expected new model.

During the master thesis a combination between statistical processing and modeling was used. Since a large part is based on receiving and processing data and find different pattern, statistical processing was an obvious choice.

Modeling and real simulations was also used. A model of a possible scenario was made, and the model was also tested, or simulated, in real life. This was done to make sure that the statistical process was giving accurate results.

During this analysis, the authors moved back and forth between the practice and the theory to select proper methods for the empirical data but also to validate results and find new ways to continue the analysis. An illustration of this model is shown in figure 10 below. How the analysis itself was performed with its different steps is explained in more detail in chapter 6.

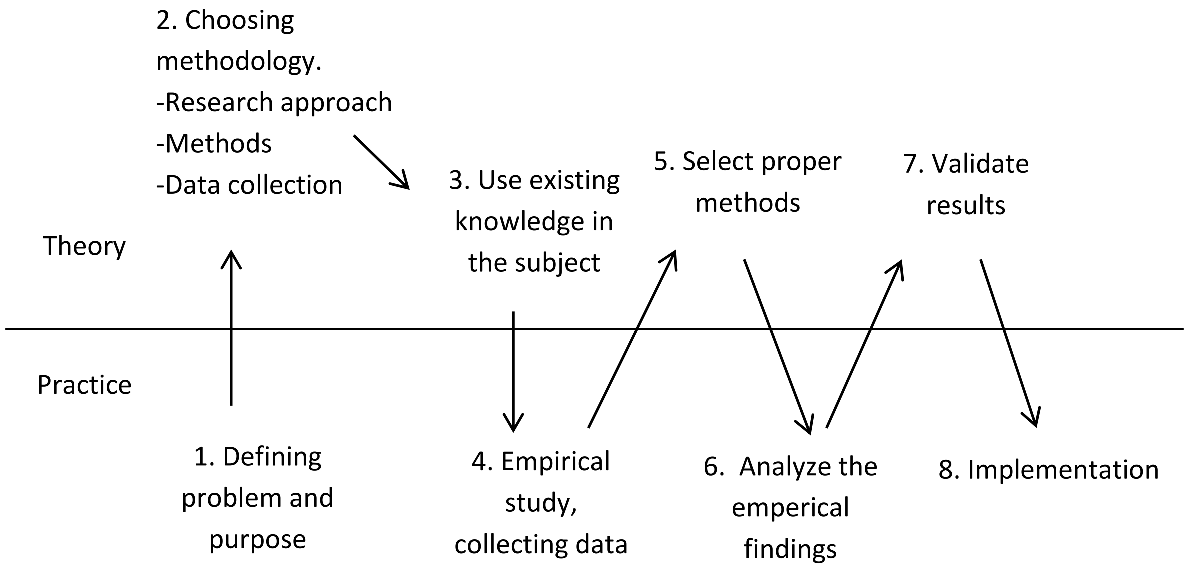

Figure 10 - Analysis model chosen by the authors.

3.5 Credibility

In all projects, tests or academic reports is it always important to maintain a high credibility. This is important both for the investigators, for the accuracy of the master thesis, but also important that someone else can read the report years later and still follow up the results. Terms often used in these discussions are validity, reliability and objectivity.

3.5.1 Validity, reliability and objectivity

3.5.1.1 Reliability

This is the measurement of the level of accuracy in instruments; with other words how well the measurement can be done many times and receiving the same results.[48] Another thing that is important for the reliability is that the test person or data is chosen randomly[49].

3.5.1.2 Validity

To be able to measure what you really want to measure is important in order to have a high and accurate validity for a project. The validity of a measurement tool, for example, a test or an analysis, is the degree to which the tool measures what it claims to measure. To reach a high validity a good way is to use triangulation, see 3.5.2 for further information.[50]

3.5.1.3 Objectivity

Another important thing for a research or a report is the objectivity. All investigators have their own values in different subjects, but the question is how much this affects the results of a project. To be objective the investigators should; keep all the facts accurate, all aspects should be seen from different angles and not use misleading words that could affect the results, like "the person X claims….".[51]

3.5.1.4 Reliability and validity

Validity is often assessed along with reliability in terms of if a measurement gives consistent results. As seen below in figure 11 validity and reliability is pictured as a dart board, and the black dots are test results. It describes how validity and reliability is connected. The picture on the left has a low validity and a low reliability. The picture in the middle has also a low validity, but a high reliability. The last picture on the right has both high validity and reliability, which is necessary to give a consistent result.

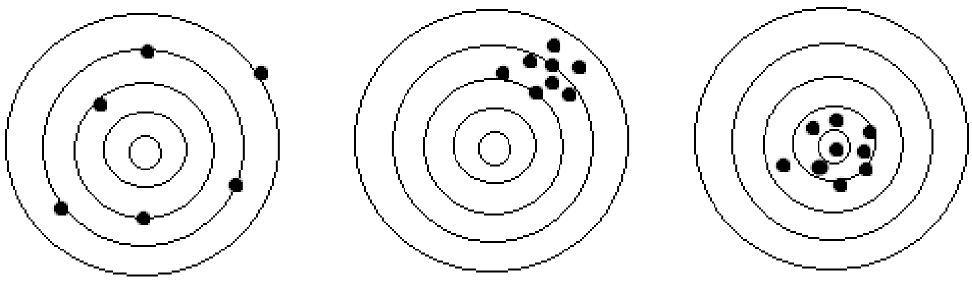

Figure 11 - Connections between reliability and validity.[52]

3.5.2 Triangulation

One way to increase the credibility of a study is to use many different methods on the same material, to get several perspectives. This is called triangulation and is used when more than two methods are used on the same material to reach the same purpose.[53]

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[48] M Björklund, U Paulsson, *Seminarieboken*, 2012, p. 59.
[49] M Höst, B Regnell, P Runesson, *Att genomföra examensarbete*, p. 42.
[50] Ibid., p. 41.
[51] M Björklund, U Paulsson, op.cit., p. 62.
[52] Ibid., p. 60.

3.5.3 Approach in this master thesis

To increase the credibility and also improve the accuracy of the results, several different methods have been used to reach that target. Since the data from the databases has been very important for the master thesis, a lot of effort has been put on having the correct data.

To increase the reliability on the data collection, analysis and tests were done several times. The data was taken twice from the databases, the analysis and statistical processing was also done twice and test was done continuously over 10 weeks.

Before downloading the data from the different databases a lot of effort was put in making sure that it was the correct data. After explaining for several different persons what kind of data that was needed, the answers were crosschecked against each other. If there were any differences between the answers of where and how the data could be found, this was further investigated. This was all done to increase the validity.

To make sure that this master thesis is objective everything was seen from different angles and opinions. For example different units of the company were interviewed during the data collection, just to get a wide range of opinion of what was important and correct.

Another aspect of validation was to always be updated with Nederman to check that the master thesis was heading in the direction that was in line with the company targets. This was done through regular meetings with the company and making sure that both the authors and the company had the same objectives. Several times during the master thesis, especially when something unexpected had occurred, the two groups had different opinions. This was always sorted during the meetings and the direction of the master thesis became in line for everyone involved.

The literature used in this master thesis has been selected to cover a range from different universities and countries to ensure that the authors are not too affected by each other. Since the fundamentals in inventory control can be found in a couple of books from well know authors like E A Silver, D F Pyke, R Peterson and S Axsäter, these classic pieces has been used and the list of authors is here quite short. The theory chosen for the master thesis has a large variation between old classic research and new updated theory with more reality focus, all to get a large variety of approaches and thoughts to ensure the credibility of the report.

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[53] M Björklund, U Paulsson, *Seminarieboken*, 2012, p. 76.

4. Theoretical framework

This chapter describes the theoretical framework for this master thesis and gives the reader a fundamental base in order to understand the analysis. It cover the areas of inventory control in terms of demand pattern determination, forecasting, replenishment systems and mapping tools that are interesting for this master thesis.

4.1 Inventory control

Supply chain management is for more or less all companies an important part of the business. All companies have a lot of capital tied up in raw material, work in progress and finished goods, which gives a great opportunity for improvements.[54]

The techniques and knowledge of how to control this tied up capital has been around for decades, but has been hard to control since it creates a massive amount of data. Advanced technology has lately changed the possibilities to apply inventory control systems since more and more processes can be controlled automatically.

Inventory control cannot be totally separated from other functions and units in a company like for example production, purchasing and marketing. There is often even a conflict between these different functions, just because of the fact that their objectives differs a lot. For example one goal is, from an inventory point of view, to keep the stock level low in order to tie up as little capital as possible. The purchasing unit on the other hand has often a goal of buying large batches from suppliers to get a discount, which will result in higher stock levels. This makes inventory control a difficult thing to handle, since there are a lot of different factors and especially human factors that affects the system.[55]

One of the important activities in an inventory control system is a clear mapping of the flow of material, goods and information. Another is to determine the demand pattern in order to decide on a proper forecast model and replenishment system.

4.2 Mapping

Mapping is a way to illustrate the supply chain in a simplified way. Supply chains become more and more complex due to todays globalized world and the extreme competitiveness between supply chains and value chains. In order to capture this complex structure and to be able to understand, analyze and explain it, a good tool to use is mapping. Mapping is also a very powerful way to illustrate less complex structures and becomes therefore very useful for many different aspects in logistics and other areas as well. Mapping is like a visual language that is used to make people working with logistic to easy understand different things.[56] There are many different shapes that are used in this language and some of them are displayed in figure 12.[57]

[54] S Axsäter, *Inventory Control*, 2006, p. 8.
[55] Ibid., p. 1.
[56] Gardner, John T & Cooper, Martha C, (2003), *Strategic supply chain mapping.*
[57] A Norrman, lecture notes – Projectt in logistics (MTTN15), 2011 p. 17.

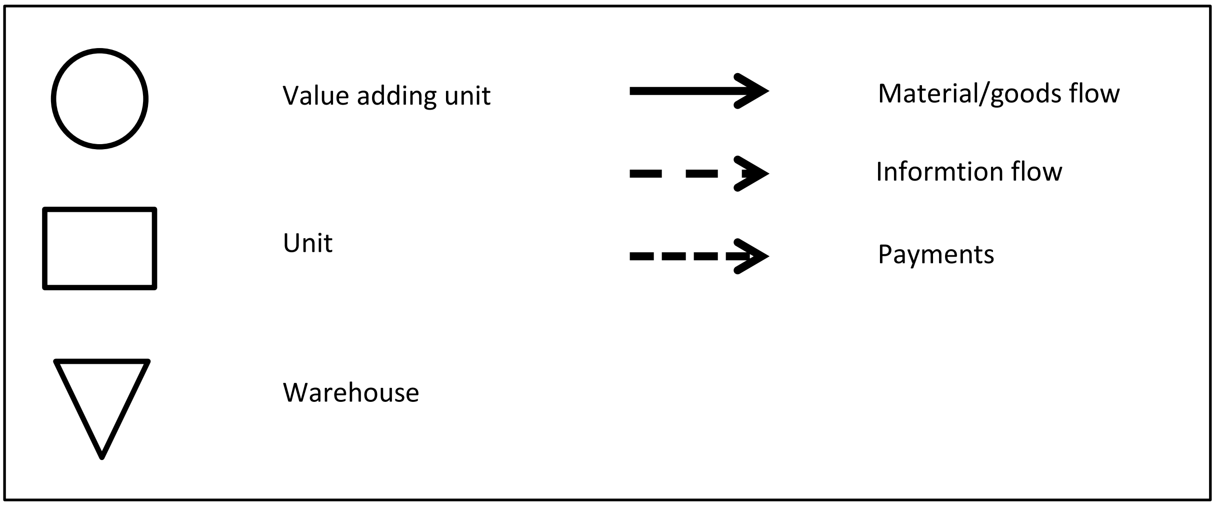

Figure 12 - Some of the most used and standardized symbols in supply chain mapping.[58]

These along with many others can be used to describe very complex and less complex structures in a way that is easy to comprehend. By doing this it is easier to understand how things are connected to each other and how they are affected by the connections.

4.3 Determining demand pattern

Determining the demand pattern for products in a company has many reasons. The main reason is always to get a good understanding of the products in order to control them in different ways. Some of the most common patterns to look for are; seasons, positive or negative trend, slow-, medium- and fast moving products and deviations in the demand pattern, see figure 13.

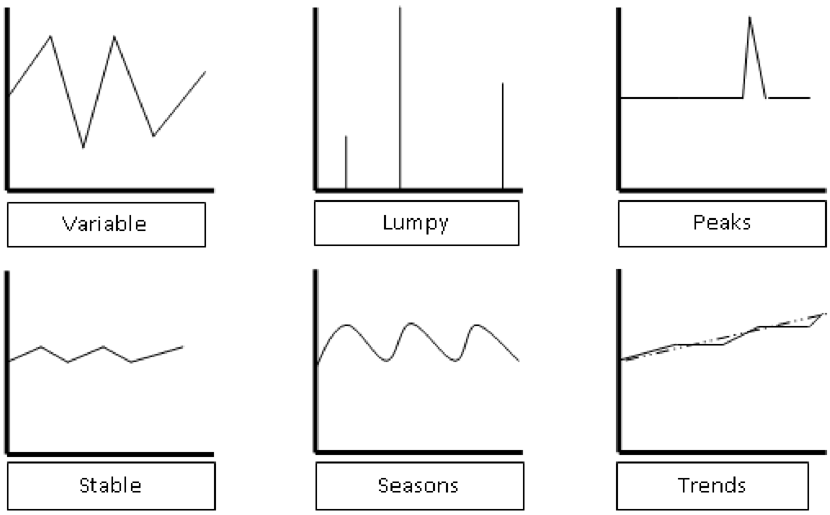

Figure 13 - Examples of different demand patterns.

All these can be identified with different tools and be further analyzed for potential actions. Some of the tools are; Regression analysis, autocorrelation, standard deviation, frequency and coefficient of variance, see chapter 4.3.1-5.

[58] A Norrman, lecture notes – Projectt in logistics (MTTN15), 2011 p. 17.

4.3.1 Regression analysis

A regression analysis can be used for determining if there are any trends in the demand of a product. This can be used as an alternative method to exponential smoothing with trend, explained in chapter 4.4.3, in the terms of forecasting.[59]

Regression analysis is the way to find the linear equation that best describes the observations of the product. If the N most recent observations, $x_t,\ x_{t-1}, \dots, x_{t-N+1}$, are collected were x_t is the most recent period, can this be fitted to the line $y_{t+k} = \hat{a}_t + \hat{b}_t k$ so that the sum of the squared errors is minimized for $k = -N+1, -N+2, \dots, 0$. Then y_{t+k} can be used for $k > 0$ as the forecast for the period, $t+k$, i.e., $\hat{x}_{t,t+k} = y_{t+k}$.

The variables $\hat{a}_t$ and $\hat{b}_t$ can now be determined by minimizing

$$\sum_{k=-N+1}^{0} \left(x_{t+k} - \hat{a}_t - \hat{b}_t k\right)^2.$$

This formula is then derived based on both $\hat{a}_t$ and $\hat{b}_t$ and set equal to zero. This results in the two formulas

$$-2\sum_{k=-N+1}^{0}\left(x_{t+k} - \hat{a}_t - \hat{b}_t k\right) = 0 \qquad (4.1)$$

$$-2\sum_{k=-N+1}^{0} k\left(x_{t+k} - \hat{a}_t - \hat{b}_t k\right) = 0 \qquad (4.2)$$

that is obtained and by using the notations

$$\bar{k} = \frac{1}{N}\sum_{k=-N+1}^{0} k = -\frac{N-1}{2}$$

$$\bar{x} = \frac{1}{N}\sum_{k=-N+1}^{0} x_{t+k}.$$

Finally the formula

$$\hat{a}_t = \bar{x} - \hat{b}_t \bar{k} \qquad (4.3)$$

comes from the formula (4.1) and this is further on used by inserted in (4.2) and $\hat{b}_t$ is from this new formula possible to determine by

$$\hat{b}_t = \frac{\sum_{k=-N+1}^{0} k(x_{t+k} - \bar{x})}{\sum_{k=-N+1}^{0}\left(k^2 - k\bar{k}\right)} = \frac{\sum_{k=-N+1}^{0}(k - \bar{k})(x_{t+k} - \bar{x})}{\sum_{k=-N+1}^{0}\left(k - \bar{k}\right)^2}.$$

When $\hat{b}_t$ is obtained it is finally used in formula (4.3) and $\hat{a}_t$ is also determined and the formula for the regression line is founded.[60]

[59] S Axsäter, *Inventory control*, 2006, p.21.
[60] Ibid., p. 21-22.

4.3.2 Autocorrelation

Autocorrelation is a method used to determine any seasonality in the demand pattern. This is determined by an autocorrelation coefficient, r_k. There is a need of at least two years of data and the coefficient can then be calculated with the below formula for every value of *k.*

$$r_k = \frac{\sum_{i=0}^{N-k-1}(D_{t-i} - \bar{A}) * (D_{t-i-k} - \bar{A})}{\sum_{i=0}^{N-1}(D_{t-i} - \bar{A})^2}$$

with

$$\bar{A} = \frac{1}{N}\sum_{i=0}^{N-1} D_{t-i} \quad and \quad k = 1, 2, 3, \ldots$$

where D_t is the demand for the period *t* and *N* is the number of months.

This can then be displayed in a correlogram, showing all the values of r_k in a column chart. And if there for any values of *k > 2* where r_k is > 0.5-0.6 it can be assumed that there is seasonality.[61]

4.3.3 Frequency

It is always an important start when determining the demand pattern to measure the frequency of how often and in which volumes a product is handled. Frequency can be measured either by volume per time unit, where the time can vary from each observation to volume per year, or regardless of the volume per time unit. The choice depends on what the further analysis will be. A problem when choosing volume per time unit is to find a proper time unit that will describe the pattern in the best possible way and be useful for the next analysis. Regardless of type or time unit this is often the start for most analysis in inventory control.

4.3.4 Standard deviation

Standard deviation, *σ*, is used to describe how predictable something is. It is a measurement of how much a number of observations are deviating from each other and the formula for this variable is

$$\sigma = \sqrt{V(x)}$$

where

$$V(x) = \begin{cases} \sum_{i=1}^{N} P(x_i)(x_i - \mu)^2, & discrete \\ \int_{-\infty}^{\infty} (x - \mu)^2 f(x)dx, & continuous. \end{cases}$$

$V(x)$ is the variance, μ is the average value of x_i *and* x_i is the observed value.

The standard deviation does not take the volume into consideration, why high volume products tends to get a higher standard deviation due to the higher risk of bigger differences in the observations than in a low volume product. This is a limitation for the usage of standard deviation

[61] Prof. Perego, Alessandro, lecture notes, Logistics Management.

and when determining the demand pattern a better tool to use can be the coefficient of variance described below.

4.3.5 Coefficient of Variance

Coefficient of variance is a method to study the demand pattern and it is similar to the standard deviation. The difference is that the volume is taken into consideration in the coefficient of variance. This makes the value of the deviation comparable independent of the volume and makes it possible to view and compare, for example, all products in a warehouse at the same time.

The coefficient of variance is calculated by

$$CofV = \frac{\sigma}{\overline{x}}$$

where $\overline{x}$ is the average frequency in terms of volume for a specific period.

It can be used to classify products in different ways. One example is to combine a simple ABC – analysis based on just the demand volume with a xyz–analysis (variability analysis). How the variability for the xyz products demand pattern is illustrated can be seen in figure 13 and they are representing stable, variable and lumpy demand. How the analysis then can be made is best explained by figure 14 and works like a cross referencing between abc and xyz.[62]

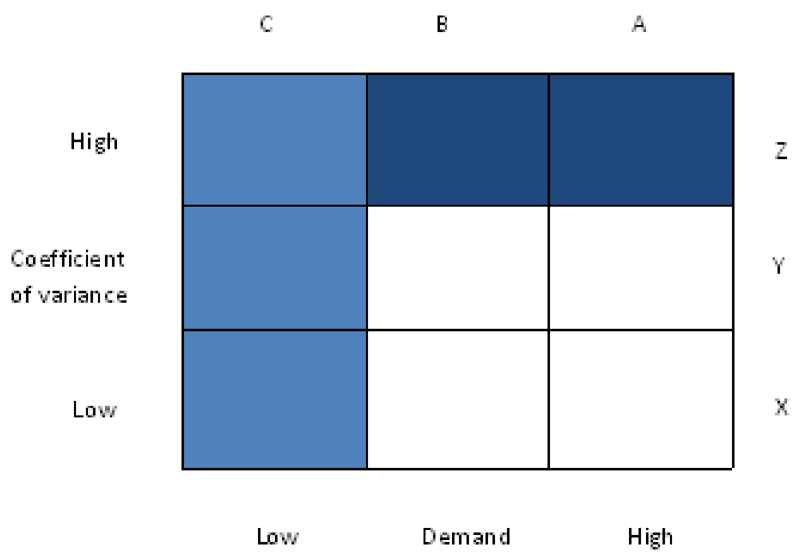

Figure 14 - Classification of products by coefficient of variance and demand.[63]

The products in the left column, shown as light blue, are to be seen as make to stock products for central warehousing. The four cells in the right bottom corner, shown as white, are standard products that should be made to stock. The last two cells in the top right corner, shown as dark blue, are very variable and should be produced to order.[64]

[62] A Norrman, lecture notes - project in logistics (MTTN15), 2011 p. 50-51.
[63] Ibid.
[64] Ibid.

The coefficient of variance and the average demand can also be plotted in a diagram with a logarithmic scale, which normally creates a pattern like in figure 15. This can be divided in 4 different categories (quadrants) of products. Q_1 is high volume low variability, Q_2 low volume low variability, Q_3 low volume high variability and the last, Q_4 with high volume and high variability.

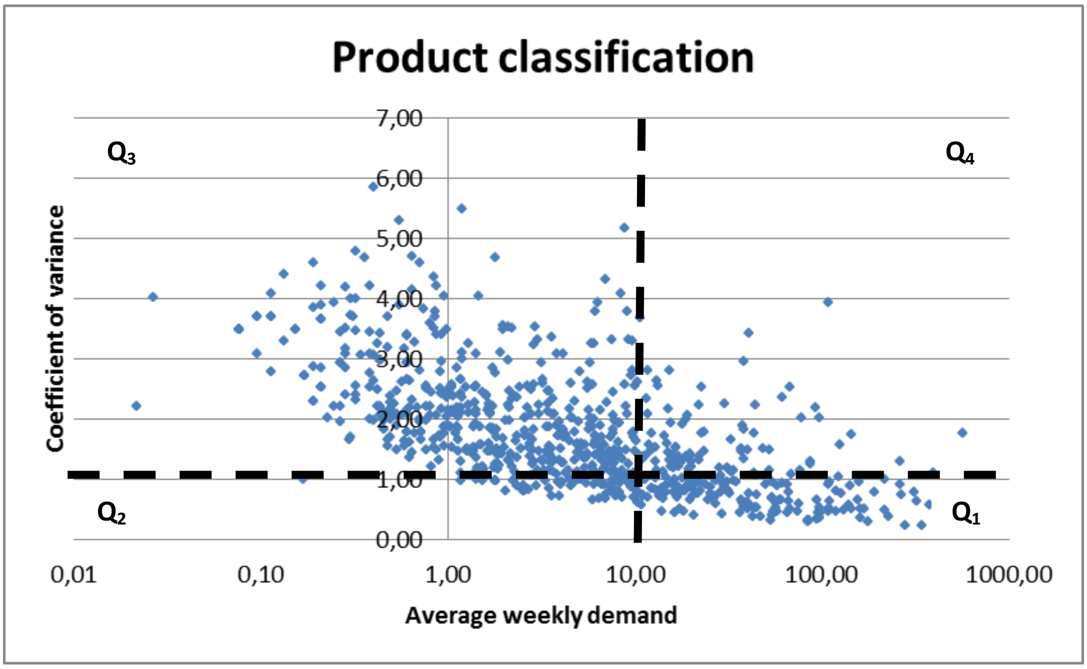

Figure 15 - Analysis of demand variability by coefficient of variance and average weekly demand.[65]

Where to draw the lines for separating products in different classification are not obvious and the lines in the figure above is just an illustrative example. Some guidelines for what a stable product is can be found, but both to find a border between stable and variable products and between low and high volume products are something that may be different for every company and different types of products. Anthony J. D'Alessandro and Alok Baveja did a study at Rohm and Haas, a German chemical manufacturer, where they used the coefficient of variance to divide products for different controlling methods. To determine the exact values for the split of the quadrants they made further analysis with historical data on production yields to separate high from low volume and the Pareto principal of 80/20 to separate high variability from low variability. The use of the Pareto principal is suggested in most theory as a good tool for segregating products and it gave them a separation line at a coefficient of variance of 0.52.[66]

Another guideline for determining high and low variability is to set the line for coefficient of variance to 0.2 to separate the groups.[67] This was done on Toyota and was a well working level for them, but for other companies this could be a way to low value.

[65] A D'Alessandro, A Baveja, Divide and Conquer: Rohm and Haas´ Response to a changing Speciality Chemicals Market, *Interfaces,* p. 5.
[66] Ibid.
[67] Jan Olhager, professor, LTH, interview 2012, 03 07.

4.4 Forecasting models

4.4.1 Moving average

One of the simplest forecast methods is moving average. The focus is to estimate the demand, *a*, expected that the demand vary slowly. *A* is based on the value of the *N* last periods, and the forecast is the average of these periods.

When using, for example, a moving average with a value of *N* equals to 6, and the updating process is done every month, the forecasted value for the next period is the average of the six months observations. When a new observation is added, the oldest period is removed and a new estimation is made.

$\hat{a}_t = estimation\ of\ the\ demand.$

$x_{t,\tau} = forecast\ for\ period\ \tau > t\ after\ observing\ demand\ in\ period\ t.$

$N = The\ N\ most\ recent\ periods.$

And the moving average formula is

$$x_{t,\tau} = \hat{a}_t = \frac{(x_t + x_{t-1} + x_{t-2} + \ldots + x_{t-N+1})}{N}.$$

The demand structure, numbers of peaks and seasonality's defines *N*. The value of *N* is based on how much *a* is expected to change over time. If *a* is changing slowly and there are a lot of peaks in the pattern, high value of *N* should be used. But if the fluctuations are low and *a* is changing more rapidly, low *N* value should be used to put more weight on the latest observations.[68]

4.4.2 Exponential smoothing

Exponential smoothing is also seen as a quite simple forecasting method and the results is similar to moving average, but there are some differences. The largest difference is the updating procedure. The focus is still to forecast the value of *a*, but this time a linear combination is used

$$x_{t,\tau} = \hat{a}_t = (1 - \alpha)a_{t-1} + \alpha x_t$$

where

$\hat{a}_t = estimation\ of\ the\ demand.$

$x_{t,\tau} = forecast\ for\ period\ \tau > t\ after\ observing\ demand\ in\ period\ t.$

$\alpha = smoothing\ constant\ (0 < \alpha < 1).$

This model gives more weight on the most recent data, but it still have a smoothing effect on the forecasted demand.[69]

[68] S Axsäter, *Inventory Control,* 2006, p. 11-12.
[69] Ibid., p. 12.

4.4.3 Exponential smoothing with trend

This forecasting method is an extension to normal exponential smoothing, but in this method another parameter is added. The parameter *b* is the trend, and gives a value for how much the forecast should be affected over time, note that *b* can be negative. The parameters are defined below as

$$\hat{a}_t = (1-\alpha)\left(\hat{a}_{t-1} + \hat{b}_{t-1}\right) + \alpha x_t$$

$$\hat{b}_t = (1-\beta)\hat{b}_{t-1} + \beta(\hat{a}_t - \hat{a}_{t-1})$$

and the forecast is obtained as

$$\hat{x}_{t,t+k} = \hat{a}_t + k * \hat{b}_t$$

where

$\hat{a}_t = estimation\ of\ the\ demand.$

$\hat{b}_t = estimation\ of\ the\ trend.$

$x_{t,t+k} = forecast\ for\ a\ future\ period\ t + k\ after\ observing\ demand\ in\ period\ t.$

$\alpha = smoothing\ constant\ (0 < \alpha < 1).$

$\beta = smoothing\ constant\ (0 < \beta < 1).$ [70]

4.5 Replenishment systems

To be able to have the right amount of goods at the right time and the right place, and also optimize the cost of handling, ordering and deciding volume for transport, the majority of companies use some kind of replenishment system. This is used to order new goods at the right time and size but also to minimize the cost. There are several different replenishment systems and there are many factors influencing when choosing the proper system for the specific situation where the demand pattern plays an essential role. Some examples are the Wilson formula, the Wagner-Whitin method and Silver-Meal heuristic. The most common and also used by Nederman is the Wilson formula, which is described in chapter 4.5.2.

4.5.1 Reordering systems

There are two different types of inspections in inventory control systems, which are continuous or periodical inspection. The main difference between them is that in continuous inspection the same order size is ordered whenever the stock level reaches the reordering point level. In periodical inspection the order sizes can vary between the ordering occasions, but they are ordered at predetermined times. This implies that a larger safety stock is required in order to meet a good service level. If the inspection period is really short, for example one day, the two systems become very similar. The most common reordering strategies are called (R,Q)-system and (s,S)-system. And in order to describe them it is necessary to define stock position, which is as follows[71]

$Stock\ position = physical\ stock + active\ orders - rest\ orders.$

[70] S Axsäter, *Inventory Control*, 2006, p. 17.
[71] S Axsäter, *Lagerstyrning*, 1991, p. 40-41.

4.5.1.1 (R,Q) – system

When the stock level reaches the level *R* the order quantity *Q* is ordered. If the demanded quantity always is one unit, the stock level will always stay between the levels of *R* - *R+Q* under the assumption of the stock position, but if multiple units are allowed a level under the *R* level can be reached. How the stock position and the physical stock level are moving over time is explained in figure 16.[72]

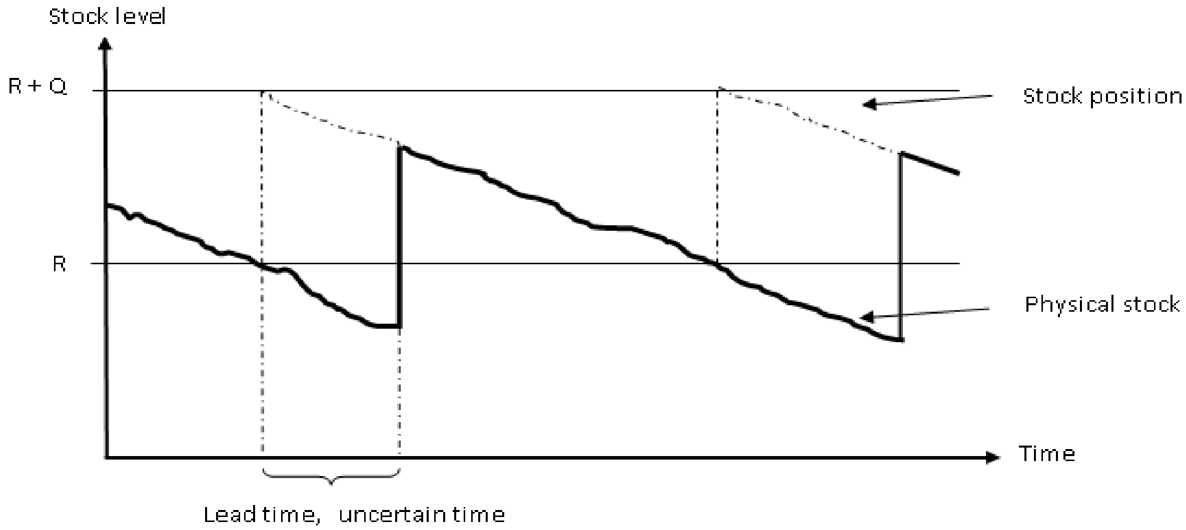

Figure 16 - (R,Q)-system with continuous inspection.[73]

4.5.1.2 (s,S)-system

The main difference is, as earlier mentioned, that the order quantity here varies and which accurse when ordered always is done up to a refill level *S.* The order is carried out whenever the inventory level reaches or become below the level *s,* the safety stock level, see figure 17.[74]

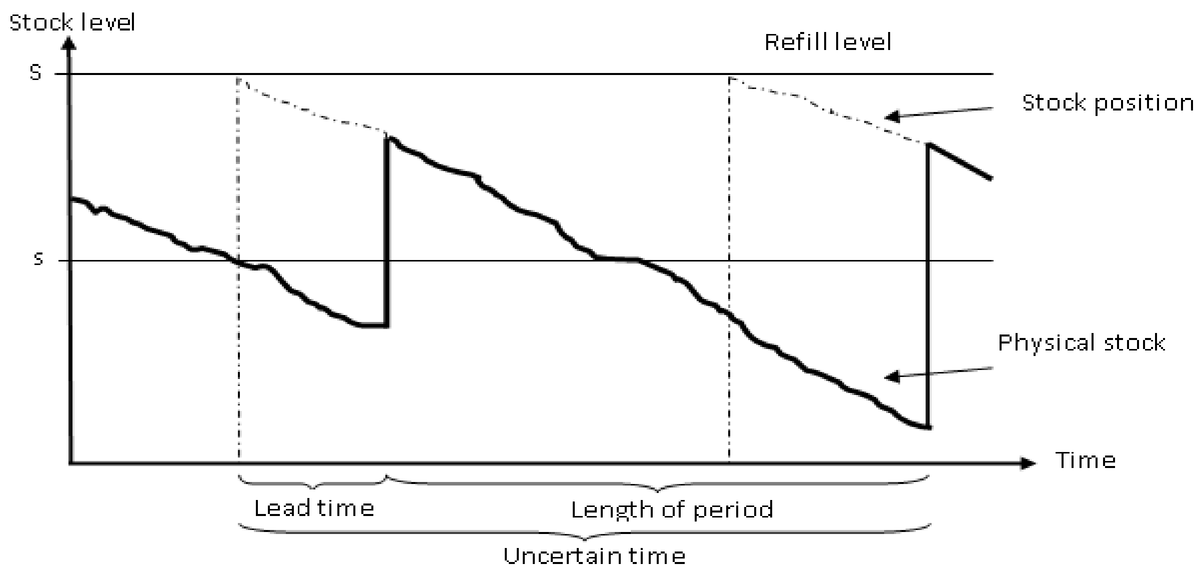

Figure 17 - (s,S)-system with periodical inspection.[75]

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[72] S Axsäter, *Lagerstyrning*, 1991, p. 42.
[73] Ibid.
[74] Ibid., p. 43.

4.5.2 Economic Order Quantity – EOQ

Economic order quantity or the Wilson formula is the most common used formula for determining order quantities.[76] The formula is based on two parameters, the carrying cost, *r* and the fixed cost for replenishment, *A*[77].

The Wilson formula is based on the following assumptions[78]

- Constant and continuous demand.
- The carrying cost and fixed cost for replenishment is constant.
- The order quantity does not have to be an integer.
- The whole order quantity is delivered at the same time.
- No shortages are allowed.

Before the formula is introduced there are some more notations to be introduced.

$Q\ =\ the\ replenishment\ quantity\ in\ units.$

$v\ =\ the\ cost\ per\ item.$

$D\ =\ the\ demand\ in\ units/unit\ time.$

$TRC\ (Q) =\ the\ total\ replenishment\ cost\ per\ unit\ time\ in\ \$/unit\ time.$

How the inventory level behaves can be illustrated by figure 18.

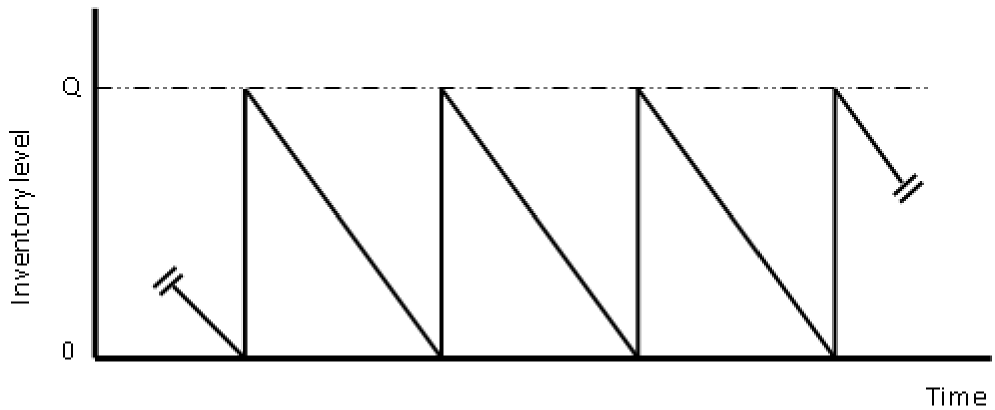


Figure 18 - How the inventory varies over time under the assumptions stated above.[79]

The total relevant cost *TRC* has two different cost drivers, the replenishment cost per unit time C_r and the cost of carrying inventory over a unit time period, C_c and they are given by

[75] S Axsäter, *Lagerstyrning*, 1991, p. 43.
[76] Ibid., p. 45.
[77] E A Silver, D F Pyke, R Peterson, *Inventory Management and Production Planning and Scheduling*, p. 149.
[78] S Axsäter, op.cit., p. 45-46.
[79] E A Silver, D F Pyke, R Peterson, op. cit., p. 153.

$$C_r = \frac{AD}{Q} + Dv$$

and

$$C_c = \frac{Qvr}{2}.$$

Where $Q/2$ is the average inventory level in units and as can be seen in the first formula the second component is independent of Q and can therefore be neglected in further discussions for determining the optimal order quantity.

By combining them, the total relevant cost is given by

$$TRC(Q) = \frac{AD}{Q} + \frac{Qvr}{2}.$$

The total relevant cost is illustrated in figure 19.

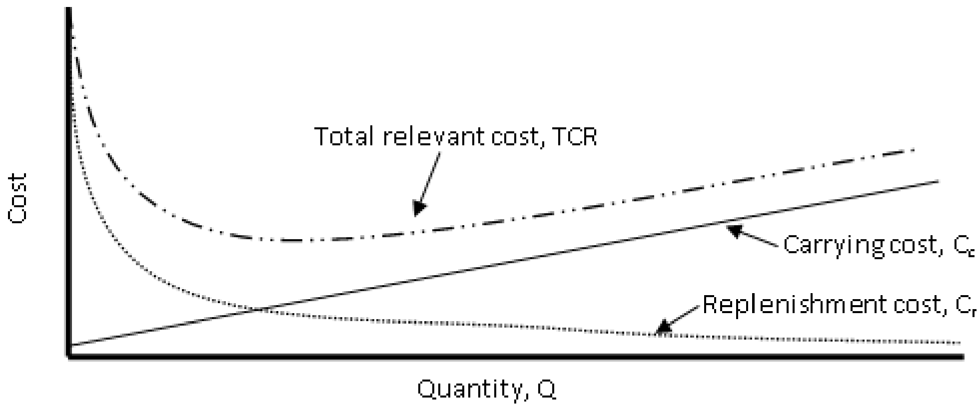


Figure 19 - How the different costs behave.[80]

As can be seen the replenishment cost gets lower with an increasing quantity while the cost of carrying inventory increases with higher quantities. This means that there is a minimum quantity to be found and this is done by deriving the function and set equal to zero

$$\frac{dTRC}{dQ} = 0$$

that with the right variables is

$$\frac{vr}{2} - \frac{AD}{Q^2} = 0$$

and this gives the economic order quantity

$$Q_{opt} \ or \ EOQ = \sqrt{\frac{2AD}{vr}}.$$

[80] E A Silver, D F Pyke, R Peterson, *Inventory Management and Production Planning and Scheduling*, p. 154.

Given that the assumptions above are fulfilled this formula is quite easy to use and the major issue is to determine a proper carrying charge. But if this is done properly this formula creates a useful tool for determining an economic order quantity.[81]

4.5.3 Safety stock

4.5.3.1 Safety stock and reordering point

If it is assumed that the proper order quantity is established the next important step is to decide at what level an order should be created. In an (R,Q)-system, meaning a reordering point system with reorder point *R* and order quantity *Q* as described earlier, the problem is to find the accurate level for *R*. The purpose is to find the level where the reordering point at a specific certainty will cover the demand during the lead time, *L*. This is determined by the average demand, $\bar{x}_L$ during the lead time and the safety stock, *SS* by

$$R = \bar{x}_L + SS.$$

This is illustrated in figure 20 as a development of figure 16 above.

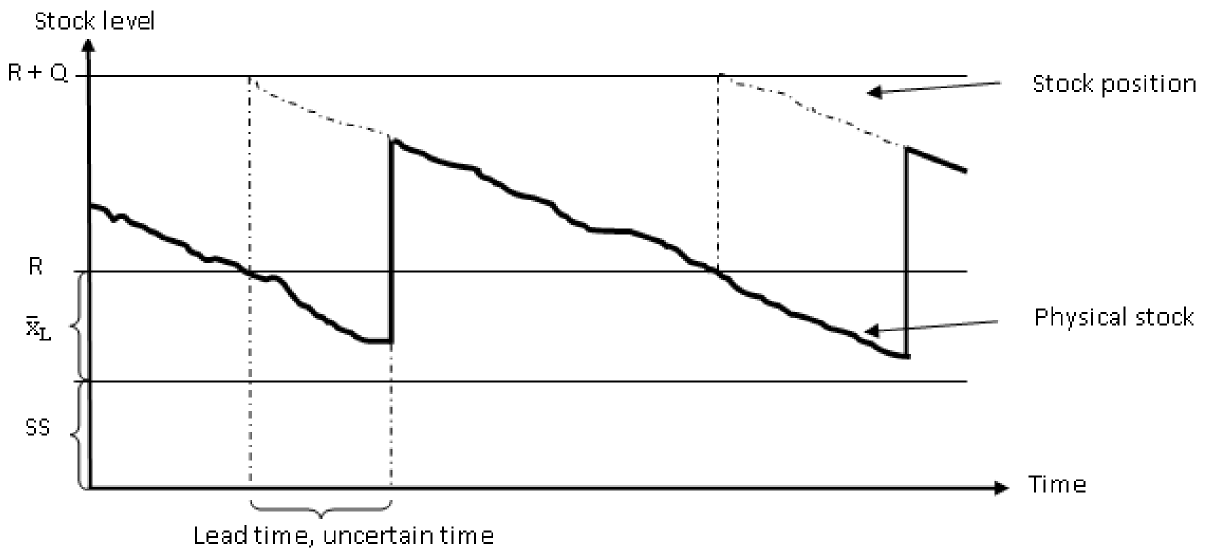


Figure 20 - (R,Q)-system showing how the safety stock and reordering point are connected.

The safety stock depends on the specification of the service level, which will be further elaborated in chapter 4.5.3.3. When the safety stock is determined the reordering point is quite easy to get and is usually the parameter used for operational usage.[82]

4.5.3.2 Uncertainty during lead time

The uncertainty in the demand during the lead time depends on both deviation in the demand and deviations in the lead time. From the forecasting system it is possible to get the mean value, *E(d)* and the standard deviation, σ_d for the demand. If there are any deviations in the lead time it is possible to determine the mean value *E(L)* and the standard deviation σ_L. Due to the problematic in collecting data for lead time deviations it is sometimes easier to use the mean absolute deviation, MAD_L instead of σ_L and this is calculated by

[81] E A Silver, D F Pyke, R Peterson, *Inventory Management and Production Planning and Scheduling*, p. 152-154.
[82] S Axsäter, *Lagerstyrning*, 1991, p. 63-64.

$$\sigma_L = \sqrt{\frac{\pi}{2}} * MAD_L \approx 1.25 * \ MAD_L.$$

If it is assumed that the forecasted demand per time unit is constant and that the deviations can be seen as independent variates with a mean value of zero, the standard deviation can be calculated by

$$\sigma_x = \sqrt{E(L)\sigma_d^2 + \left(E(d)\right)^2 \sigma_L^2}.$$

But if the lead time is constant, *E(L) = L* and $\sigma_L = 0$, the formula above can be adjusted to

$$\sigma_x = \sigma_d L^{1/2}.$$

In order to proceed with the calculations a suitable probability distribution has to be selected for the parameters. If the demand is high the most common choice is normal distribution which is fairly easy to use for calculations and depends on two parameters. Even though it has many advantages it also has some disadvantages. The main disadvantage is that it is a continuous function, which means that the demand during the lead time does not have to be an integer. This is not a problem for a relative large demand where it is possible to calculate with a continuous demand and then roundup the reordering point to an integer since the errors becomes negligible. It creates a problem where the demand is very low and there is even a risk that the demand from a theoretical aspect can be negative. The probability for this is very low but it is important to have in mind.

Where the demand is low it can be better to use Poisson distribution, which is a discrete distribution with only one parameter, λ. If the variates is denoted *x* the formula for the distribution is expressed by

$$P(x = k) = \frac{\lambda^k}{k!} e^{-\lambda}, \qquad x = 0,1,2, \dots$$

with the mean value

$$E(x) = \lambda$$

and the variance

$$\sigma_x^2 = E(x - \lambda)^2 = \lambda.$$

Since there is only one parameter it is always good to validate that $E(x) \approx \sigma_x^2$. And since there only is of interest to replace the normal distribution for Poisson distribution for low demand there is some conditions that can be analyzed. One example of this is that Poisson distribution should be used if

$$(x) < 10, 0.8 * \sqrt{E(x)} < \sigma_x < 1.2 * \sqrt{E(x)}.$$ [83]

[83] S Axsäter, *Lagerstyrning*, 1991, p. 64-67.

4.5.3.3 Service level

When determining the safety stock it can either be done by a service specification or a shortage cost. It is usually easier to determine the service level and the two most common ones are $SERV_1$ and $SERV_2$.

$SERV_1$ = the probability not to have a shortage during an order cycle.

$SERV_2$ = the fraction of the demand that can be collected directly from the warehouse.

$SERV_1$ is fairly easy to use but it has it´s clear disadvantages. The main problem is that it does not take the order quantity into consideration. If the order quantity is large and thereby cover the demand during a long time it does not really have a big impact that $SERV_1$ is low. The reverse situation is when the order quantity is low and it is here possible to have a really low service even though the theoretical level is high. $SERV_2$ gives a much more accurate image of the real service level but is a lot more difficult to use.

To calculate the safety stock with $SERV_1$ is as mentioned earlier quite simple. Under the assumptions the demand has a normal distribution with a standard deviation, σ_x and a safety stock, *SS*. The probability not to get a shortage during the order cycle is then equal to the probability that the mean values deviation of the demand is less than *SS* that results in

$$SERV_1 = \emptyset(SS/\sigma_x).$$

For a given value on the service level the safety stock can now be calculated by

$$SS = k\sigma_x$$

where *k* is a safety factor responding to a certain service level and it can be found in a table for normal distribution, see Appendix B.

$SERV_2$ is as earlier mentioned much more difficult to calculate but will give a more accurate service level. Since $SERV_2$ stands for the fraction that can be delivered directly from the warehouse and every order quantity tends to have an average shortage this shortage has to be found. If it is assumed that every shortage will be delivered as soon as the next delivery arrives and *u* is the average deviation of the demand during the lead time. Whenever *u* becomes higher than *SS* there will be a shortage responding to one of the following

$$SS \leq u \leq SS + Q \rightarrow u - SS$$

$$u > SS + Q \rightarrow Q.$$

Under the assumption that the demand is normal distributed can the average deviation of the demand be expressed by

$$\frac{1}{\sigma_x}\varphi(u/\sigma_x)$$

and the average shortage

$$shortage = \int_{SS}^{SS+Q} (u - SS) \frac{1}{\sigma_x} \varphi(u/\sigma_x)\, du + Q \int_{SS+Q}^{\infty} \frac{1}{\sigma_x} \varphi(u/\sigma_x)\, du =$$

$$= \int_{SS}^{\infty} (u - SS) \frac{1}{\sigma_x} \varphi(u/\sigma_x)\, du - \int_{SS+Q}^{\infty} (u - SS - Q) \frac{1}{\sigma_x} \varphi(u/\sigma_x)\, du$$

and by inserting

$$G(v) = \int_{v}^{\infty} (x - v)\varphi(x) dx = \varphi(v) - v(1 - \emptyset(v))$$

is it possible to after simplification express the shortage by

$$shortage = \sigma_x G(SS/\sigma_x) - \sigma_x G((SS + Q)/\sigma_x).$$

The second term in the formula becomes close to zero if the order quantity is large and it is then possible to use the approximation

$$shortage = \sigma_x G(SS/\sigma_x).$$

The fraction of shortages is $shortage/Q$ and this defines the last formula

$$shortage/Q = 1 - SERV_2.$$

By combining the latter formulas, depending on the order quantity, the formulas for determining the safety stock is

$$G(SS/\sigma_x) - G((SS + Q)/\sigma_x) = \frac{Q}{\sigma_x}(1 - SERV_2)$$

or when the order quantity is large

$$G(SS/\sigma_x) = \frac{Q}{\sigma_x}(1 - SERV_2).$$

The easiest way to use those formulas is by using values from a table for G(x), see Appendix C, and if there are any needs for values that are not in the table, meaning a value in between two values, it can be determined by interpolation.[84]

[84] S Axsäter, *Lagerstyrning*, 1991, p. 68-72.

5. Empirical study

This chapter will give an overview of which data that has been collected and studied throughout the master thesis. It will describe the current situation at Nederman followed by description of the data collected for the study and where it has been obtained.

5.1 Current state analysis[85]

All the information about the current state at Nederman was gathered via interviews and conversations with employees, especially from Fredrik Aborelius, Maria Waidele and Erik Blix, but also from other employees to verify and strengthen the trustworthy of the information. The majority of the information has its base in one interview with Fredrik Arborelius, see Appendix D. This information has later been confirmed and readjusted by conversations and meetings with Fredrik and other employees at Nederman on several occasions.

Nederman is, as earlier mentioned, a global company with its headquarters in Helsingborg. The site holds two warehouses and a combined assembly station that together supplies Europe and the Middle East. It also supplies the two distribution centers in North America and China with components that for different reasons are not available there, see figure 21.

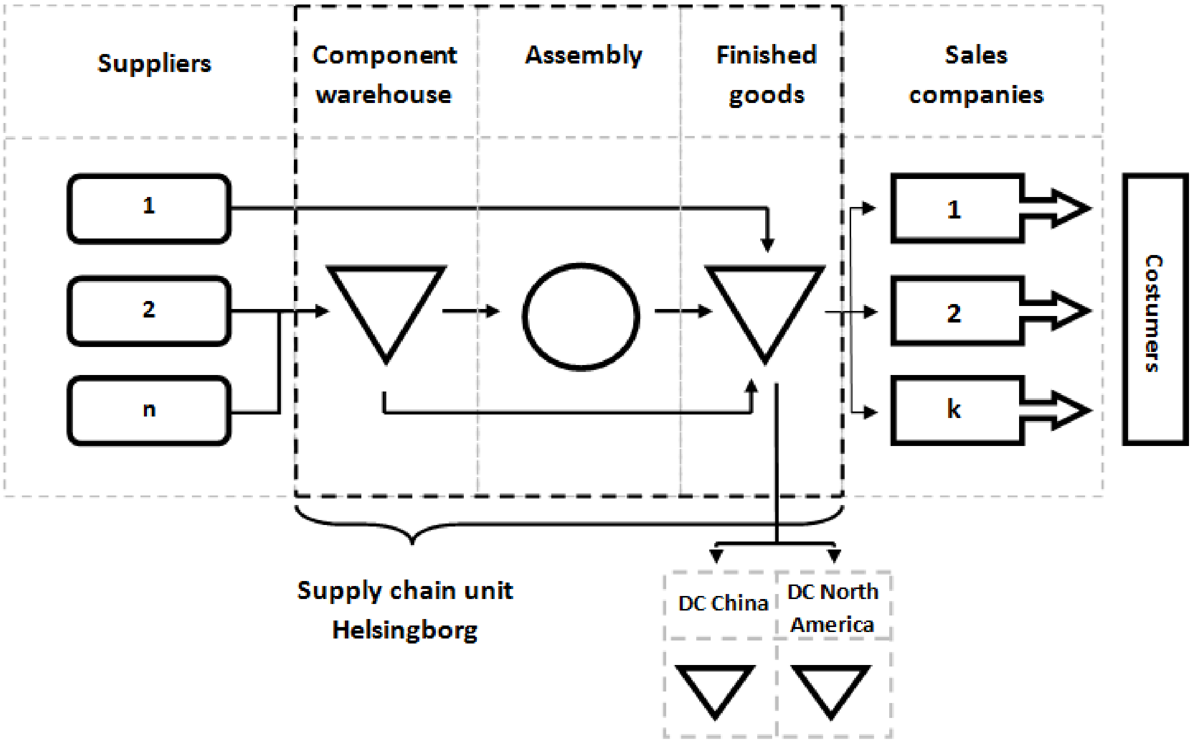


Figure 21 - Mapping of the flow at Nederman from suppliers to customer.

The distribution channel in Helsingborg is controlling around 26 000 active products and around 6500 of those are stock items and the rest are made or purchased towards customer orders. Out of those stock items are around 1100 manufactured and 5400 purchased. If all 26 000 products are considered, about 7300 of these are manufactured and 18 600 purchased.[86] This implies that the

[85] Fredrik Arborelius, Logistic Analyst, interview 2012, 02 02.
[86] Erik Blix, Plant manager, interview 2012, 02 06.

reality of the different products at Nederman ends up in a quite complex structure with a huge range of different products from components as tiny screws, to complex products like massive industrial vacuum cleaners. This indicates that this urges for a quite sophisticated controlling system.

All products that are classified as stock items are controlled in a software called MySigma that is interconnected to IFS, which is the ERP system used by Nederman, see chapter 5.2.1-2 for further explanation. Every month a forecast is made with a software for forecasting called Demand Planning. The values are then sent to MySigma, via IFS, and the safety stock and reordering points are calculated. After this is made, the new calculated safety stock and reordering point are transferred back into IFS. The whole process is a reordering point system that is updated every month. Where the reordering point is set by the safety stock and the demand during the lead time and the safety stock is set by SS-bas, the forecasted demand and an adjustment factor for the lead time. The formulas for the two are further explained in chapter 5.1.2.2-3. And SS-bas is as earlier mentioned safety days controlled in a matrix system based on two parameters, product value and the frequency that ends up in groups with different amount of safety days.[87]

5.1.1 Forecasting

The forecasting at Nederman has two purposes. The first is to establish a demand for the upcoming period that is used for setting the safety stock and thereby the reordering point. The second is to in advance give the suppliers information regarding the future demand and this is used just like an indicator. The method used is moving average based on the last six months data times two, to create a yearly demand. It is only historical data that is used in the forecasting process and no information about the future is taken into consideration.[88]

The company is aware of that this might be a blunt way of forecasting the demand and was during the autumn 2011 performing a project together with a group of students from LTH, where the authors of this master thesis where members. The project was to map the current situation and from there evaluated it in comparison to a few other forecasting methods. The result of that project showed that based on the product range and demand pattern at Nederman it would not gain sufficient improvements in changing method if only historical data were used. This indicated that, with existing software, future predictions could be interesting to take into consideration but needed further investigation and that better communications where needed between involved persons in order to make good use of the process.[89]

The forecasting process starts with some manual adjustment for new products and other special products. When that is done all products are transferred from IFS to Demand Planning where the forecast is made. They are then sent via IFS to MySigma where the new reordering points are calculated. All products that have a change in their reordering point by more than 15 % are suggested for changes. When decided which products that are supposed to be changed the new reordering points are transferred to IFS and mails are going out to suppliers and the material planners. This process is illustrated in figure 22.

[87] F Arborelius, Logistic Analyst, interview 2012, 02 07.
[88] F Arborelius & C Holmkvist, interview 2012, 01 21.
[89] D Arrelid, S Backman, M Grönlund, P Svanfeldt, Analysis of the forecasting methods at Nederman.

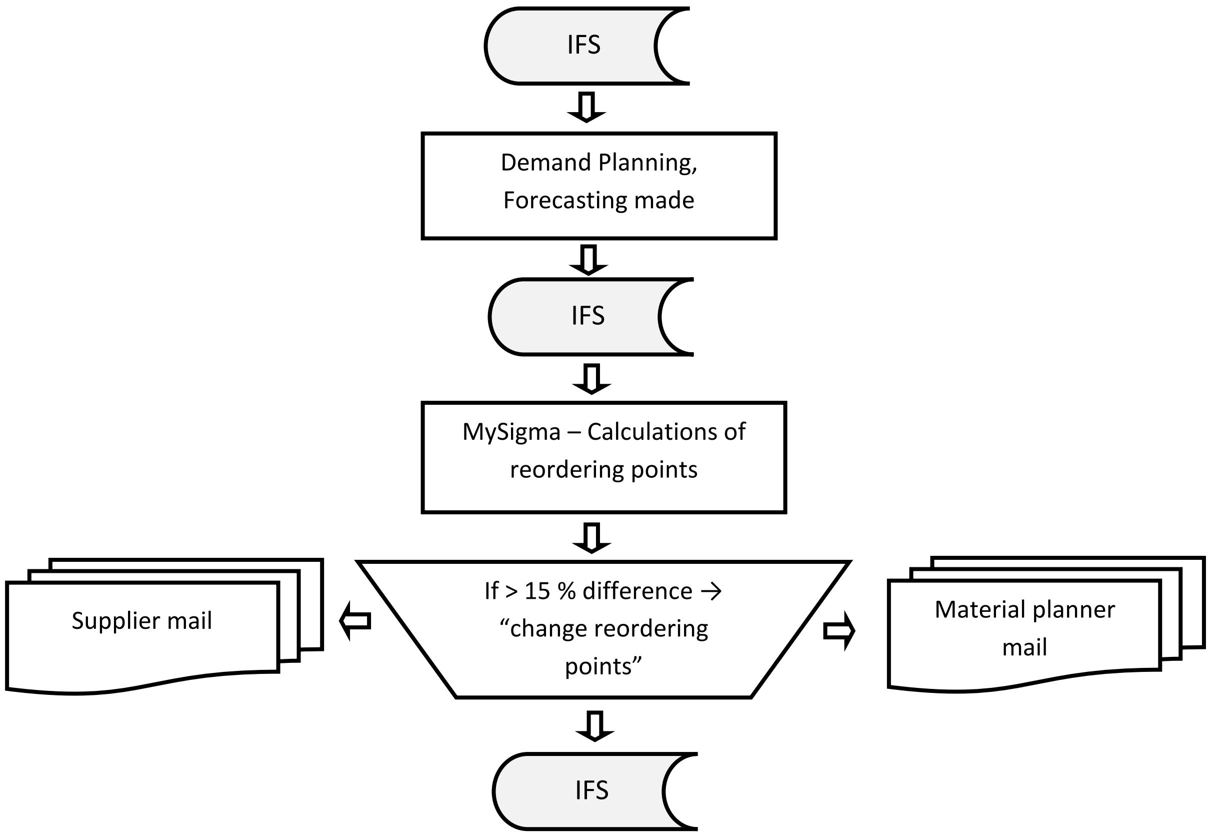


Figure 22 - Mapping of the forecasting process at Nederman.

5.1.2 Replenishment system

Nederman is using a reordering point system for all its stock items. All products that are stock items are today controlled by the same methods regardless of the specific item properties. Their order quantities are normally set once a year and then updated only if any impacting changes or new better deals occur. Whenever the reordering point is reached a new order is suggested for either manual creation or automatically created depending on the specific product. The reordering point is set by the demand during the lead time and the safety stock that is controlled by the in advance determined safety days, SS-bas based on frequency and value, a lead time adjustment factor and the predicted demand.

The reordering points are supposed to be updated once every month after the forecast is made, but this is not happening in reality and there are always different circumstances affecting this, resulting in the infrequent updates. If there for example is a very low service level, for a period, there is a risk that only the suggestions for increasing reordering point values will be executed and the reverse in an event of very high overall stock value. This makes the system flexible but also very vulnerable and dependent on the behavior of the employees.

5.1.2.1 Stock levels

How the stock level and replenishment sizes are determined in the company is a combination of different methods. Several methods are used both in combinations and as a single source and it is very hard to keep track of which products that have an order size set by one specific method. One of the established theoretical methods used is the Wilson formula and the company has defined the formula and the variables according to the following

$$EOQ = \sqrt{\frac{2 * D * A}{P * h}}$$

where

$D = the\ yearly\ forecasted\ demand.$

$A = the\ fixed\ ordering\ cost.$

$P = the\ price\ on\ the\ article.$

$h = the\ holding\ cost\ asa\ percentage\ of\ the\ item\ value.$

Whenever the formula is used the fixed ordering cost is varying with the different type of products, but the most common used at Nederman is 100 SEK/order and the percentage for the holding cost is 20% of the stock value. Other factors and methods used for determining order sizes are minimum allowed batch sizes from suppliers, discounts gained from the purchasers, experience and so on. The order sizes are set once a year and then used throughout the period with some exceptions like project orders or identified problems at supplier.

5.1.2.2 Reordering point

The reordering point is supposed to be updated every month and is based on the safety stock and the predicted demand during the lead time.

$$ROP = SS + (LT * \frac{D}{365})$$

Every month when the new reordering points are calculated the employees has to decide which updates that are going to be done. The reordering points that differs more than 15 % compared to last month are suggested as potential changes. It is here possible to select special product groups, product families, products in certain assembly stations and so on and then decide whether or not the updates should be performed.

5.1.2.3 Safety stock

The safety stock is as earlier mentioned based on a beforehand decided amount of safety days, an adjustment factor for the lead time and the demand. The formula used for the safety stock is

$$SS = SS_{bas} * \sqrt{\frac{LT}{30}} * \frac{D}{365}$$

This was introduced when MySigma was created. It is a bit unclear why $\sqrt{LT/30}$ is used but it is believed that the most common lead time at that time was 30 days and that it therefore acted like an adjustment factor that creates balance that arises with uncertainty in long or short lead times. MySigma is programmed with the real lead time but it is also possible to adjust the lead time if desired depending on the delivery accuracy of the supplier.

5.1.2.4 SS-bas

The most unique thing about the inventory control at Nederman is the SS-bas, which is a way of categorizing the products like a type of ABC analysis. All products are by Nederman divided into two categories, manufactured and purchased goods that creates two SS-bas matrices. There are two parameters in the matrices and those are value and frequency. The difference between the two matrices is the amount of safety days. In the matrices, low value and low frequency are premiered with more days resulting in higher safety stock. Both matrices have then a decreasing amount of safety days with increasing value and frequency resulting in lower inventory levels in terms of the safety stock. The days has once been set by the creator of MySigma and has since then been adjusted by someone, often the plant manager, Erik Blix and now Fredrik Arborelius. The adjustments are based on the actual service level of each cell, which is monitored frequently and adjustments are then done according to that when needed. The two matrices with their original values in terms of safety days are displayed in table 2 and 3 below.

Table 2 - Original SS-bas values for all purchased products, shown in "safety days".

Purchased	Value				
Frequency	A(min)	B	C	D	E(max)
A(min)	50	50	50	30	25
B	50	50	50	30	25
C	50	45	53	30	25
D	50	30	26	30	25
E	45	28	24	27	20
F	12	11	14	7	9
G(max)	12	12	11	9	9

Table 3 - Original SS-bas values for all manufactured products, shown in "safety days".

Manufactured	Value				
Frequency	A(min)	B	C	D	E(max)
A (min)	0	0	0	0	0
B	90	90	90	60	25
C	90	90	60	50	25
D	90	90	60	33	25
E	60	30	30	18	16
F	15	12	10	7	6
G(max)	15	12	9	7	6

The reason for the row with zeros (frequency, A) in table 3 is that a decision was made recently that all manufactured products with a frequency within the limits of A are supposed to be treated as made to order products.

5.1.2.5 Service level

The service level is measured on all stock items and it refers to that the goods should be delivered within the lead time with backorders allowed. Backorders means that part delivery is allowed when agreed. The service level target is an overall goal for all products, which means that every cell in the SS-bas matrix can have different targets. There is no clear dividing between the cells of what the targets should be in every cell but in general, items with low value and high frequency are controlled towards a higher service level. The service level has recently had a goal level of 92%, but during 2011 the service level was only 84 %. This is one reason of why it is important to work on this and maybe find new solutions. The new goal for 2012 is 94% and there may be a need of changed working methods to reach this goal.

5.2 Transactions records

Since Nederman has over 26 000 active products and hundreds of thousands of order lines every year they have a lot of data and transactions records to overview and control. Nederman is currently using three different systems, IFS, MySigma and QlickView, to fully cover the warehouse activities. These three systems are all used to help and optimize the supply chain at Nederman.

5.2.1 Used databases

The systems that are described below have more applications than stated but these are the ones used in this master thesis.

5.2.1.1 IFS

IFS are an ERP system that keeps record over the whole warehouse and from here the reordering points for products can be updated and changed. All transactions, purchases and other statistical information at Nederman can be found in IFS. All information regarding lead time, cost, reordering points and all other information that can be connected to a specific product, can also be found in IFS. Information can be extracted from IFS into an excel file and from there analyzed in different ways.

5.2.1.2 MySigma

MySigma is a calculation program that creates a report every month containing all products, active and inactive. The report contains updated information of every product like demand, lot size, reordering points, different stock values etc.

MySigma calculates new reordering points for products using the data from the Demand Planner. Looking at the latest 6 months of transactions, it calculates a new optimal reordering point for every product on stock. This is made every month, but updates are only changed and made in IFS if the new order point is 15 % higher or lower than the current one and approved by Fredrik Arborelius.

5.2.1.3 QlickView

QlickView has a lot of applications but is mainly used to overview the service level. With QlickView it is easy to see and follow up on the service level in the warehouse and from there see how the products are performing.

With QlickView the service level for a specific product or for a group of products can be measured. Both the current levels and the historical levels can be measured and monitored, but the downside is that only products from the finished goods warehouse can be measured.

5.2.2 Imported data

Throughout the master thesis a lot of data has been downloaded and imported from the different databases for different analysis and below is a description of the data used.

5.2.2.1 IFS

The largest part of the data was downloaded from IFS and the focus here was to find historical sales and transaction records. When extracting data from IFS, different time periods can be chosen and for this master thesis the data chosen was between the time periods of 2010.01.01 – 2011.12.31. Since Nederman is using two different warehouses in Helsingborg, one mostly for components and one for finished goods, the downloaded data was separated between these two warehouses.

When downloading data from IFS it becomes transferred to a excel file that is created with a lot of information. Every line contained specific information regarding one order line for one product. For example, if one product is used in the production from the components warehouse five times during a week, five lines will be created in the file from the components warehouse. This created two large files, one for the component warehouse and one for the finished goods. Some of the products where present on both of the lists, but was just added to each other when merging the lists later. In total the two lists contained around one million lines and 120 columns. Every order line contained a lot of information, but only three columns where of interests for the master thesis, see table 4.

Table 4 - Information types used from IFS

Column	Description
Product number	Gave the information of which product that had been used
Volume	Described how many of the product that was used that specific time.
Date	Gave the day, week, month and year for the event

5.2.2.2 MySigma

Most of the information connected to the products where received in a file that was created by MySigma every month. The file contains information about all products, and it is a file that has around 56 000 lines, one for every product, and every product have around 50 columns with specific information to every product. The information was used as a complement to the data from IFS and gave more information to every product. Nine columns of information were primary used in this master thesis, see table 5.

Table 5 - Information types used from MySigma.

Column	Description
Descriptions	Full name of the product
Status	Describes if the product is active or not
Creating date	The day that the product was created in the system
Current order point	Minimum number of goods when a new order is sent
Lead time	Number of days it takes for the supplier to deliver to Nederman
Value	Value in SEK for one product
Manufactured / Purchased	Gives the information if the product is manufactured in house, or purchased ready directly from a supplier
Frequency	Number of times the product was sold during the last 12 months
Demand	Previous 12 months of sales

5.2.2.3 QlickView

QlickView was first used in the end of the analysis, after the implementation was done. QlickView can give a list of all products that have been sold or used in production during a specific time period.

A weekly report from QlickView contains around 500 lines, one for every product that has been sold during the week, and eight columns with further information for every product.

Only three columns were needed for this master thesis, see table 6.

Table 6 - Information types used from QlickView.

Column	Description
Product number	Gave the information of which product that had been used
Delayed	Gave the information if the product was delayed or not
Date	The date when the transaction was done

With this information a weekly pivot table was created to be able to easy follow and see how the different products where performing. The list has one column containing how many times one product had been ordered and another column contained how many times the product was on time. This makes it easy to display how the service level develops over time.

6. Analysis

This chapter will describe the analysis of the empirical data according to the theoretical framework. It starts with the current state analysis and moves to the analysis of the demand pattern and continuous with a selection of new SS-bas matrices. The chapter will after this explain how the new start values in the new matrices were calculated and finally showing how the new solution was implemented and updated in IFS.

6.1 Current state analysis

The first part of the analysis was to analyze the current situation at Nederman to be able to understand their working methods and processes along with their different software in order to find any potential for improvements.

In order to understand the quite complex structure of the product range, how the different types are controlled and how they are linked together, the first step was to create a map, see figure 23. This map gave like the theory suggests a good overview of the different products and gave the authors a good understanding of which data that was needed and how it should be summarized to be able to analyze all products in the same way. This gave also information about which products that where more interesting than others for the analysis and the implementation.

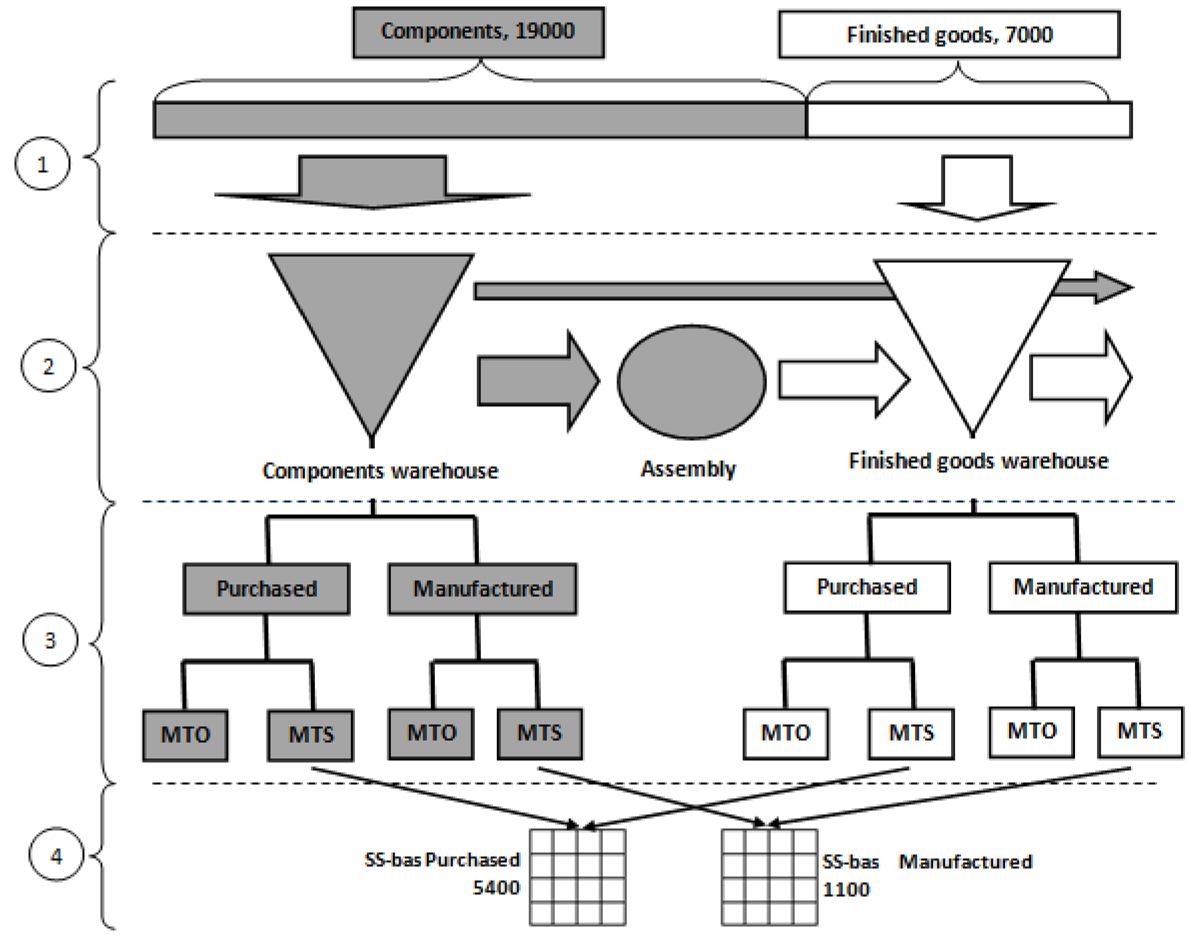


Figure 23 - Complexity of how the products are handled and classified on different levels.

Figure 23 describes the complex product handling in terms of controlling and classifications. The first stage (1) is showing how the products are divided between components and finished goods, this is also how the transaction data is divided. The next stage (2) is the part describing the supply chain unit and the flow of the products. The third step (3) is showing how the products are classified in IFS and how that is linked to the production and warehouses between manufactured and purchased and that both can exist in components and finished goods making the structure complex. And the last step (4) shows how products from all directions can end up in the two SS-bas matrices of purchased and manufactured. So there are many different classifications in different system and to keep track of how the products move between all this is quite difficult.

The next step in the current state analysis was to understand how the stock products where controlled by the matrices along with the formulas and how this was used and performed in reality.

The analysis of these actions gave information of that the order sizes were determined by a mixture of many different methods. And that there was no information of which products that is ordered based on which method. Based on this, the group decided not to analyze this any further and that the order sizes determined should be seen as good enough and not be a part of the further analysis. But it would be in the interest of Nederman to start use for example economic order quantity as the base for the order sizes so that all the employees would have any information of what would have been the optimal quantity.

The analysis of the two SS-bas matrices gave indications of that it in every cell could be products with many different demand pattern resulting in a smoothing of all different demands to one average line, which would give some products a way to high safety stock and others way to low. The very positive thing about those matrices is that they create a very easy tool to handle the huge complexity of the products and that it controls the warehouse at an acceptable level, but that it in order to make any improvements needed to be further developed. This was in line with the thoughts of the project commissioner, Erik Blix and confirmed that this contained possibilities for improvements.

The formula for the safety stock has very little theoretical ground and is special adapted to the software and situation at Nederman. To use a more theoretical formula could improve the specific safety stock for the different products. The analysis, a comparison between the theoretical calculations based on $SERV_1$ and the calculations based on the Nederman formula showed that differences in the stock levels, where $SERV_1$ gave an in total higher value but this was based on a higher service level. How this analysis was continued is further described in 6.5 since a lot of the analysis was focused on this.

The reordering point itself follows the theory with an (R,Q)-system and needed therefore no further analysis. Since the order sizes are predetermined in the company an (s,S)-system would not work without any major changes and due to the fact that an (R,Q)-system is a good method to use no further investigations were made to determine if there were any improvements to be made if changing the system. It was discussed about the limits of 15 % for the reordering point changes and was after some analysis decided that this was making up for the quite blunt forecasting methods in a good way. Since the forecasting methods at Nederman was investigated just a few months before this master thesis the authors decided not to make any new analysis of this and instead use the result from that study, that moving average was the most suitable method for Nederman and that no major improvements would be achieved by start to using exponential smoothing or exponential smoothing with trend.[90] The report about the forecasting method gave further indications of that the 15 % limits for changes were good to make up for the smoothing created in the forecasted demand.

When the current situation was mapped and understood, the authors decided to move on with the analysis of the demand pattern and from there be able to divide them into new matrices. And finally create the updating model and make a test implementation.

6.2 Second phase analysis introduction and overview

This part of the analysis was the largest part of the master thesis and started with a massive amount of raw data and ended in a partly implemented but fully developed solution. It was divided in four main parts, which creates the base of the analysis. These four parts was divided in several smaller parts, which will be explained later in the chapter. Since Nederman wanted a new and more sophisticated SS-bas and that this was confirmed by the group as a good focus, the focus of the analysis was to develop a better and more optimal SS-bas to be able to make the safety stocks more accurate. As earlier mentioned this was made in four different steps, and can be seen in figure 24.

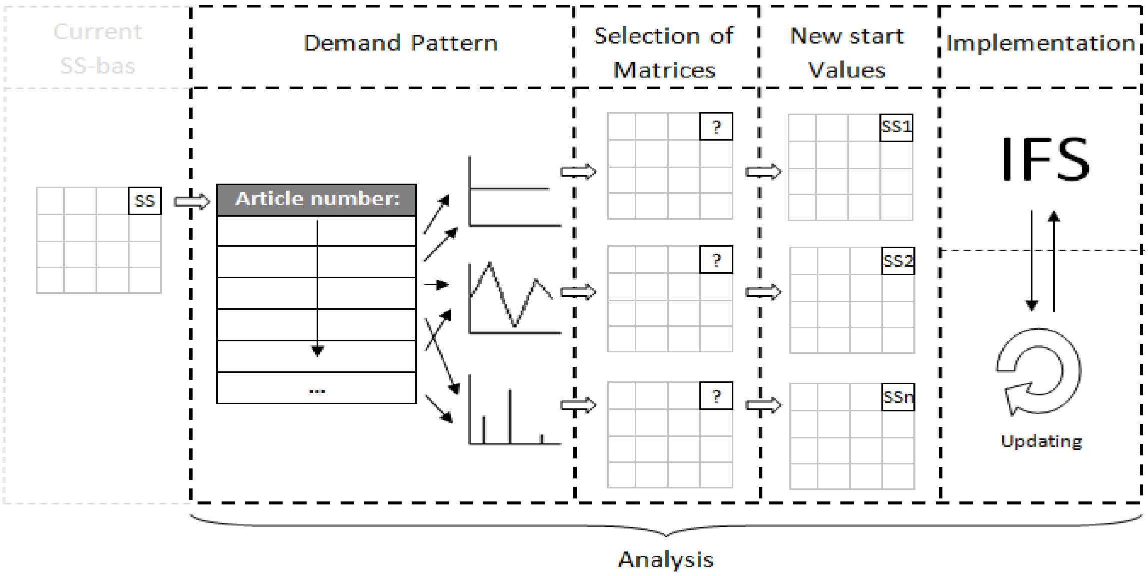


Figure 24 - Overview over the analysis model.

- *Demand Pattern; During* the first step different demand patterns from the raw data was analyzed and further put in different groups after pikes, variability and frequency.
- *Selection of Matrices;* The groups created in the first step ended up in new SS-bas matrices, based on purchased and manufactured products.
- *New start values;* In the third step the new values for the matrices was calculated, based on products in the group and the old SS-bas.
- *Implementation;* Last the selecting of the test group and control groups was made, and also an updating model was made.

[90] D Arrelid, S Backman, M Grönlund, P Svanfeldt, Analysis of the forecasting methods at Nederman.

6.3 Demand pattern

6.3.1 Creating the demand plot

As Nederman has no current classification of the demand pattern and controls all products in the same way, the analysis first step was to find all the different demand patterns among the products.

To determine the pattern, data from IFS was used and transferred into a pivot table, with the product numbers on the y-axis and the time, divided into weeks on the x-axis and the demand in the main frame of the table, see figure 25. This gave a simple view over the demand pattern for all products during 2010 and 2011. To be noted, all products introduced during these two years, was removed from the analysis since the demand pattern for these products had too short test period. Throughout the analysis the weekly demand was used as frequency but when allocated in the right matrices they were distributed in the matrix according to frequency in terms of orders.

Year	2010								2011
Week	1	2	3	4	5	6	7	…	52
Product number ↓ …					**Weekly demand**				

Figure 25 - How the final document looked like after the raw data was summarized.

All products that had at least one order line during the last two years received a line in the pivot table, this created over 8000 lines. Since it would take way too much time and work to analyze and see the demand pattern for every line individually, a more quantitative method was used.

To be able to see all products demand pattern in one simple plot, more calculations was added to every products line. These calculations were based on the weekly demand, the standard deviation and the frequency of use for every product. Using the standard deviation and average weekly demand the coefficient of variance was also calculated.

With the new added information, a plot was made by all products. This plot contained average weekly demand and coefficient of variance, all to give a first overview of the demand pattern. It is shown in figure 26 below, and also as can be seen, products with a high weekly demand, have a low coefficient of variance.

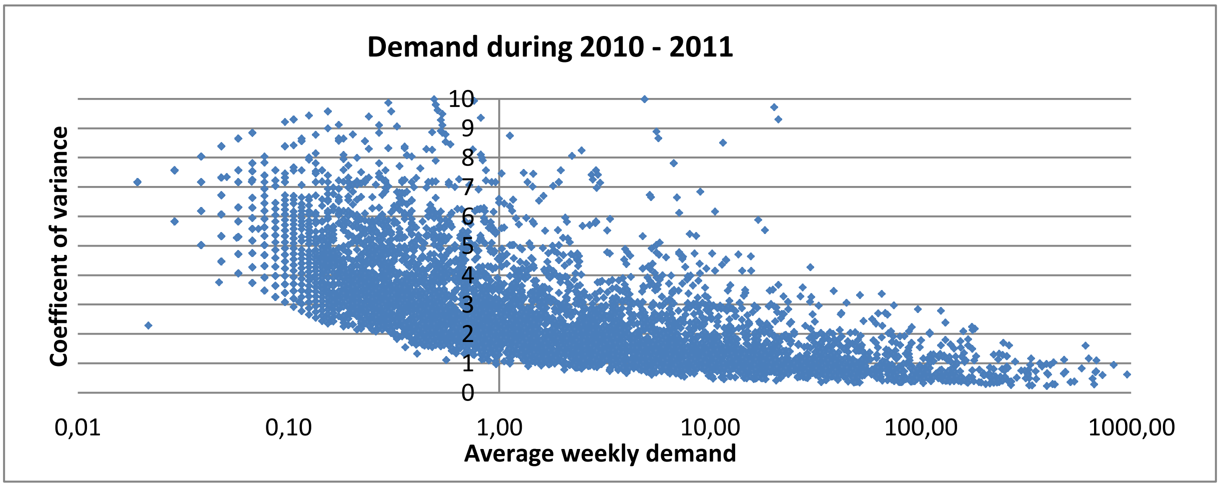


Figure 26 - Plot over all products, with the avarge weekly demand in logaritmic scale.

6.3.2 Sorting the data

The plot of the coefficient of variance and the weekly demand was later used to set the different matrices, but before this was done, more cleaning of the data were needed to be able to compare the new solution with the current one.

Three steps were needed to sort out and take away all data not essential for the master thesis. The three steps was to delete the data from 2010, set limits for make to order and make to stock, and cross check the data with the current classification of make to order and make to stock in order to have comparable products for the implementation, see figure 27.

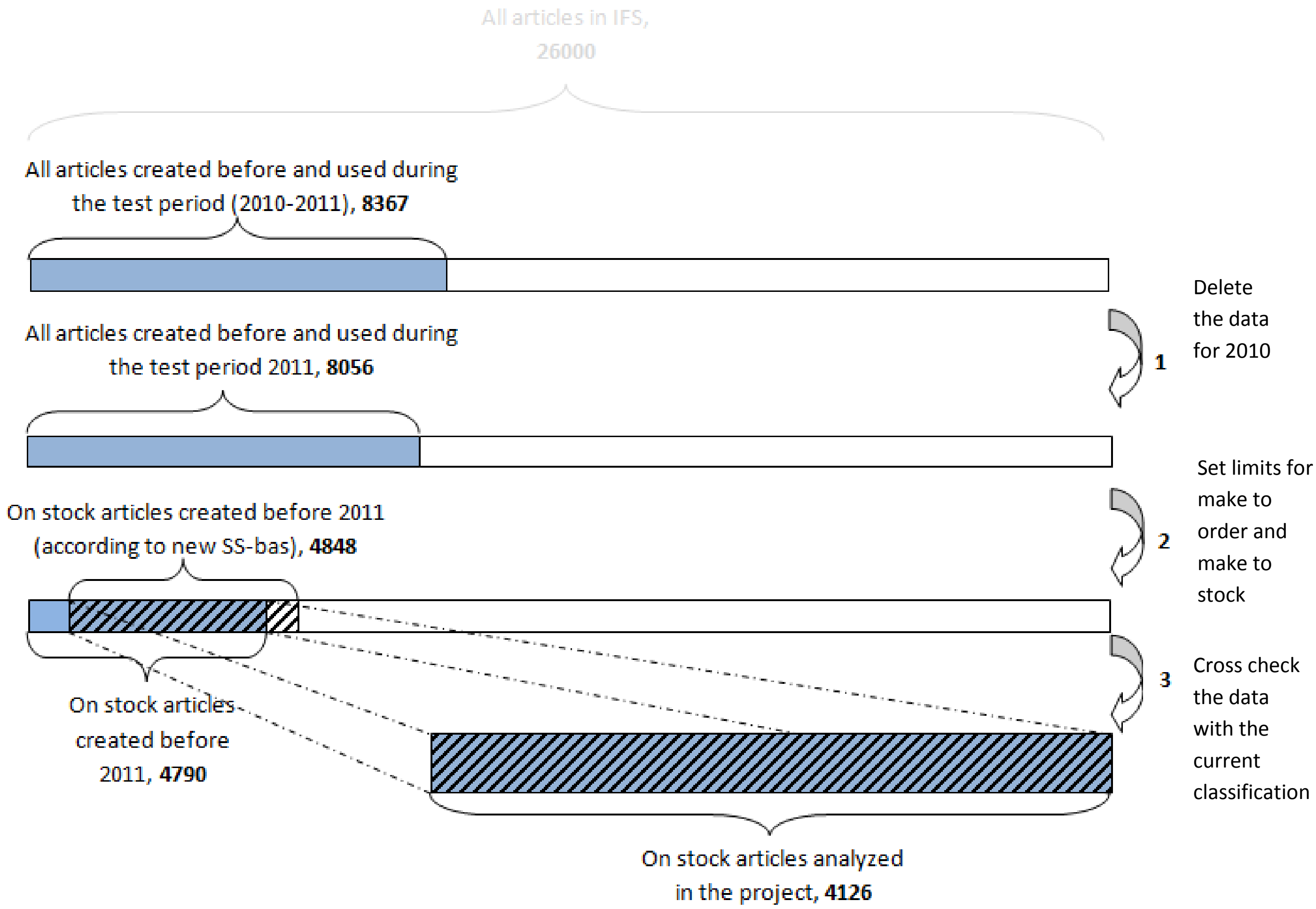


Figure 27 - Overview of the process in data selection for the end analysis.

The first step was to eliminate the used data from 2010, see figure 27, (1). When the data was downloaded from IFS, the last two years was collected to be able to determine the demand pattern for the products. This was done to be able to prove that demand pattern for products stayed the same over time, and did not change so fast. In an updating point of view, it would be much easier to just use one year of data, since peaks in demand for example, is hard to find when using a long period of historical data.

To be able to determine that the products gave the same pattern during just 2011 another plot was made, just for 2011, see figure 28. As seen, the demand pattern was very similar for 2011 when comparing with 2010-2011. After this comparison, the data from 2010 was deleted from the analysis.

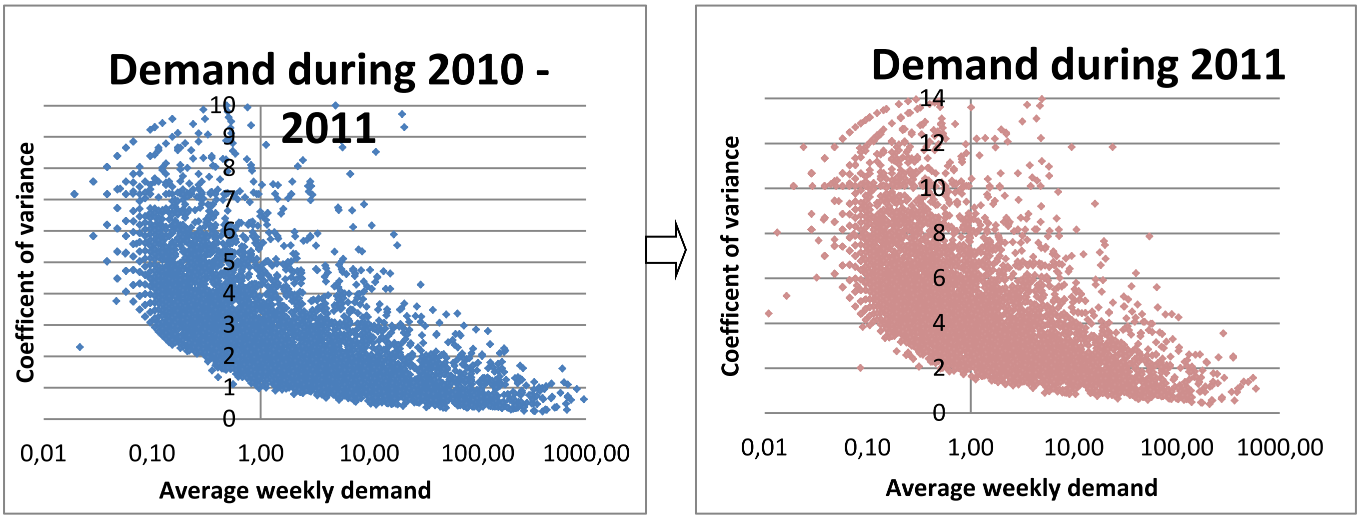


Figure 28 - Comparison off the demand pattern between 2010-2011 and only 2011.

The next step was to set limits for make to order and make to stock, see figure 27, (2). There are few guidelines of how the set limits for these sorts of things, since it differs so much between different companies and warehouses. The limits for this warehouse, to separate between make to order and make to stock, was set to eliminate products that had a very low frequency and a very high coefficient of variance. After testing possible limits and also comparing the number of products in the two different groups with the current numbers, the limit was set. Products that are seen as make or purchased to order if the coefficient of variance is over 6 or if the weekly demand frequency is under 4 per year for the purchased products and 13 per year for the manufactured, where weekly demand frequency is how many weeks a product were demanded. The results of the make to order and make to stock groups can be seen in figure 29.

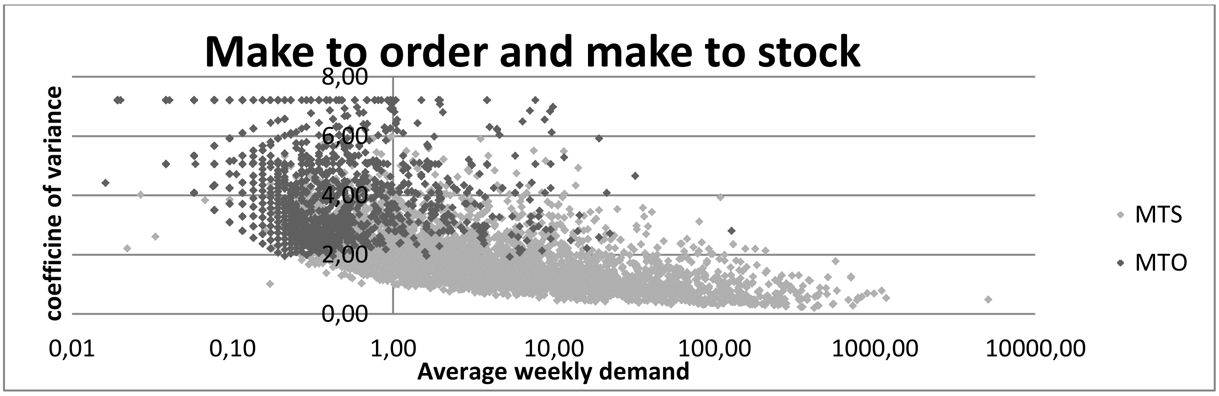


Figure 29 - Plot over all products, separated between make to order and make to stock.

The last step was to cross reference the products in the on stock group with the ones that are current on stock in the warehouse, see figure 27, (3). This was done to get good reference groups when doing the rest of the analysis.

To be able to see any improvement or differences between our solution and the current one, it was essential that the data was containing the same products. According to the new solution limits, over 700 products should be stock items, and over 500 should stop being on stock and be make to orders instead, see table 7.

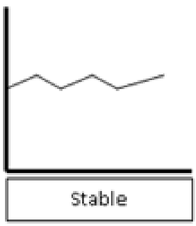
Table 7- Difference between products on stock today and what the new solution implies.

	Numbers of products	Reordering point value of having/not having them on stock
Products on stock today but not according to new solution	513	425 000 SEK
Products on stock according to the new solution, but not on stock today	720	1 670 000 SEK

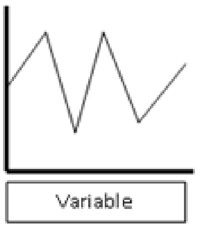
Since the authors did not know the reason for having, for example, some products that have been order one time the last two years on stock, and also the other way around, products that were ordered more or less every week in make to order, they were removed from the analysis. According to interviews with employees at Nederman, these particular products could be requests from the sales organization to always have them on stock or it could be another request not having products on stock. Since these reasons are uncertain they were, as earlier mentioned, deleted from the data. After this third step the sorting of the data was done, and the 4126 products was left to analyze.

6.3.3 Finding the different demand patterns

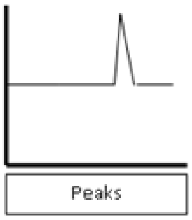
After the initial demand plot and the sorting of the data was done, the focus of the analysis was to find the different demand patterns more specific for the remaining products. This was done via the data and the calculations that were previously done. Regression analysis and autocorrelation showed that there were no significant trends or seasonality. This together with oral statements from the employees stated that there was no substantial seasonality or trends to use for the dividing of the products. The frequency, standard deviation and coefficient of variance was then used to determine other demand patterns like stable, variable and lumpy and the results ended in a couple of different demand pattern types, and the result clearly showed that the products had different demand and had the potential to be controlled in different ways.



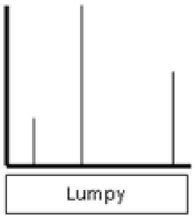
Stable demand pattern was common among the products of Nederman. The potential for improvements is highest for this group since the stock level can be low and the service level is still high for the group.



Variable products are the most common demand pattern types. This is a group that is difficult to control in all aspects since the stock levels needs to be very high to be able to have a good service level. The variation could be very large from week to week and makes the products unpredictable.

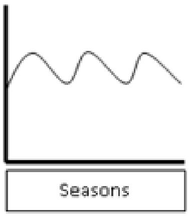


The peak group is a group that has a stable or variable demand, except for a few peaks, in terms of large order quantities at specific occasion. This affects the stock level and increases the level unnecessary high. The problem is that these products are difficult to control, since the peaks often occur unexpected.



Lumpy products were also a common demand pattern at Nederman. This is a group that is really affected in a negative way in the current way of controlling the warehouse. These products will always have a stock level, since the stock level is based on the average demanded, but they will have a very low service level.

A couple of the products showed signs of trends, both decreasing and increasing. But these trends were too few and had a short timeframe and therefore were these products classified with other pattern.



There was no sign of seasonality's that could be further analyzed, or taken into consideration for the analyses. Some products showed some increases and decreases during periods, but not enough consistent to build a model for it.

6.4 Selection of matrices

After the different demand patterns at Nederman were identified and represented the product range in a good way, the next target was to determine the exact parameters and values for separating the different patterns. Further analysis was made in order to find out where optimal limits between the groups were supposed to be. Regardless of where the limit is set, there is always products close to the limit on both sides that might have properties more similar to the other group. This is something that is impossible to avoid when grouping products and the main task was to find borders where the least amount of products ended up in the wrong group.

The first separation was between stable and variable demand and after many tests and visual analysis of individual demand patterns at different coefficient of variance values a suitable limit was found. Further analysis of the weekly demand frequency showed that apart from the really low frequency, representing make to order products, a new line between lumpy and just normal variable products was found for the purchased products. The last thing was to separate the products with peaks from the rest. After additional visual and individual analysis it was established that due to a general higher volume of the purchased products different boundaries where needed for purchased and manufactured products and then found.

In order to place the products in the right matrix the following order for decision was used after all make to order products were separated and all lines and terms were specified.

1. If it is a peak product.
2. If is a lumpy product.
3. If it is a stable product.
4. The rest becomes variable.

The analysis resulted in seven different matrices, four for the purchased and three for the manufactured. The reason for the differences in the number of matrices between them was that there was no clear group of lumpy products among the manufactured products.

6.4.1 Matrices for purchased products

As stated above, four distinct groups of make to stock products were identified and separated from each other by values of coefficient of variance, weekly demand and peaks.

6.4.1.1 P1 - Stable

After a thorough analysis of the coefficient of variance in terms of stability in the demand pattern a separation line were drawn at a value of CofV = 1.0. This resulted in approximately 25 % of the purchased products and all of them having an average weekly demand of over one product per week. How the products are distributed in the matrix is displayed in table 8. As can be seen it is only products with high frequency in this matrix and the majority has a quite low item value.

Table 8 - How the products are distributed in the matrix, shown in quantity, “nbr of products”.

Purchased (P1)	Value					
Frequency	A(min)	B	C	D	E(max)	Total
A(min)	0	0	0	0	0	0
B	0	0	0	0	0	0
C	0	0	0	0	0	0
D	0	0	0	0	0	0
E	46	53	27	5	0	131
F	199	178	77	9	0	463
G(max)	139	122	28	0	0	289
Total	384	353	132	14	0	883

6.4.1.2 P2 – Variable

The largest group was the purchased variable products. They are represented by the segment in between the stable products and the make to order products, responding to a value between 1.0 < CofV < 6.0. The majority of those are between 1.0 < CofV < 3.0 and just a few have a value in the higher end. The variable products are more spread out in the matrix, see table 9. But as can be seen, they are having their largest concentration in the middle section.

Table 9 - How the products are distributed in the matrix, shown in quantity, “nbr of products”.

Purchased (P2)	Value					
Frequency	A(min)	B	C	D	E(max)	Total
A(min)	0	0	0	0	0	0
B	0	0	0	0	0	0
C	5	26	25	7	0	62
D	60	144	135	27	1	367
E	181	281	211	42	3	718
F	75	87	29	3	0	194
G(max)	27	15	4	0	0	46
Total	348	553	404	79	4	1388

6.4.1.3 P3 – Peaks

Almost all products have some type of peaks in their demand pattern, whether it is small or large. So to determine if the peak is a peak or just a normal variable demand is very important. A peak that not is representing the normal demand pattern will give a too high value for the forecasting since the forecast is based on historical data.

In order to find those products, different peak values were tried and then analyzed visually. Since the forecast is based on the last six months so were the peaks. A peak was defined as a peak if there were one, two or three values that were higher than a certain level above the average level and a minimum average level. Different levels were tested and analyzed both by looking at the peak products but also by looking at the other products to see that they did not contain any products that should be allocated as peak products. After many tests, a level of six times the average level was decided as a good level. The other factor, that the average demand should be higher than a certain level was established at 5 products per week. With these levels the group only contained products with significant peaks and the other groups were spared from those types of products. The peak products were, as expected, spread in the matrix in the same way as the variable products, see table 10.

Table 10 - How the products are distributed in the matrix, shown in quantity, "nbr of products".

Purchased (P3)	Value					
Frequency	A(min)	B	C	D	E(max)	Total
A(min)	0	0	0	0	0	0
B	0	0	0	0	0	0
C	19	29	3	1	0	52
D	14	33	9	0	0	56
E	46	49	20	2	0	117
F	22	22	10	2	0	56
G(max)	14	9	0	0	0	23
Total	115	142	42	5	0	304

6.4.1.4 P4 – Lumpy

The last group is the products that have a lumpy demand pattern, meaning that they are demanded few times over a time period but when they are demanded the volume can vary a lot. These are as earlier mentioned punished heavily by the old method by given a quite low safety stock often resulted in a low service level whenever demanded. This pattern were only found in significant numbers in the purchased products and after a thorough analysis it was decided that products demanded one time or less per month, corresponding to less than a weekly demand frequency of 13 weeks per year should be treated as lumpy products. The lumpy products are spread in the matrix according to table 11. As can be seen the majority of the products is in frequency group C, but all in the top left corner of the matrix.

Table 11 - How the products are distributed in the matrix, shown in quantity, "nbr of products".

Purchased (P4)	Value					
Frequency	A(min)	B	C	D	E(max)	Total
A(min)	0	0	0	0	0	0
B	2	10	3	3	1	19
C	115	234	269	81	0	699
D	16	32	25	6	0	79
E	3	0	3	1	0	7
F	0	0	0	0	0	0
G(max)	0	0	0	0	0	0
Total	136	276	300	91	1	804

6.4.2 Matrices for manufactured products

The manufactured products where fewer to the numbers but showed a similar demand patterns as the purchased products. The main difference was a general lower weekly demand. In the analysis of the lumpy products, a weekly demand frequency of less than 13 weeks per year for the manufactured products were shown more suitable for make to order than make to stock resulting in only three matrices. By comparing with the old classifications almost all of those products were classed as make to order and this gave additional information to support the decision. Another important aspect is that the manufactured products often takes more space and have shorter lead times if all components are in place. This is also a contributing factor to the decision in the choice between lumpy products or products made to order.

6.4.2.1 M1 – Stable

The limits chosen earlier for separation between stable and variable products were after analysis proven to be suitable for the manufactured products as well and they were distributed in the matrix in the same way, see table 12.

Table 12 - How the products are distributed in the matrix, shown in quantity, "nbr of products".

Manufactured (M1)	Value					
Frequency	A(min)	B	C	D	E(max)	Total
A(min)	0	0	0	0	0	0
B	0	0	0	0	0	0
C	0	0	0	0	0	0
D	0	0	0	0	0	0
E	1	10	12	8	0	31
F	2	23	40	13	0	78
G(max)	2	18	21	4	0	45
Total	5	51	73	25	0	154

6.4.2.2 M2 – Variable

The analysis showed that coefficient of variance was a little lower in general for the manufactured products than for the purchased. The separation line was kept at a level of six but the highest value in reality was lower than four. As understood there were fewer products with a really high frequency among the manufactured but apart from that were they spread out in the matrix in a similar way like the variable purchased, see table 13.

Table 13 - How the products are distributed in the matrix, shown in quantity, "nbr of products".

Manufactured (M2)	Value					
Frequency	A(min)	B	C	D	E(max)	Total
A(min)	0	0	0	0	0	0
B	0	0	0	0	0	0
C	0	3	5	2	0	10
D	1	20	55	39	1	116
E	6	51	94	53	3	207
F	0	18	26	16	0	60
G(max)	1	0	0	0	0	1
Total	8	92	180	110	4	394

6.4.2.3 M3 – Peaks

The peak products were the only group that after analysis got other boundaries than the purchased. The analysis showed that products with up to three peaks even here should be seen as peak products. Among the analyzed products there were only one product with three peaks and the rest had one or two peaks. The main difference that the analysis showed was that products with a lower weekly average demand showed the peak pattern and the lower level was after further analysis set to one product per week in average. So peak products were here defined as products with a weekly average demand over one product per week and up to three weekly values reaching a level of six times the average weekly demand. The products were once again distributed similar to the purchased matrix, see table 14. With a high concentration in group E on the frequency and like the variable products there were no max frequency products.

Table 14 - How the products are distributed in the matrix, shown in quantity, "nbr of products".

Manufactured (M3)	Value					
Frequency	A(min)	B	C	D	E(max)	Total
A(min)	0	0	0	0	0	0
B	0	0	0	0	0	0
C	0	0	0	0	0	0
D	1	13	21	6	0	41
E	1	27	61	51	1	141
F	0	2	9	6	0	17
G(max)	0	0	0	0	0	0
Total	2	42	91	63	1	199

6.4.3 Summary of the selection

To make a clear image of how all products has been divided from their original matrices and allocated in the new matrices two figures will serve as a good explanation. The first, table 15 will summarize the different limits and levels for separation and the second, figure 30 will show the distribution of the products between the matrices in a more perspicuous way.

Table 15 - Limits and values separating products for distribution in the new matrices.

Product type	Separating limits and values
Make to order (P)	Weekly demand frequency < 4, CofV > 6
Make to order (M)	Weekly demand frequency < 13, CofV > 6
Stable (P1)	(No peaks, no lumpy), CofV < 1
Stable (M1)	(No peaks), CofV < 1
Variable (P2)	(No peaks, no lumpy), 1 < CofV < 6
Variable (M2)	(No peaks), 1 < CofV < 6
Peaks (P3)	Weekly average demand > 5, 1-3 values > 6*Weekly demand
Peaks (M3)	Weekly average demand > 1, 1-3 values > 6*Weekly demand
Lumpy (P4)	3 < Weekly demand frequency < 13

In which order the decision is made is explained in the beginning of chapter 6.3, but to further simplify, MTO → Peaks → Lumpy → Stable and Variable and the limits and values follow the decision order displayed in the table above by which order they are presented in every row.

Figure 30 below explains first how the distribution were between purchased and manufactured and then how the limits and values separated the two matrices in the seven new matrices with their number and percentages.

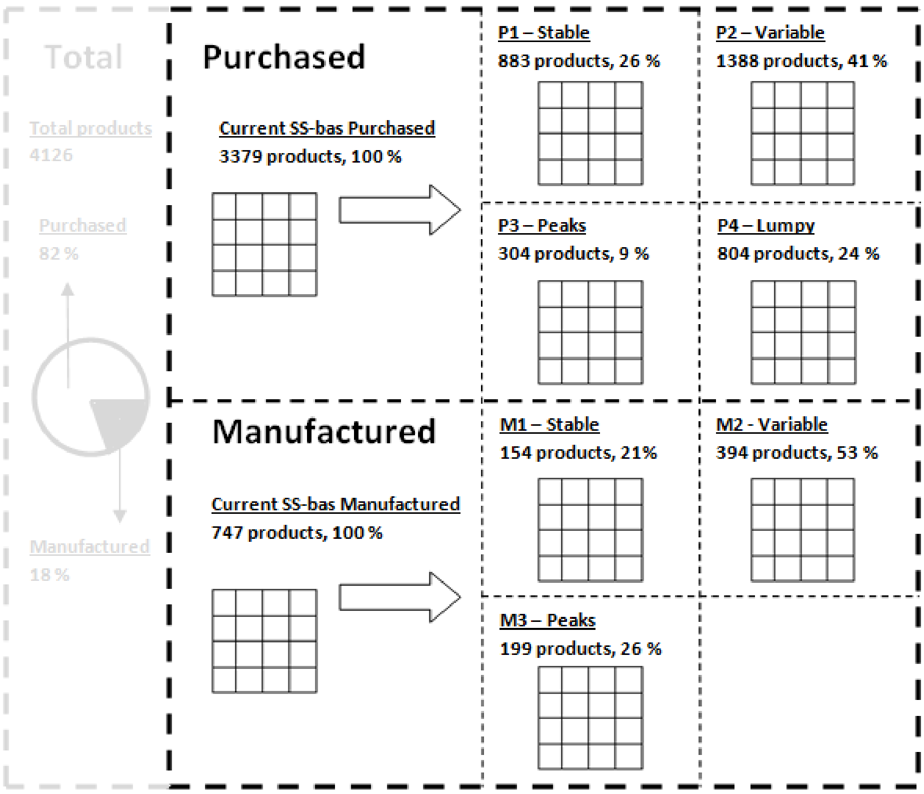


Figure 30 - Distribution of products from the initial start number to the new matrices.

6.5 New start values

When the products were divided into the seven matrices, the process of creating the new start values for the matrices started. This was a process that was really affected by the limitations of the master thesis, in terms of using Nedermans current formulas for the safety stock and ordering point.

6.5.1 New SS-bas on product level

The current way of calculating the safety stock is based on the SS-bas, demand and lead time. To be able to calculate new start values for SS-bas the safety stock needed to be calculated for the products, see the formulas below.

$$SS = SS_{bas} * \sqrt{\frac{LT}{30}} * \frac{D}{365} \quad \Longrightarrow \quad SS_{bas} = SS * \sqrt{\frac{30}{LT}} * \frac{365}{D} \qquad (6.1)$$

The focus was now to find a different way of calculating SS-bas, the answer was found in the theory. There are several of different ways of calculating the safety stock, but one of the simplest ways is to use the standard deviation and a pre-set service level, and from there calculate the safety stock for every single product and use that in the formula above. For a given value on the service level the safety stock can be calculated according to $SERV_1$ by

$$SS = k\sigma_x$$

Where $\sigma_x$the standard deviation and *k* is a safety factor responding to a particular service level and it can be found in table for normal distribution, see Appendix B.

The option of using $SERV_2$ instead of $SERV_1$ for the calculations was evaluated. The problem was that even if $SERV_2$ are a better and more sophisticated method in many ways, the use of order sizes in $SERV_2$ makes the method harder to control since more parameters must be taken into consideration. The order sizes has not been evaluated since Nederman does not always follow the Wilson formula for order sizes, it became impossible to use $SERV_2$ while the order size became a too uncertain factor.

To be able to determine *k* for all the products, the service level needed to be set for all the seven matrices. It was important to put focus on the products in the high frequency and low value groups and set a lower service level on the once with low frequency and high value.

To be able to determine the total service level for the entire product range, an analysis were made by connecting all the seven matrices new service level to the total frequency for all the products in the cells. By multiplying the service level in one specific cell, with the total frequency of all the products in that cell, repeat this for all the cells in all the matrices and in the end summaries this and divide it with the total frequency of all the products, the total summarized service level was calculated. Below in table 16, the different service levels for all the cells in the matrices are seen (all four purchased and three manufactured matrices have the same percentage per cell), and in table 17, the calculated total service level after multiplying all products frequency with the new specified service level from table 16 can be found.

Table 16 - All service levels for all cells, both manufactured and purchased, in percentages.

Purchased	Value				
Frequency	A(min)	B	C	D	E(max)
A(min)	50%	50%	50%	50%	50%
B	50%	50%	50%	50%	50%
C	70%	70%	70%	70%	50%
D	97%	97%	96%	80%	50%
E	97%	96%	96%	80%	50%
F	95%	95%	92%	80%	50%
G(max)	95%	92%	92%	80%	50%

Manufactured	Value				
Frequency	A(min)	B	C	D	E(max)
A(min)	50%	50%	50%	50%	50%
B	50%	50%	50%	50%	50%
C	70%	70%	70%	70%	50%
D	98%	98%	97%	80%	50%
E	98%	97%	97%	80%	50%
F	97%	97%	94%	80%	50%
G(max)	97%	94%	94%	80%	50%

Table 17 -The total service level.

	Purchased	Manufactured	Total
Service level total	93,71%	92,03%	93,47%

When all the service levels were defined, *k* for all products could easily be found. Since the standard deviation was calculated from before, individually safety stock for all products could be calculated. And with the new calculated Safety Stock, a SS-bas for every product could be calculated, see formula 6.1. As can be seen in table 16 there are a lot of cells containing a percentage of 50 %. This results in a value of *k* = 0 which in turn results in a SS-bas value of zero. The reason for this is that the authors have chosen to have those types of products as make to order products due to very low frequency or extremely high item value.

6.5.2 Calculating the SS start values from product to group level

When all products had their own new SS-bas the next step was to create new start values that were representative for all the products in the different matrices. To do this, two different alternative methods were tested to create the start values.

6.5.2.1 Alternative 1

Many of the cells in the matrices contain a lot of products, and they varied a lot. The best way of getting a number to represent the entire group was to take the median instead of the average value of all the products calculated SS-bas values. It was tried to use the average value but it did not give any good values, since several groups contained some products with very high values, which gave a very high and not representative value.

The median for all matrices and cells were calculated, see figure 31, (SS1-SS3), and the numbers were also cleaned form misleading high, or low, values. These values occurred in groups that had very few products, and where really affected if one or two showed unrealistic high or low numbers. After this was done, the new median numbers was added to the new SS-bas, see figure 31, (New calculated SS-Bas).

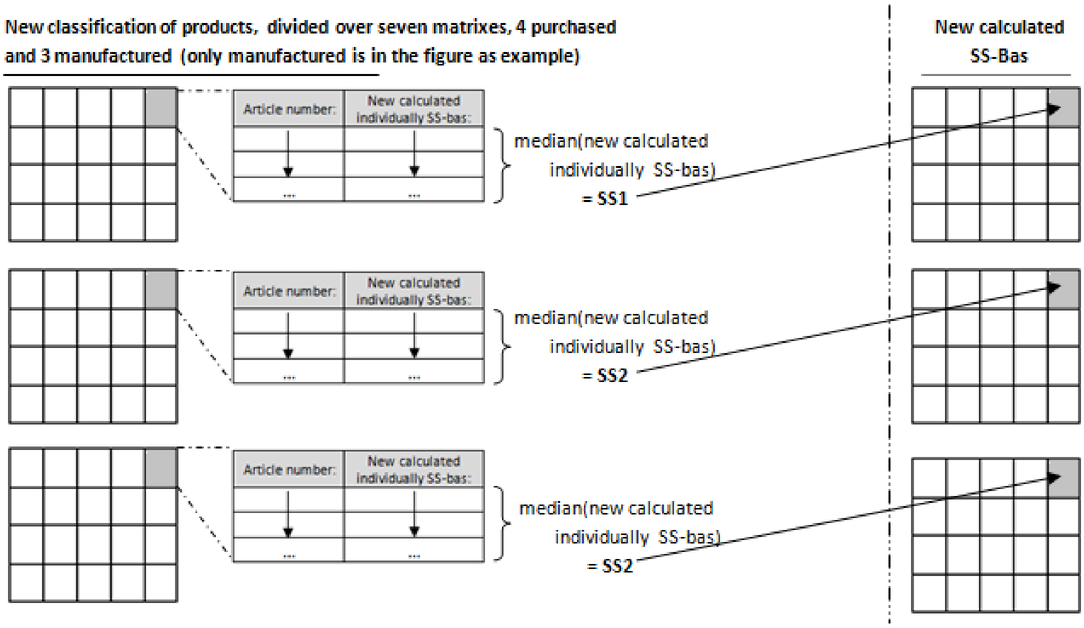


Figure 31 - The process in Alternative 1 to calculate SS-bas.

When the first median calculation was done the total safety stock value for both the new calculated SS-bas and the numbers for the current values was summarized. The results showed that with alternative 1, using seven matrices, with a target of a service level on almost 94 %, the total safety stock value would increase with 3 MSEK. It was no surprise that the safety stock would increase, since this solution aimed for a significant higher service level, and it was also know that the current SS-bas values were set to a low level to try to push the stock value down and this alternative was totally separated from the current values.

6.5.2.2 Alternative 2

This solution used the same median values as in the first alternative but this time the old SS-bas values were used to create the new values. In this method, the old classification of products was used, and by using the two current matrices, and also calculating the median of these matrices and cells, a new SS-bas index was calculated, see figure 32, (index SS).

This new SS-bas index was made to be able to compare it with the other medians from the new seven matrices. If one SS index cell was divided with the same cell in a new matrix, a percentage value was created, which indicates if the new square had potential to decrease or increase its new start value compared to the old one. This percentage value was later multiplied with the current numbers, see figure 32, (Old SS-Bas, A)

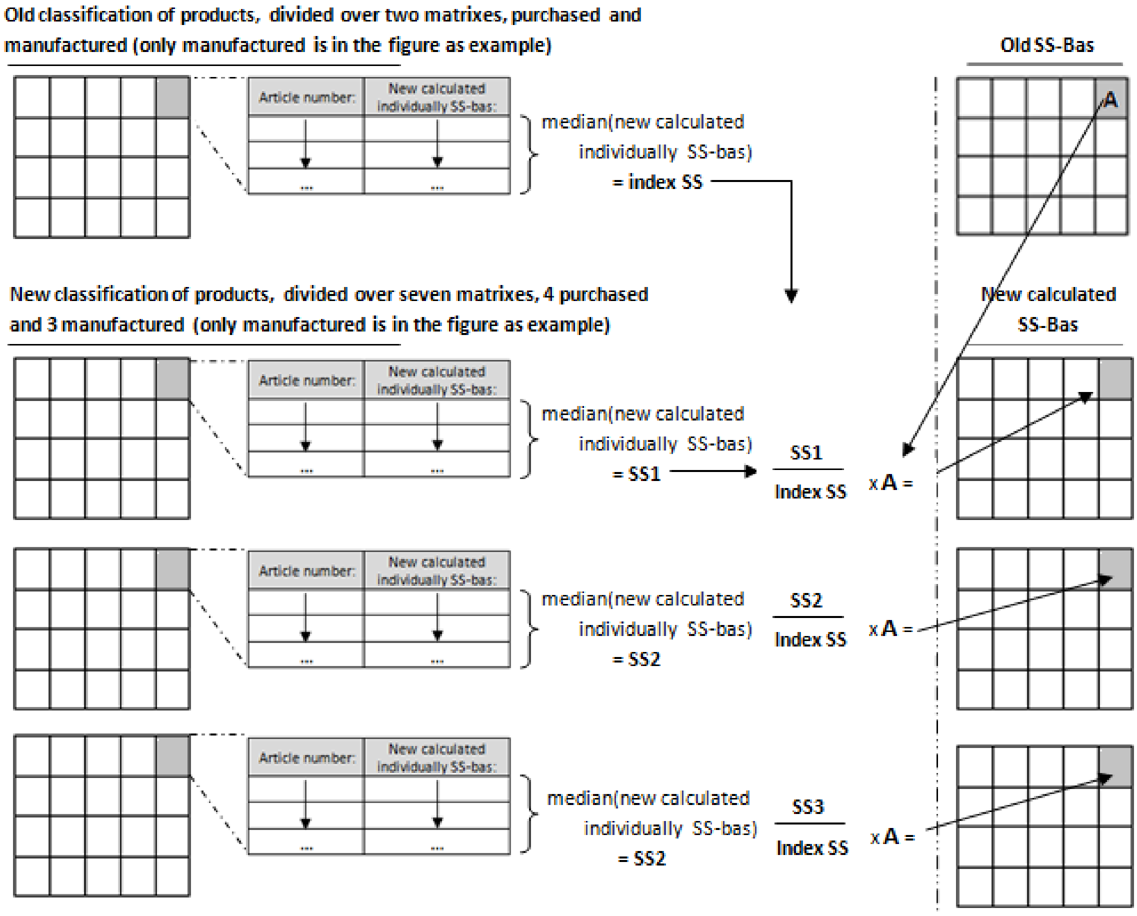


Figure 32 - The process in Alternative 2 to calculate SS-bas.

This process was done for all the new matrices, always comparing and using the old numbers and multiplies them with the new percentage number from the median deviation. Just like in alternative 1 some cleaning of the data was done and unrealistic numbers where further analyzed. The results showed that with alternative 2, using seven matrices, the total safety stock value would decrease with 0.5 MSEK.

6.5.2.3 Alternative 1 vs. Alternative 2

The authors together with the supervisors at Nederman decided to continue working with alternative 2, and therefore drop alternative 1. There were a lot of benefits with alterative 1, but the outcome of the results in alternative 1 was not in line with the targets of this master thesis. Nederman wanted to establish if an extra dimension to the current SS-bas was able to improve the warehouse. Alternative 1 could prove that the warehouse would improve, in terms of service level, but it could not establish that this was a direct result of the new dimension. The improvement could be a result of the new dimension, but it could also be an effect of the $SERV_1$.

Using alterative 2, and instead using the current SS-bas as an index for the new model, made it possible to prove that the possible improvements are a result of the new dimension. This is the most important reason for choosing the second method instead of the first. Another reason was also that alternative 1 increased the warehouse with 3.0 MSEK, and that is the opposite of Nedermans long term target.

6.5.3 Matrices

After the new SS bas was calculated for the different cells and matrices, there was still some work to do before the implementation. There were still two main things that needed to be done, one affecting just two matrices and one concerning all.

The first thing that needed to be done was to handle the peak matrices. To be able to earn from the benefit of having them in groups, the matrices values needed to be decreased. The demand that they were based on gave too high values since the peaks affected them too much. To sort this out, the peak values was removed from the calculations and new ones were calculated and the median differences between the old and the new gave a percentage values that was used to decrease these two matrices SS-bas. The percentages was 70% (0.70) for both the peak matrices, and were therefore multiplied with the new SS-bas values, see figure 33.

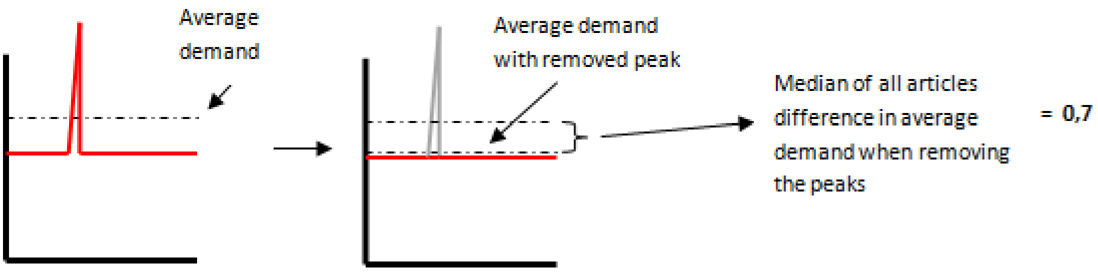


Figure 33 - Removing the peak value from the demand.

Since only the cells in the matrices that contained products were calculated in the first step, was it important that the other cells also got a start value, since products can move between the cells if the demand or value changes when the model is updated. The empty numbers were calculated by cross looking between the different matrices. For example if one matrix contained a SS-bas value of 20 in one square and 10 in the one below and another matrix had one of these two squared filled in with, an index from the two first values was calculated, and with this index the missing square was created, see figure 34.

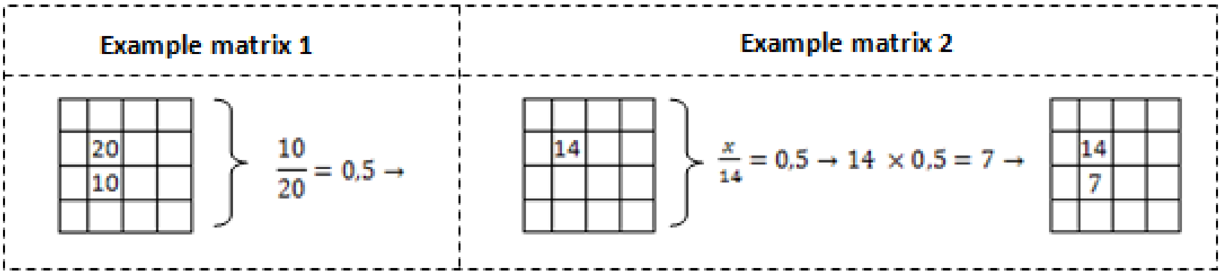


Figure 34 - Creating start values for empty cells.

After these two steps were done all numbers were set in the cells in the matrices. All the seven matrices exact calculated values can be found in Appendix E.

6.6 Implementation

The last step was the implementation of the suggested model. As decided in the start of the master thesis the authors were supposed to have a model ready for implementation after 10 weeks. This was decided in order to receive as much data as possible from the test run that would capture the changes in reordering points and the service level responding to these. It was also essential that the products would be demanded enough for the inventory level to reach critical levels and by means create new orders for as many products as possible. Because without any new orders during the test period, the service level measured may not be a result to the new parameters.

6.6.1 Selection of test group

The first step in the implementation was to select products. After discussing a good number back and forth between the different supervisors, a level of 20 percent of the products were decided as a good number. This was sufficient enough to cover the whole product range giving indications on the total result but also the individual matrices and cells, but still not devastating in an event of a total failure of the implementation. It was decided that the whole product range should be divided in five groups, one test group and four different controlling groups. The products were selected and divided randomly between the groups. There were only one condition and that was that the products from every matrix should be equally distributed by numbers between the groups.

6.6.2 Reordering points and values

The four controlling groups were left as normal and new reordering points for the test group was calculated based on the new matrices. The implementation of the new values was made the 21st of March and the monitoring started with the first obtained values the 30th of March.

When the new reordering points were introduced they ended up with a higher total reordering point value than the rest of the groups. The reason for this was that it had been a long time since a huge update of the reordering points was made. This was planned to the 4th of April and when that was done the control groups ended up with a higher total value and received the same type of increase as the test group in the initial stage. After this all groups had one additional update where all suggested decreasing reordering points were updated and this was made the 26th of April. How the reordering point values have developed for every group during this test period can be seen in figures 35 and 36.

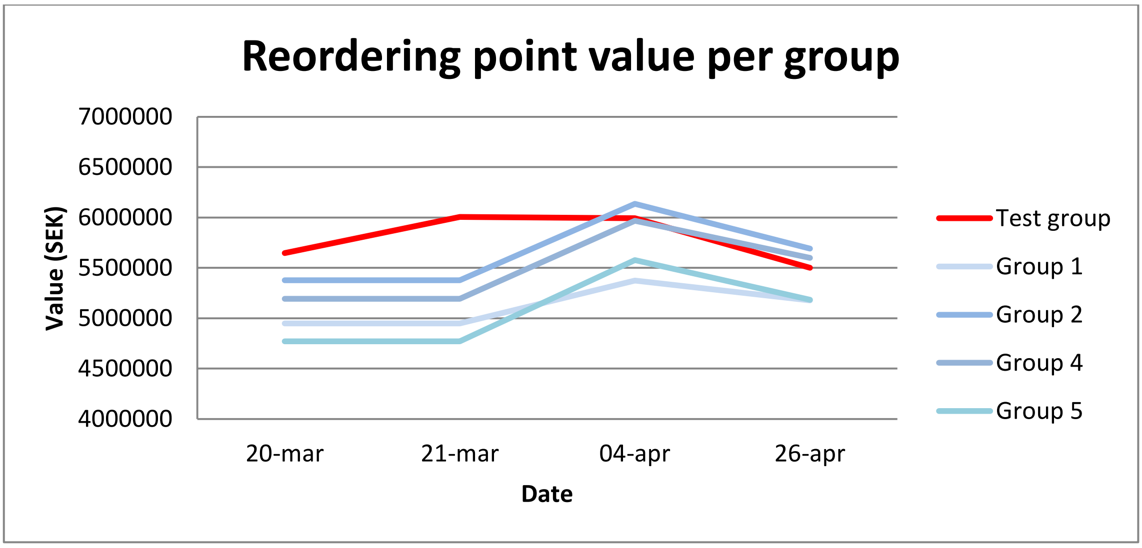


Figure 35 - Development of reorder point values throughout the implementation period.

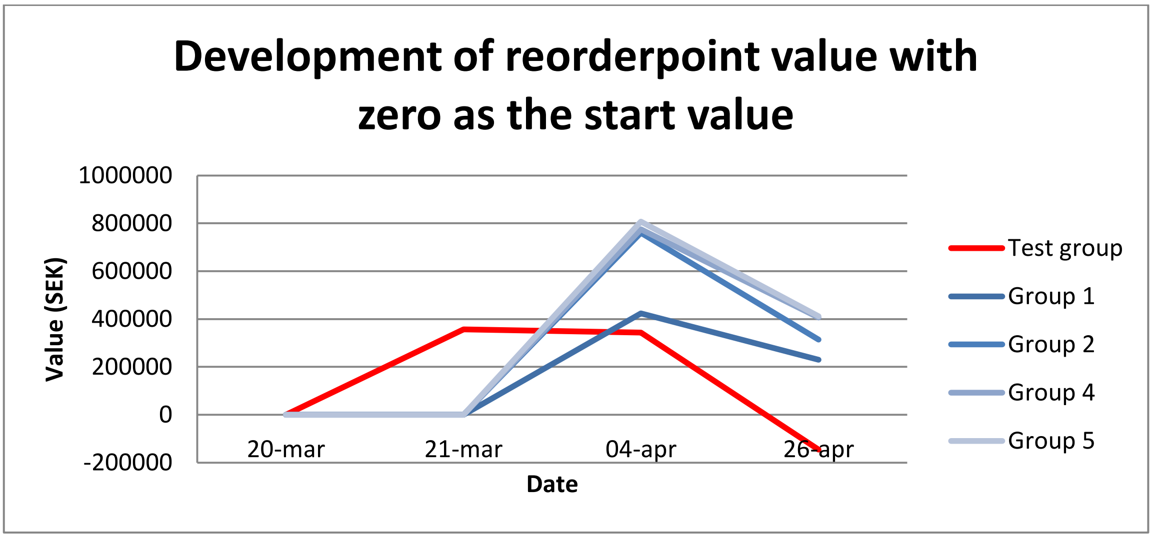


Figure 36 - Changes during the implementation period based on the start value as the zero level.

As can be seen in the figures above, the test group is the only group having a lower value in the end that its start value. This can be an indication of that the stock values are too high since the service level is maintained on the same level. The exact values are displayed in Appendix F.

6.6.3 Service level

Apart from the monitored value changes the service level has been monitored on a weekly bases resulting in eight different observation times. Every week sales data has been collected from QlickView and been displayed as number of orders per products versus number of orders per products delivered in time. This resulted in the service level per products and after summarizing, also the service level for the entire group. This was done on all groups and it is only possible to do on the finished goods, which are representing around 30 percent of every group. How the service level has developed over time for all groups is shown in figures 37 and 38.

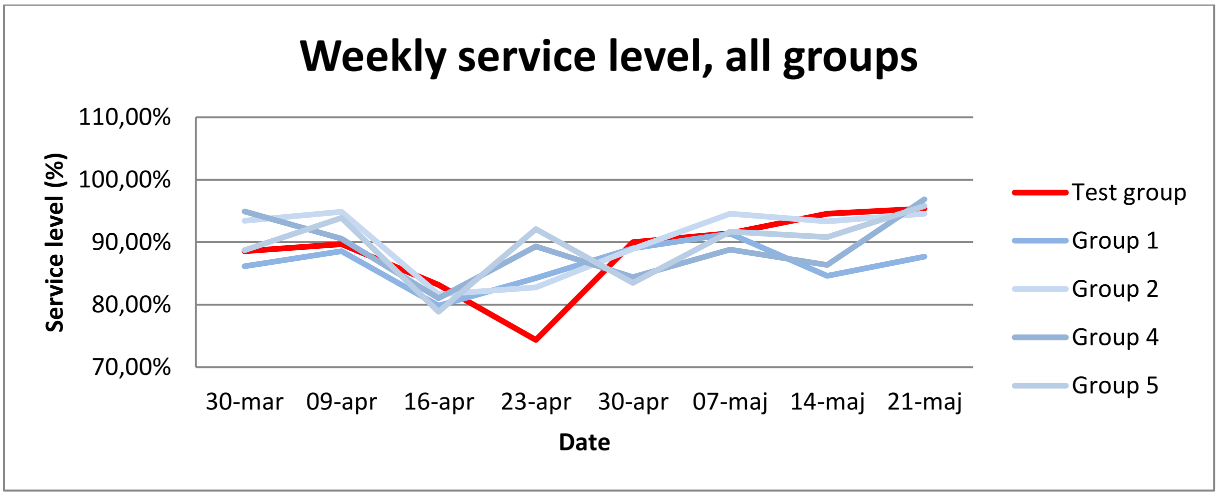


Figure 37 - How the service level has developed during the implementation period per group.

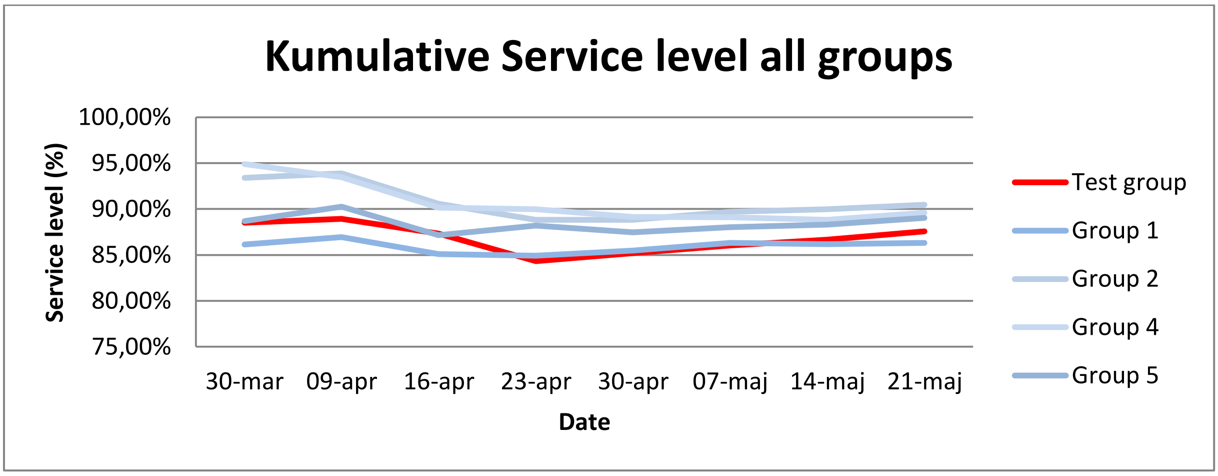


Figure 38 - Development of service level cumulative during the implementation period per group.

As can be seen in figure 37, the groups are following each other except from the dip in the service level for the test group at the 23rd of April. This dip was further analyzed to establish that this did not have to do with the new SS-bas value and that the group was suffering from external factors. The analysis showed that a high number of orders were defined as “backorders not allowed” that week, and when the insight of that the orders not were going to be able to be delivered the customer were contacted and asked if backorders could be allowed. After the contact backorders became allowed but this was never updated with new dates in IFS. This human factor resulted in errors from orders containing an over-represented amount of products from the test group. And the low service level at that specific week could thereby be explained by a combination of the human factor and uneven distribution of the error between the groups. The exact values for figure 37 and 38 are displayed in Appendix G.

The cumulative service level after this period shows that the test groups is following the other control groups, indicating that the service level could be maintained with a more accurate and also lower value of the reordering point.

Another analysis of the service level on the components was also made to support the result. A shortage list for the components were created based on if a product is on stock when the demand planners are planning for the production for the next five days. This is not a fully developed way to analyze those shortages since a component ends up on the list if it is out of stock at the specific day even if a delivery will arrive during these five days. This will not give a fully accurate service level of the components but it works as an indicator if the components are on shortages or close to shortage and can therefore be used to compare the groups with each other to see if there are any major differences. How these shortages are distributed between the groups is displayed in figure 39.

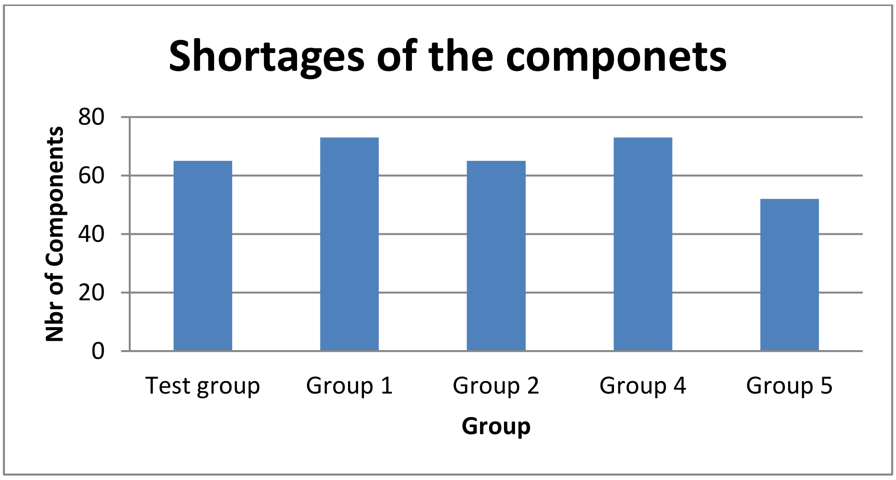


Figure 39 - How the shortages of the components are distributed between the groups.

As can be seen in the figure, the shortages are distributed fairly even between the groups, giving further indications that the parameters in the new model can keep the service level. The data has been collected for the time period of 21st of March until 27th of April.

6.6.4 If fully implemented

Since the test group has shown a trend in following the service level like the other groups and still manage to lower the value in comparison to the others. Analysis has been made to simulate how the value could have changed in a full implementation from a start value at 25.9 MSEK.

The value of the test group decreased during the implementation period with 2.58 percentages. If it is assumed that all groups could have had similar decreases during the same period, the reordering point value could have landed on a value of 25.2 MSEK and decreased with almost 0.7 MSEK.

If the test group would have continued without changing the parameters the end value can be estimated by de average increase of the controlling groups. The average increase was at a level of 6.74 percentages and by adding that to the test group as an end value, the total reordering point value could have ended up in 27.7 MSEK.

By comparing the both results a difference of 2.5 MSEK could have been achieved in a lower reordering point value during the implementation period in an event of a fully implementation of new parameters. All the figures above are summarized in table 18 and 19 below. It is worth to stress that this only is estimation based on the implementation and that the outcome could be different if the right parameters were implemented for all groups.

Table 18 - How the reordering points has developed in reality during the implementation (SEK).

	BP (Start)	BP (End)	Diff (Start vs End)	Percentage	
Test group	5647672	5501883	-145790	97,42%	
Group 1	4948354	5178098	229744	104,64%	
Group 2	5376631	5691314	314683	105,85%	
Group 4	5192676	5599143	406468	107,83%	
Group 5	4770761	5181973	411213	108,62%	
Total	25936094	27152411	1216317	104,69%	106,74%

Table 19 - Estimation of how the values could have developed if fully implemented (SEK).

	BP, Old SS-bas (Start)	BP, Old SS-bas (End)	BP, New SS-bas (End)	Diff (End values)	Diff, New SS-bas (Start vs. End)
Test group	5647672	6028082	5501883	-526199	-145790
Group 1	4948354	5178098	4820617	-357481	-127737
Group 2	5376631	5691314	5237838	-453475	-138793
Group 4	5192676	5599143	5058631	-540512	-134044
Group 5	4770761	5181973	4647608	-534365	-123153
Total	25936094	27678610	25266577	-2412034	-669517

Throughout the master thesis it has always been very difficult to compare calculated values and values collected via IFS and MySigma. The reason for this is that all calculated values are based on the demand, lead time and item value from MySigma and then calculated with SS-bas and the safety stock as the base. While the collected values from IFS and MySigma are a result from a top controlling of the reordering points and that it in every update is chosen which products that is supposed to be updated. The reordering points in the system are not an exact match to the calculated values at every specific time.

To be able to make an as good comparison as possible of the difference between values based on old and new parameters of SS-bas, calculations were based on values from the same MySigma file and all values were calculated. The file is the last created up to this point and would therefore serve as the base if this would be used for a full implementation at this moment. Both the safety stock and the reordering point would end up with a lower value around 0.9 MSEK in total compared to the old SS-bas, see table 20.

Table 20 - Values if the system were fully implemented at this point (SEK).

	Sum of SS (old) 26.04.12	Sum of SS (new) 26.04.12	Sum of BP (old) 26.04.12	Sum of BP (new) 26.04.12
Test group	2218510	1978243	5779199	5538932
Group 1	2169500	1983316	5399226	5213041
Group 2	2326775	2088396	5985541	5747163
Group 4	2262993	2014496	5649560	5401063
Group 5	2154942	2146803	5410099	5401960
Grand Total	11132720	10211255	28223625	27302160

Another very interesting thing is how those values are distributed over the seven matrices when transferring from the old SS-bas to the new model with seven SS-bas matrices. This is illustrated in figure 40 and 41 as column charts showing the safety stock and the reordering point value and how they would be affected in an event of full implementation. The tables for the exact values are to be found in Appendix H. As can be seen in the figures it is only matrix P4 that are showing an increasing value. The reason for this is that those products are very difficult to control in a good way and that all purchased matrices are controlled towards the same service level per cell. This is giving indications that there are potential for lowering the value by working with the service level.

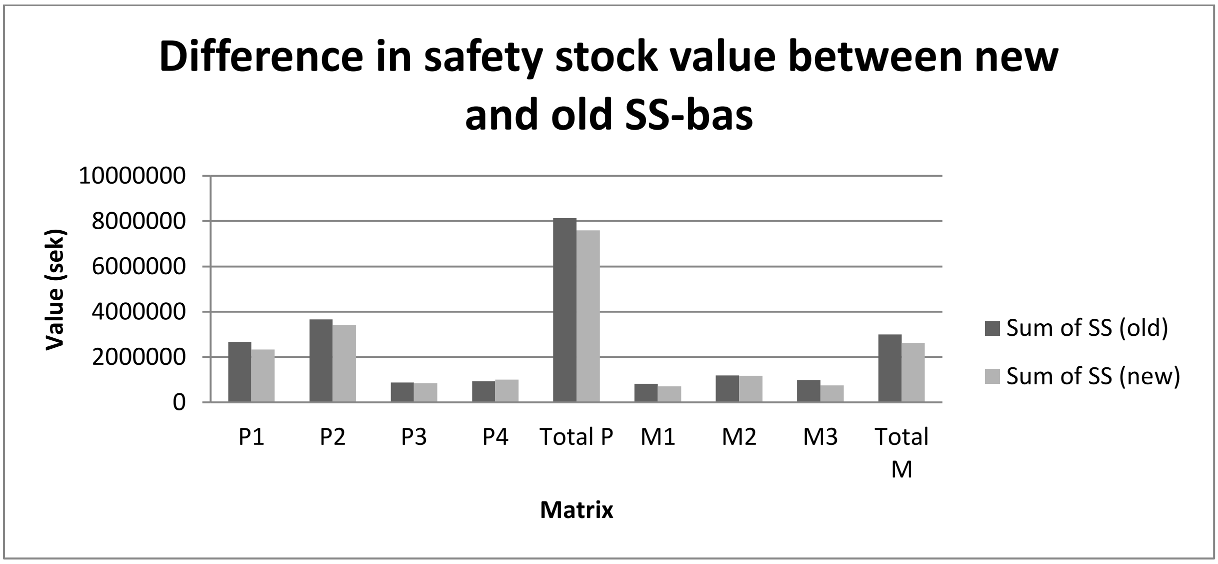


Figure 40 - Change in safety stock value per matrix if the system were fully implemented.

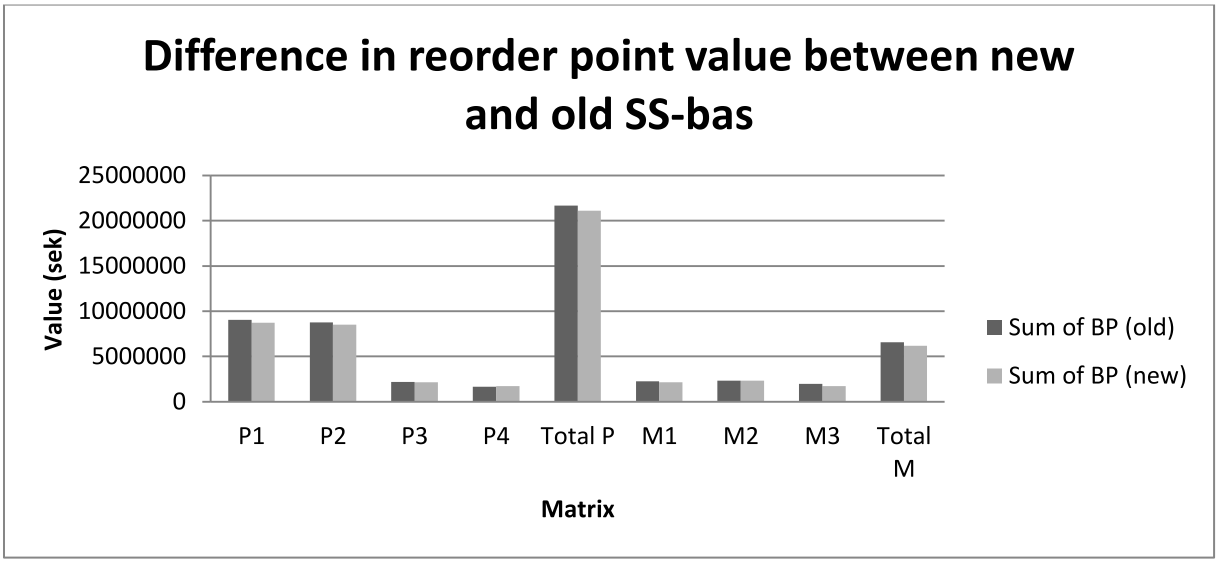


Figure 41 - Changes in reorder point value per matrix if the system were fully implemented.

Regarding the decreases there is no surprise that the stable products for both purchased and manufactured products would get a lower value. These are products that are heavily affected in a negative way by the old system. The new system is, by the separation, giving the stable products a lower and more accurate value. It is believed that there may be further decreases to achieve by monitoring the service level for these matrices and keep lowering the SS-bas values as long as the service level is kept. The variable products should not receive any major decreases since they are representing a quite difficult segment similar to how all products are controlled by the existing system. The peak products were supposed to receive a quite large decrease since the SS-bas values were adjusted with a factor to make up for the unfair high demand resulting from the peak values. This can be seen among the manufactured products indicating that the model is performing as it should, but that the service level for this matrix is of importance to follow. The purchased products would at this point not receive any major changes indicating that the adjustment factor for these products may be too small. This can be improved by lowering the SS-bas values and monitoring the service level in the same way as for the stable ones.

6.7 Updating model

The very last step in the analysis was to create an updating model for Nederman to use in the further work. The authors know very well how to make the updating, but this information needed to be passed on to Nederman in an understandable way that then is easy to use.

The first thing to decide was how often the updating of the entire analysis needed to be done. With other words, the full process of downloading the data, and then use the formulas for deciding the demand pattern and distribute the products in the proper matrices. The best solution is to make this update often since products changes demand pattern over time. The longer time that has passed since the updating was done, the more products are out of the limits of their demand pattern matrices and in reality should be in another one.

The time does not affect the stable, variable and lumpy matrices that much, since these products are often stable in their groups since the difference between the patterns are large. The situation is a bit different for the peak matrices, since the products in these matrices are there because of a couple of peaks the last months before the updating, and there is no guarantee that these peaks will happen again. It is likely, but not a guarantee.

Even if the best thing for this model is too update often, it is also a downside of doing it too often. Every time new ordering points are implemented, the system takes a while to adjust to the numbers and this often results in a temporary increase of value. Also, the model for making the entire master thesis took several months to make and a person that knows how to do it should be able to do it in 1-2 working days the first time and then much faster. This does not sound that much, but it is still quite time consuming.

In the end, after conversations with Nederman, it was decided that the update should occur once every 6 months, or every 4 months, depending on workload on the supply chain department. This is a time frame that does not change the order points to often, but still happens so continuously that the products stays more or less in the same demand pattern matrix.

In the end of the master thesis, three different documents or files will be handed in to Nederman. First of all the report, including the background and analysis and so on, second of all the excel document, including all the data, calculations, plots, pivot and so on, and last a updating model document will be handed in, including a full simple description how to redo this analysis again. The updating model document can be found in Appendix I.

7. Conclusions and Recommendations

This chapter provides overall conclusions of this master thesis, together with reflections over the different steps throughout the master thesis. The chapter will also compare the problem statement and purpose with the actual results, and finally present future recommendations for Nederman.

7.1 Conclusions

To be able to make any general conclusions whether the purpose and goals for this master thesis are fulfilled, the main targets of the master thesis need to be discussed. This master thesis main purpose was to improve the inventory control at Nederman in Helsingborg. Two problem statements were composed and served as the main goal of the entire master thesis.

- Find a way to divide the products into different classifications based on their demand pattern in order to improve the inventory control.
- Finding ways to control the different classifications that will lead to improvements on stock levels given a certain service level.

The first statement was completely fulfilled during the master thesis. The demand patterns were classified and the products were divided into different groups. After modeling these groups, it became clear that the inventory control could be improved. The second statement, explaining the conditions for reaching the first statement, was partly fulfilled. The stock level did decrease and therefore improved during the implementation, but this was not done to a certain service level from a theoretical aspect. Why this occurred will be explained further down in the conclusions where the different parts of the master thesis are described and discussed.

7.1.1 Current state analysis

The analysis of the current state showed that Nederman had a lot of active products to handle in a quite complex structure. Many of those products were controlled by the two matrices, giving indications that this is a very important area for improvements. The matrices have a major strength and this is that it is very easy to control the system by these two matrices and that the outcome is quite good based on the conditions. The downside is that there has to be a good knowledge of the different products to understand why they have ended up with a certain type of controlling parameter. Especially that this is a quite blunt way of controlling stock items for reaching satisfying stock levels and a high service level.

The analysis showed that there were potentials for improvements in the existing system and the two things that had the best potential for this was the matrices and the formula for the safety stock. Activities not to be further analyzed were the order sizes and the forecasting process for the demand used in the formulas.

By using a theoretical established formula for calculating the safety stock it was concluded that the wanted service level would be more likely to reach the targeted level. The downside with this was that the stock level would increase in value compared to the current situation if this new formula was used for the safety stock and as a result the SS-bas was backtracked in order to be able to use the matrices. The authors believe that the best way to control the products in order to reach the service level and have an accurate stock level is to do this on a product level without SS-bas.

Since the purpose of the master thesis was to find a better way to use the existing methods of SS-bas and the connected formula the analysis continued with focus on that, where the first thing was to establish the different demand patterns.

7.1.2 Found demand patterns

During the demand pattern phase of the master thesis there was two different aspects to discuss. It was in general easy to state the conclusion that different products had different demand patterns. Some are frequent and stable and others are completely variable. Since the analysis overviewed over 8000 products there was not a surprise that all products did not have the same demand pattern, but what this analysis proved was that there was enough products with the same demand pattern so they could be sent to different groups and from there be controlled differently. By dividing the products into this groups the smoothing of the demand pattern could be smaller and from there give the products more accurate safety stock levels. As earlier mention, two other aspects are interesting to discuss that occurred during the demand pattern phase.

The first thing that was notable during this analysis was that the products varied a lot. The really stable, with a very low standard deviation and coefficient of variance, was few and the products that were seen as stable, was for many other warehouses, literature and from other companies point of view, unstable. So in general it can be said that all products were a bit unstable, but there was still enough levels of instability that it was room for dividing the products.

The second thing to discuss was the limits between make to order and make to stock. There are many products among the product range at Nederman that are suitable for make to order. When comparing the current products that are on stock, with the ones that are on stock according to the new limits, there was a quite large difference between these numbers. There was no surprise that some products that are close to the limits for make to order would differ, but that the difference would be this significant was surprising. The reason for these differences can be many, but are probably results of the sales organizations requests, a not updated database and incentives for keeping the stock level down. How these products should be handled by Nederman will be further discussed in chapter 7.3.

7.1.3 The new matrices

After the limits were set for the dividing, seven different matrices was concluded as the proper amount, a high enough number to cover the different demand patterns but still not too many matrices making it impossible to control. For every matrix more time has to be used in order to handle and follow up the results of the service level. On the other hand, more matrices give a more individually controlled system with smaller groups and to find an optimal number of matrices is essential. The limits and values for allocating the products in respective matrix were quite difficult but after a thorough analysis it was concluded that the chosen levels were the most suitable based on the product range.

7.1.4 The new start values

One of the largest discussions and decisions that the authors were facing during the master thesis happened during the creation of the start values. This was a more complex procedure than initial thought and the reason for the more difficult calculations was the use and adaption of the current way of calculating.

The current way of calculating and controlling the safety stock and reordering points today made it very difficult to theoretical show that the inventory control could be improved. Since it was impossible to fully use any theoretical methods on the warehouse, and the methods used were modified to adapt to the current calculations system, the effect of the modified methods was hard to predict and prove.

The decision of how to calculate the start values was between two different methods. One was to use a more theoretical method that was adopted after a specific service level and another method that was more based on the current system and not specified after a service level. In the end, after discussion with Nederman, the second alternative was used, which forced the authors to move away from the theory and also the problem statement of using a specific service level of 94 %. The conclusion from this is that alternative 2 would give the best answer to the question if the existing system could be improved by adding one additional dimension, while alternative 1 would have given a more accurate stock level based on a certain service level.

7.1.5 The implementation

The most interesting part of the master thesis was the implementation and the results of this. The implementation showed that Nederman can draw benefits from controlling products on different variables depending on historical demand pattern. Nederman has the possibility to change the inventory system and control products more individually and can maintain or increase the service level and decreasing the stock level.

The reference group system worked out well and to be able to compare the value and the service level with four different other group made the modeling more reliable. The problem was to be able to see the service level properly since only parts of the product range are measured by Nederman.

7.2 Academic contribution

The contribution to the academic world, in terms of this report, is a further establishment of a working method. The method to use Coefficient of variance on a large article range to divide products into different groups after demand pattern has been tested before, but was also proven to work during this master thesis.

What is more unique with this thesis is that it has also established further that it is possible to make these sorts of separations for very variable products. The common research in this area is focused on a product range with a generally more stable demand pattern. To show that it is possible to divide a product range where the stable products have a coefficient of variance below 1, is rare and the common values is usually much lower. This shows that it is possible, for almost all companies, to control the stock levels by using the demand pattern, stable or unstable.

The master thesis further shows that the limits between the different demand patterns are highly individually for companies, and should be fully adapted to the specific company's product range and needs. How the demand patterns are, and what kind of targets the company has, affects the limits and makes it hard to compare between different companies.

A third thing that also was shown in this thesis was the way to use demand pattern to control products. There are many other more common ways to control articles and products, like setting the safety stock after level of price or volume. With this master thesis it has been further established that demand pattern can be a good way to control the safety stock and inventory level.

7.3 Recommendations

The recommendations to Nederman after the master thesis are divided in two parts. The first one is based on the authors overall experience and conclusions regarding the future for Nedermans distribution center and the other one is based on if Nederman chooses to continue with the implementation of the result from this master thesis.

The product range at Nederman is very large and the demand is generally very variable for the different products. The current system at Nederman, with how the service level is controlled and the reordering point is calculated is not efficient enough to control the warehouse in the future even if the new dimension is added. After this analysis, and development of the current system, the authors have come to the conclusion that a new and even more sophisticated system than this would have large potential for Nederman. A new system could control all products individually and be able to control the products in a more optimal way.

The master thesis has showed that the new model would make improvements on the inventory control and if Nederman wishes to fully implement the suggested system and believes that this will be sufficient for the near future the following actions are recommended for the new model.

- Use the guidelines for make to order in order to separate the stock items from the products more suitable for make or purchased to order.
- Change the two matrices to the seven matrices developed during the master thesis.
- Update the demand pattern for all products every 4 months and allocate them into the matrices.
- Keep working on the SS-bas values in the different cells and matrices by doing regular changes according to monitored service levels to find additional savings in stock level with a maintained service level.

If this is done and some extra time is used for this, there may be further improvements than the implementation has showed and therefore o huge recommendation from the authors to keep on working on. Another huge benefit is the areas that has been identified throughout this master thesis as potential for improvements but not have been a part of the analysis. And the authors recommend Nederman to overview those areas for further improvements. Taking everything into consideration, both the implementation and the information revealed during the master thesis this new model becomes a fairly good alternative for the near future. It is also a recommendation from the authors to overview variable products with high coefficient of variance that according to the new limits should be made to stock products. This is important since there may be products that has a low demand and a very short lead time and therefore can be suitable as make to order product and thereby contribute to a lower stock level.

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9. Appendices

Appendix A – Organization map

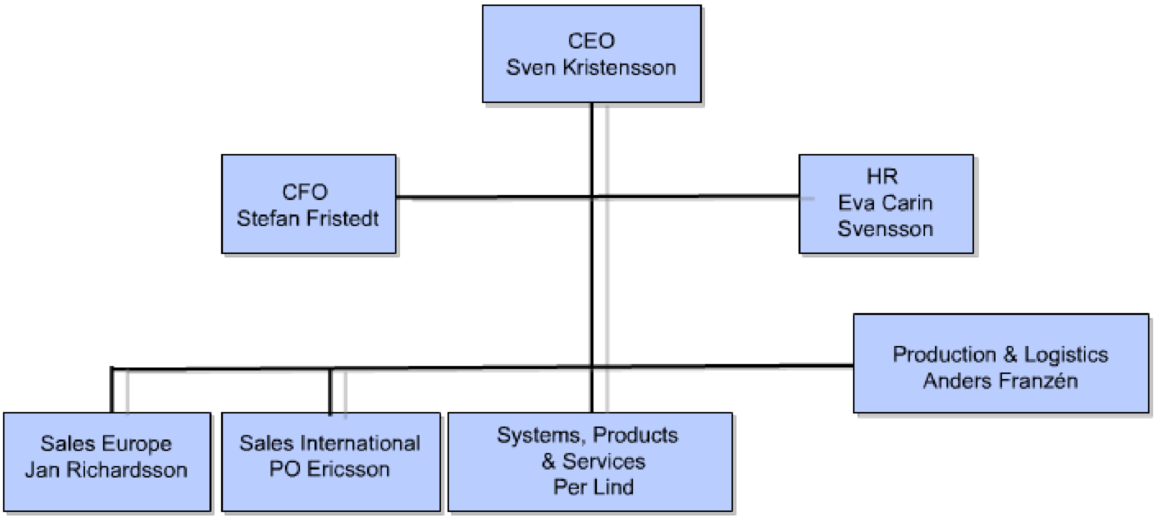

Figure 42 - The organization map for Nederman.[91]

[91] Nederman. (2010). *Nederman Company Presentation.*

Appendix B – Normal distribution table for SERV 1

k-värde	*,00*	*,01*	*,02*	*,03*	*,04*	*,05*	*,06*	*,07*	*,08*	*,09*
0,0	0,5000	0,5040	0,5080	0,5120	0,5160	0,5199	0,5239	0,5279	0,5319	0,5359
0,1	0,5398	0,5438	0,5478	0,5517	0,5557	0,5596	0,5636	0,5675	0,5714	0,5753
0,2	0,5793	0,5832	0,5871	0,5910	0,5948	0,5987	0,6026	0,6064	0,6103	0,6141
0,3	0,6179	0,6217	0,6255	0,6293	0,6331	0,6368	0,6406	0,6443	0,6480	0,6517
0,4	0,6554	0,6591	0,6628	0,6664	0,6700	0,6736	0,6772	0,6808	0,6844	0,6879
0,5	0,6915	0,6950	0,6985	0,7019	0,7054	0,7088	0,7123	0,7157	0,7190	0,7224
0,6	0,7257	0,7291	0,7324	0,7357	0,7389	0,7422	0,7454	0,7486	0,7517	0,7549
0,7	0,7580	0,7611	0,7642	0,7673	0,7704	0,7734	0,7764	0,7794	0,7823	0,7852
0,8	0,7881	0,7910	0,7939	0,7967	0,7995	0,8023	0,8051	0,8078	0,8106	0,8133
0,9	0,8159	0,8186	0,8212	0,8238	0,8264	0,8289	0,8315	0,8340	0,8365	0,8389
1,0	0,8413	0,8438	0,8461	0,8485	0,8508	0,8531	0,8554	0,8577	0,8599	0,8621
1,1	0,8643	0,8665	0,8686	0,8708	0,8729	0,8749	0,8770	0,8790	0,8810	0,8830
1,2	0,8849	0,8869	0,8888	0,8907	0,8925	0,8944	0,8962	0,8980	0,8997	0,9015
1,3	0,9032	0,9049	0,9066	0,9082	0,9099	0,9115	0,9131	0,9147	0,9162	0,9177
1,4	0,9192	0,9207	0,9222	0,9236	0,9251	0,9265	0,9279	0,9292	0,9306	0,9319
1,5	0,9332	0,9345	0,9357	0,9370	0,9382	0,9394	0,9406	0,9418	0,9429	0,9441
1,6	0,9452	0,9463	0,9474	0,9484	0,9495	0,9505	0,9515	0,9525	0,9535	0,9545
1,7	0,9554	0,9564	0,9573	0,9582	0,9591	0,9599	0,9608	0,9616	0,9625	0,9633
1,8	0,9641	0,9649	0,9656	0,9664	0,9671	0,9678	0,9686	0,9693	0,9699	0,9706
1,9	0,9713	0,9719	0,9726	0,9732	0,9738	0,9744	0,9750	0,9756	0,9761	0,9767
2,0	0,9772	0,9778	0,9783	0,9788	0,9793	0,9798	0,9803	0,9808	0,9812	0,9817
2,1	0,9821	0,9826	0,9830	0,9834	0,9838	0,9842	0,9846	0,9850	0,9854	0,9857
2,2	0,9861	0,9864	0,9868	0,9871	0,9875	0,9878	0,9881	0,9884	0,9887	0,9890
2,3	0,9893	0,9896	0,9898	0,9901	0,9904	0,9906	0,9909	0,9911	0,9913	0,9916
2,4	0,9918	0,9920	0,9922	0,9925	0,9927	0,9929	0,9931	0,9932	0,9934	0,9936
2,5	0,9938	0,9940	0,9941	0,9943	0,9945	0,9946	0,9948	0,9949	0,9951	0,9952
2,6	0,9953	0,9955	0,9956	0,9957	0,9959	0,9960	0,9961	0,9962	0,9963	0,9964
2,7	0,9965	0,9966	0,9967	0,9968	0,9969	0,9970	0,9971	0,9972	0,9973	0,9974
2,8	0,9974	0,9975	0,9976	0,9977	0,9977	0,9978	0,9979	0,9979	0,9980	0,9981
2,9	0,9981	0,9982	0,9982	0,9983	0,9984	0,9984	0,9985	0,9985	0,9986	0,9986
3,0	0,9987	0,9987	0,9987	0,9988	0,9988	0,9989	0,9989	0,9989	0,9990	0,9990
3,1	0,9990	0,9991	0,9991	0,9991	0,9992	0,9992	0,9992	0,9992	0,9993	0,9993
3,2	0,9993	0,9993	0,9994	0,9994	0,9994	0,9994	0,9994	0,9995	0,9995	0,9995
3,3	0,9995	0,9995	0,9995	0,9996	0,9996	0,9996	0,9996	0,9996	0,9996	0,9997
3,4	0,9997	0,9997	0,9997	0,9997	0,9997	0,9997	0,9997	0,9997	0,9997	0,9998
3,5	0,9998	0,9998	0,9998	0,9998	0,9998	0,9998	0,9998	0,9998	0,9998	0,9998
3,6	0,9998	0,9998	0,9999	0,9999	0,9999	0,9999	0,9999	0,9999	0,9999	0,9999
3,7	0,9999	0,9999	0,9999	0,9999	0,9999	0,9999	0,9999	0,9999	0,9999	0,9999
3,8	0,9999	0,9999	0,9999	0,9999	0,9999	0,9999	0,9999	0,9999	0,9999	0,9999
3,9	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000
4,0	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000

Figure 43 - Normal distribution table for SERV 1.

Appendix C - Normal distribution table for SERV 2

k-värde	*0,00*	*0,01*	*0,02*	*0,03*	*0,04*	*0,05*	*0,06*	*0,07*	*0,08*	*0,09*
0,0	0,3989	0,3940	0,3890	0,3841	0,3793	0,3744	0,3697	0,3649	0,3602	0,3556
0,1	0,3509	0,3464	0,3418	0,3373	0,3328	0,3284	0,3240	0,3197	0,3154	0,3111
0,2	0,3069	0,3027	0,2986	0,2944	0,2904	0,2863	0,2824	0,2784	0,2745	0,2706
0,3	0,2668	0,2630	0,2592	0,2555	0,2518	0,2481	0,2445	0,2409	0,2374	0,2339
0,4	0,2304	0,2270	0,2236	0,2203	0,2169	0,2137	0,2104	0,2072	0,2040	0,2009
0,5	0,1978	0,1947	0,1917	0,1887	0,1857	0,1828	0,1799	0,1771	0,1742	0,1714
0,6	0,1687	0,1659	0,1633	0,1606	0,1580	0,1554	0,1528	0,1503	0,1478	0,1453
0,7	0,1429	0,1405	0,1381	0,1358	0,1334	0,1312	0,1289	0,1267	0,1245	0,1223
0,8	0,1202	0,1181	0,1160	0,1140	0,1120	0,1100	0,1080	0,1061	0,1042	0,1023
0,9	0,1004	0,0986	0,0968	0,0950	0,0933	0,0916	0,0899	0,0882	0,0865	0,0849
1,0	0,0833	0,0817	0,0802	0,0787	0,0772	0,0757	0,0742	0,0728	0,0714	0,0700
1,1	0,0686	0,0673	0,0659	0,0646	0,0634	0,0621	0,0609	0,0596	0,0584	0,0573
1,2	0,0561	0,0550	0,0538	0,0527	0,0517	0,0506	0,0495	0,0485	0,0475	0,0465
1,3	0,0455	0,0446	0,0436	0,0427	0,0418	0,0409	0,0400	0,0392	0,0383	0,0375
1,4	0,0367	0,0359	0,0351	0,0343	0,0336	0,0328	0,0321	0,0314	0,0307	0,0300
1,5	0,0293	0,0286	0,0280	0,0274	0,0267	0,0261	0,0255	0,0249	0,0244	0,0238
1,6	0,0232	0,0227	0,0222	0,0216	0,0211	0,0206	0,0201	0,0197	0,0192	0,0187
1,7	0,0183	0,0178	0,0174	0,0170	0,0166	0,0162	0,0158	0,0154	0,0150	0,0146
1,8	0,0143	0,0139	0,0136	0,0132	0,0129	0,0126	0,0123	0,0119	0,0116	0,0113
1,9	0,0111	0,0108	0,0105	0,0102	0,0100	0,0097	0,0094	0,0092	0,0090	0,0087
2,0	0,0085	0,0083	0,0080	0,0078	0,0076	0,0074	0,0072	0,0070	0,0068	0,0066
2,1	0,0065	0,0063	0,0061	0,0060	0,0058	0,0056	0,0055	0,0053	0,0052	0,0050
2,2	0,0049	0,0047	0,0046	0,0045	0,0044	0,0042	0,0041	0,0040	0,0039	0,0038
2,3	0,0037	0,0036	0,0035	0,0034	0,0033	0,0032	0,0031	0,0030	0,0029	0,0028
2,4	0,0027	0,0026	0,0026	0,0025	0,0024	0,0023	0,0023	0,0022	0,0021	0,0021
2,5	0,0020	0,0019	0,0019	0,0018	0,0018	0,0017	0,0017	0,0016	0,0016	0,0015
2,6	0,0015	0,0014	0,0014	0,0013	0,0013	0,0012	0,0012	0,0012	0,0011	0,0011
2,7	0,0011	0,0010	0,0010	0,0010	0,0009	0,0009	0,0009	0,0008	0,0008	0,0008
2,8	0,0008	0,0007	0,0007	0,0007	0,0007	0,0006	0,0006	0,0006	0,0006	0,0006
2,9	0,0005	0,0005	0,0005	0,0005	0,0005	0,0005	0,0004	0,0004	0,0004	0,0004
3,0	0,0004	0,0004	0,0004	0,0003	0,0003	0,0003	0,0003	0,0003	0,0003	0,0003
3,1	0,0003	0,0003	0,0002	0,0002	0,0002	0,0002	0,0002	0,0002	0,0002	0,0002
3,2	0,0002	0,0002	0,0002	0,0002	0,0002	0,0002	0,0001	0,0001	0,0001	0,0001
3,3	0,0001	0,0001	0,0001	0,0001	0,0001	0,0001	0,0001	0,0001	0,0001	0,0001
3,4	0,0001	0,0001	0,0001	0,0001	0,0001	0,0001	0,0001	0,0001	0,0001	0,0001
3,5	0,0001	0,0001	0,0001	0,0001	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000

Figure 44 - Normal distribution table for SERV 2.

Appendix D – Interview guide and answers

Interview made with Fredrik Arborelius, Logistic analyst the 2nd of February 2012.

Nulägesanalys

SS-bas

- Behöver ha tillgång till matriserna (tillverkade/inköpta), kan vi få detta?.
- Finns det någon historik för detta, hur de har ändrat sig?
- När görs uppdateringar?
- Vad finns i dessa siffror?
- Vart kan man hitta SS-bas per artikel?
- Kan man plocka fram historiska SS-bas?

Säkerhetslager

- Formel, vart kommer den ifrån och hur har den bestämts?
    - $ss = ss_{bas} * \sqrt{\frac{LT}{30}} * \frac{D}{365}$
- Hur ofta räknas dessa om?
- Är ledtiden som är angiven från leverantör som används eller sker justeringar?
    - Hur ofta uppdateras ledtiderna?
- Finns det arkiverat någon stans om vilken service nivå levrantörerna håller?
- Är efterfrågan årsefterfrågan från prognosen?
    - Beräknas den om varje månad?
- Vart kan man hitta ss per artikel?
- Kan man plocka fram historiska ss?

Beställningspunkt

- Formel
    - $BP = \left(LT * \frac{D}{365}\right) + ss$
    - Denna tar då alltså inte hänsyn till om efterfrågan är större en viss månad?
- När och hur ofta uppdateras den?
- Hur indikeras det sen att lagernivån har nått beställningspunkten?
- Vart hittar man den aktuella BP:n?
- Kan man plocka fram historiska beställningspunkter?

Orderstorlekar

- Hur bestäms orderstorlekarna?
    - Hur ofte bestäms de?
    - I vilken utsträckning används Wilsonformeln?
    - På både komponenter och färdigvaror?

        - $EOQ = \sqrt{\frac{2*D*A}{P*h}}$
        - Vilken demandperiod D, tittar man på?
        - Vilka parametrar finns i ordersärkostnaden, skillnader mellan FVL och komponent?
        - Vad är lagerhållningskostanden, h?
            - Och vilka parametrar finns i denna, dvs hur har den bestämts?
    - Hur efterföljs dessa orderkvantiteter?
    - Finns det någon data över hur många kvantiteter som bestäms efter pris före wilson?
    - Vilka artiklar är det som styrs efter dessa?
- Vart ser man lagernivå gällande antal/värde/volym per artikel?
- Finns det att plocka fram historisk data för hur lagernivåerna har legat för perioder eller datum?

Servicenivå

- Hur har 92 % servicenivå definierats?
- Vad är den exakta definitionen på vad den avser?
- Finns det inga uttalade underklasser?
    - Finns det outalade underklasser?
        - ABC?
            - Vad baseras i sånna fall klassningen på, parametrar?
        - Jobbas det mer med dessa?
- Hur kontrolleras det hur servicenivån ligger?
    - När uppdateras det?
    - Hur redovisas detta?
        - Per artikel/grupp?
- Vart hittar man den aktuella servicenivån?
- Finns det historiska nivåer att plocka fram?

Appendix E – New start values for the new SS-bas matrices

The first table below contains explanation for the different colors.

White	Given a service level of 50 % resulting in a value of zero due to the value of *k=0.*
Grey	Calculated from existing products in the cells.
Light grey	Has no products today and have been calculated from an index explained in chapter 6.5.3

Table 21 - The new calculated start values for matrix P1 - stable, values are in "safety days"

Purchased (P1)	Value				
Frequency	A(min)	B	C	D	E(max)
A(min)	0	0	0	0	0
B	0	0	0	0	0
C	22	24	30	9	0
D	26	19	18	11	0
E	29	21	18	22	0
F	11	10	12	6	0
G(max)	10	11	10	5	0

Table 22 - The new calculated start values for matrix P2 - variable, values are in "safety days"

Purchased (P2)	Value				
Frequency	A(min)	B	C	D	E(max)
A(min)	0	0	0	0	0
B	0	0	0	0	0
C	32	32	35	21	0
D	51	29	24	29	0
E	47	29	24	27	0
F	20	16	21	9	0
G(max)	31	25	18	8	0

Table 23 - The new calculated start values for matrix P3 - peaks, values are in "safety days"

Purchased (P3)	Value				
Frequency	A(min)	B	C	D	E(max)
A(min)	0	0	0	0	0
B	0	0	0	0	0
C	42	29	38	13	0
D	45	21	20	30	0
E	42	25	20	43	0
F	16	13	12	7	0
G(max)	24	17	10	6	0

Table 24 - The new calculated start values for matrix P4 - lumpy, values are in "safety days"

Purchased (P4)	Value				
Frequency	A(min)	B	C	D	E(max)
A(min)	0	0	0	0	0
B	0	0	0	0	0
C	50	48	54	30	0
D	49	35	31	34	0
E	101	35	31	66	0
F	50	18	22	14	0
G(max)	40	23	18	12	0

Table 25 - The new calculated start values for matrix M1 - stable, values are in "safety days"

Manufactured (M1)	Value				
Frequency	A(min)	B	C	D	E(max)
A(min)	0	0	0	0	0
B	0	0	0	0	0
C	58	57	41	28	0
D	55	56	41	18	0
E	52	20	21	11	0
F	15	11	8	5	0
G(max)	12	12	9	7	0

Table 26 - The new calculated start values for matrix M2 - variable, values are in "safety days"

Manufactured (M2)	Value				
Frequency	A(min)	B	C	D	E(max)
A(min)	0	0	0	0	0
B	0	0	0	0	0
C	62	90	60	50	0
D	58	88	60	33	0
E	60	29	29	18	0
F	51	15	13	9	0
G(max)	43	17	15	12	0

Table 27 - The new calculated start values for matrix M3 - peaks, values are in "safety days"

Manufactured (M3)	Value				
Frequency	A(min)	B	C	D	E(max)
A(min)	0	0	0	0	0
B	0	0	0	0	0
C	89	73	46	34	0
D	84	72	45	22	0
E	73	27	24	15	0
F	31	11	10	6	0
G(max)	26	13	11	8	0

Appendix F – Values for reordering point during implementation

Table 28 - Development of reorder point values throughout the implementation period.

	20-mar	21-mar	04-apr	26-apr
Test group	5647672	6004041	5991522	5501883
Group 1	4948354	4948354	5372248	5178098
Group 2	5376631	5376631	6136740	5691314
Group 4	5192676	5192676	5968069	5599143
Group 5	4770761	4770761	5577424	5181973

Table 29 - Changes during the implementation period based on the start value as the zero level.

	20-mar	21-mar	04-apr	26-apr
Test group	0	356369	343849	-145790
Group 1	0	0	423895	229744
Group 2	0	0	760109	314683
Group 4	0	0	775393	406468
Group 5	0	0	806663	411213

Appendix G – Service level during the implementation

Table 30 - How the service level has developed during the implementation period per group.

	30-mar	09-apr	16-apr	23-apr	30-apr	07-maj	14-maj	21-maj
Test group	88,52%	89,69%	83,18%	74,36%	90,00%	91,40%	94,55%	95,35%
Group 1	86,12%	88,57%	79,82%	84,25%	89,01%	91,35%	84,62%	87,65%
Group 2	93,40%	94,85%	81,65%	82,76%	88,89%	94,55%	93,33%	94,57%
Group 4	94,88%	90,57%	81,03%	89,31%	84,38%	88,80%	86,36%	96,84%
Group 5	88,70%	93,88%	78,86%	92,06%	83,49%	91,67%	90,80%	95,79%

Table 31 - Development of service level cumulative during the implementation period per group.

	30-mar	09-apr	16-apr	23-apr	30-apr	07-maj	14-maj	21-maj
Test group	88,52%	88,93%	87,34%	84,33%	85,19%	86,03%	86,66%	87,56%
Group 1	86,12%	86,94%	85,11%	84,91%	85,49%	86,31%	86,17%	86,31%
Group 2	93,40%	93,88%	90,57%	88,82%	88,83%	89,71%	89,99%	90,47%
Group 4	94,88%	93,46%	90,16%	89,96%	89,16%	89,10%	88,83%	89,61%
Group 5	88,70%	90,24%	87,14%	88,21%	87,46%	88,04%	88,31%	89,04%

Appendix H – Difference in new and old SS-bas safety stock- and reorder point value per matrix

Purchased	Sum of SS (old)	Sum of SS (new)	Sum of BP (old)	Sum of BP (new)
P1	2671692	2323155	9058536	8709999
P2	3656779	3424663	8758360	8526243
P3	878589	843854	2181073	2146339
P4	926219	999113	1662136	1735031
Total P	**8133279**	**7590786**	**21660105**	**21117612**

Manufactured	Sum of SS (old)	Sum of SS (new)	Sum of BP (old)	Sum of BP (new)
M1	817648	700149	2252957	2135458
M2	1188972	1168126	2331992	2311146
M3	992822	752194	1978571	1737944
Total M	**2999442**	**2620469**	**6563521**	**6184548**

Appendix I – Updating model

- **Data from IFS**
  - 12 months back in time
    - Bacflush for components warehouse
    - Oeship for finished goods warehouse
  - Extract the date, article number and amount of articles for every order line from the data
  - Merge the two documents into one (Bacflush and Oeship)
- **Demand plot**
  - Use the data to create a pivot table, with the article number on the y-axis and the dates in weeks on the x-axis. The weekly demand should be plotted in the middle.

Year	2010								2011
Week	1	2	3	4	5	6	7	…	52
Article nbr ↓ …	**Weekly demand**								

  - Calculate, for every article, average weekly demand, the standard deviation, coefficient of variance, and how many weeks the demand where over 0 (weekly demand frequency).
  - Use the latest MySigma file to add the following information to every article: Description, status, creating date, current order point, lead time, value, manufactured/purchased, frequency and demand.
  - Calculate the pikes for every article, by checking how many times one week demand was more than 6 times larger than the average demand.

- **Selection of matrices**
  - Use the predetermined matrices limits and the calculations from the pivot diagram to divide the articles into the different matrices.

Product type	Separating limits and values
Make to order (P)	Weekly demand frequency < 4, CofV > 6
Make to order (M)	Weekly demand frequency < 13, CofV > 6
Stable (P1)	(No peaks, no lumpy), CofV < 1
Stable (M1)	(No peaks), CofV < 1
Variable (P2)	(No peaks, no lumpy), 1 < CofV < 6
Variable (M2)	(No peaks), 1 < CofV < 6
Peaks (P3)	Weekly average demand > 5, 1-3 values > 6*Weekly demand
Peaks (M3)	Weekly average demand > 1, 1-3 values > 6*Weekly demand
Lumpy (P4)	3 < Weekly demand frequency < 13

  - Cross check the current classification list with the new one and make the new changes of classification.
- **Implementation**
  - Give the new products that have changed matrices the current SS-bas value, and implement in the system.