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Development of Replenishment and Planning Strategies
A case study at Duni AB

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Acknowledgements

It seems like a couple of days ago our journey began at Lund University, Faculty of Engineering. Our minds were open and knowledge was more or less thrown at us. We fought our way through exams, the dialect in southern Skåne and wind. Three years later a new chapter begun, the rising stars began their master’s at the department of Industrial Management and Logistics at Lund University, Faculty of Engineering.

Six months ago a new door opened, and Duni AB welcomed us with open arms and with an assignment larger than anything we had experience before. Although, we had prepared for this battle since the start of our education, guidance from Carl Risholm at Duni was mission critical. A special thanks to you!

The assignment went back and forth, up and down, etc. The warriors had almost given up hope when the turning point came. Jan Olhager guided us through the battle and we were victorious. Thank you Jan, for your insights, knowledge and guidance.

The journey is at its end. The final analysis has been made, the last napkins have been folded, the last words have been written. Although, be aware, new sails have been set and a new journey have begun.

COYG!

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Abstract

Advanced technology has changed the way in which inventory control techniques can be applied. An efficient inventory system can be a competitive advantage, and companies have become aware of the importance of inventory systems that control the flow of goods and optimises the cost of goods. (Axsäter, 2006)

This project focuses on how a decision framework should be designed for replenishment and planning strategies at Duni. The reason for this project is that Duni has identified the need to assess other types of replenishment and planning strategies than forecast driven replenishment. Therefore, this research analyses how Duni’s articles can be replenished and planned by dividing the article assortment into classes.

The research method chosen for this project was an embedded case study, where the subunit of analysis was the different product characteristics to be able to study how strategies could be organised. Nine interviews were performed with employees at Duni with both operational and management roles, which gave a holistic view and objective understanding of the case. By comparing the empirical findings with the frame of references combined with quantitative data analysis the foundation for the analysis was set. The analysis started with a comparison of frame of references and empirical findings. Factors that enabled to divide articles into different classes depending on characteristics were established and analysed by mathematical modelling.

This study has proven that it is possible to increase the service level, decrease the tied up capital and increase the planning efficiency through alternative replenishment strategies at Duni. The decision framework has been the foundation of the results and performing a suitable classification has shown to be essential. Controlling articles with low variation with stochastic demand models have been concluded to be successful in terms of service level, tied up capital and planning efficiency. It has also been concluded that articles with a high volatility and low demand are suitable for MTO. Finally, demand forecast accuracy can be improved by aggregating forecasts on warehouse level.

Key words: Inventory Control, Supply Chain Management, Replenishment Strategies, Planning Strategies, Coefficient of Variation, Demand Forecasting

Table of content

Table of Abbreviations

This table explains to the reader the abbreviations used in this report.

Table 1: Abbreviations used in the report

Abbreviations	Explanation
BA	Business Area
BU	Business Unit
CS	Consumer, business area at Duni
DOC	Days of Coverage, average number of days of inventory to cover demand
DOI	Days of Inventory, average number of days an article is in inventory
EOQ	Economical order quantity
ERP	Enterprise Resource Planning
KPI	Key Performance Index
MAPE	Mean Average Percentage Error
MOQ	Minimum Order Quantity
MRP	Material Requirements Planning
MS	Meal Service, business area at Duni
MTC	Make-to-Contract, Duni's definition of a mix between MTS and MTO
MTO	Make-to-Order, production or purchase based on order
MTS	Make-to-Stock, production or purchase based on inventory rule
POS	Point of sales, sales made by a company for a specific period
S1	Service level 1, method to calculate service level
S2	Service level 2, method to calculate service level
SKU	Stock Keeping Unit
SNP	Supply Network Planner, a system provided by SAP
TT	Table Top, business area at Duni

1 Introduction

This chapter will introduce the reader to the background of the problem. In addition, a brief description of the company and the problem at hand will be discussed, followed by purpose and research questions. Focus and delimitations, target groups, and the structure of the project will also be presented in this chapter.

1.1 Background

Companies today have realised the true importance of inventory control systems that controls the flow of goods and optimises the inventory costs. An efficient inventory system can be a competitive advantage that can bring either a higher service level and/or decrease costs in inventory, and releasing cash for other purposes.

Advanced technology has changed the way in which inventory control techniques can be applied. Today, computer systems have made it possible to implement information systems that can handle extensive data to optimise the inventory system fully by controlling products down to article number. (Axsäter, 2006)

Due to lead times between order and delivery, and due to ordering costs that makes it sometimes necessary to order in batches instead of unit for unit, companies need to order items before customers place their orders. To be able to do so companies need to look ahead and forecast the demand. The forecast is an estimate of the average demand for some future time period. However, knowing the average demand is not enough. The uncertainty in the forecast needs to be measured to determine how much safety stock that needs to be stored to compensate for the forecast error. (Axsäter, 2006)

As forecasts are complex to perform for products with low or sporadic demand, the forecast error tend to be high for these types of products. Therefore, it is common to use other inventory control techniques to cope for the high forecast error.

Earlier research has shown that it is possible to classify a product range into different demand patterns and therefore be able to better predict future sales by analysing historical sales data. An example where this was performed is the company Rohm and Haas, in 2000. The company increased both the service level and reduced the tied up capital in stock after the products were sorted and controlled depending on the respective demand pattern. (D'Alessandro & Baveja, 2000)

1.2 Company Description

Duni is a company in the paper industry, who produces and supplies disposable goods to the hotel, restaurant, event and consumer industry. The paper goods are produced by Duni meanwhile goods of other materials are purchased from suppliers. Examples of products supplied by Duni are napkins, plastic take-away boxes and candles. Duni has developed a concept called “goodfoodmood”, which explains the market Duni is in. “goodfoodmood” consists of products that creates pleasurable eating and drinking occasions. Duni has four Business areas (BA): Table Top (TT), Meal Service (MS), Consumer (CS) and New Markets. (Duni AB, 2016)

Duni supplies “goodfoodmood” to 40 markets and is market leader in the central and northern parts of Europe. Duni has 2100 employees in 18 countries, the head office is located in Malmö, Sweden. The production facilities are located in Bramsche, Germany and Poznan, Poland. Duni has four main warehouses, two of them are owned by Duni and located in connection with production facilities in Bramsche and Poznan. The other two warehouses are owned by third party logistics providers and are located in Norrköping, Sweden and Riihimäki, Finland. (Duni AB, 2016)

This project will be facilitated from the head office in Malmö, where the central demand planning department is located. Demand planning is performed central from Malmö and the local planning is performed from field offices. The supervisor from Duni for this project is the international demand manager who works in Malmö.

1.3 Problem Discussion

[redacted]. There are several factors that affect reliability but Duni has identified delivery performance as the crucial factor. [redacted]

Demand planning is an important component of the supply chain, all succeeding components are affected and make decision based on the output from demand planning. Steady and reliable plans are crucial for a good delivery performance and an efficient supply chain.

[redacted]. There is much to gain by reducing inventory levels, for example, the complexity of the supply chain can be reduced. The cost of using external warehouses can be reduced or even avoided, in addition tied up capital in stocks will be reduced.

Duni has during the course of the last three years improved their forecast error for all their BAs, Days of Inventory (DOI) has decreased for the larger part of the article assortment, and the delivery performance has improved. However, the total warehouse space need has increased. These results have been realised due to improvements of the current replenishment and planning strategy, which mainly consists of forecast driven replenishment.

To take the next step, in improving the overall demand planning process, Duni has identified the need to assess other types of replenishment and planning strategies than forecast driven replenishment. Therefore, Duni is requesting an investigation of alternative replenishment and planning strategies to further improve delivery performance, reduce stock levels, and increase the efficiency of the planning process.

1.4 Research Purpose and Questions

The purpose of this project is to present a proposal for replenishment and planning strategies aiming to improve delivery performance, reduce stock levels, and increase the efficiency of the planning process.

The following research questions will be answered in this project.

1. What kind of replenishment and planning strategies suits Duni's product assortment?
2. How should a decision framework be designed for replenishment and planning strategies at Duni?

The authors have identified four stakeholders that are affected by this project. The stakeholders are: Duni, the authors, research and the community. All stakeholders have different incentives or purposes to this project.

Duni's incentive to this project is to get an alternative proposal for how to handle their replenishment and planning activities. The proposal will include a classification of Duni's articles, replenishment and planning strategies will be proposed to each category.

The authors purpose of this project is to gain a deeper theoretical knowledge in inventory control and supply chain management. The authors will also gain knowledge how these subjects are dealt with in practise. The authors will also gain experience how to plan and perform a large project.

The contribution to research is to investigate if already known theoretical strategies within inventory control and supply chain management can be applied or even confirmed.

The contribution to society will be in form of environmental impact. A reduction of tied up capital and/or increase service level implies that less resources need to be spent by Duni. Less spent resources lead to a reduction of environmental impact which contributes to the society.

1.5 Project Focus and Delimitation

This project will focus on Duni's activities in Europe. Suppliers, production facilities, warehouses and customers in Europe are all included in the project. Suppliers located outside of Europe will not be included. The BA New Markets are performing the majority of their activities outside of Europe, the whole BA will be excluded from the project.

The BAs that will be in focus during this project is: TT, MS and CS. All of these BAs' have a mix of products produced by Duni and traded goods. These three BAs cover the industries: Restaurant, hotel, event and consumer. Furthermore, the restaurant industry can be divided into fine dining and take-away industry. Since the three BAs will be in focus, the corresponding industries will also be in focus. The three BAs have year around and seasonal products, both product types will be in focus for this project.

In all BAs there is a category called Private Label. A Private Label article is a customised article made by Duni upon customers' request. A Private Label article has often a unique design or a customer want to print their name on the article. A directive given by Duni is to exclude all Private Label articles, mainly because Duni's way of working with Private Label articles is different compared to the other assortment. A removal of Private Label articles will reduce the complexity of the project, in addition there are doubts that a feasible solution for controlling Private Label articles can be implemented or even accomplished.

Duni is collaborating with some customers, the collaboration is in form of exchange of information. Point of sales (POS) data and forecasts are provided by customers that Duni collaborate with although this kind of information is limited. Information from customers will be excluded in the project which means that no exchange of POS data and forecasts will be available in the project. The focus will be on internal information, which the researchers will gather from Duni, an example of internal information is sales history.

1.6 Target Groups

This project is aimed to the management at Duni, researchers and students at a University level. All stakeholders are assumed to work with inventory control or supply chain management, therefore the stakeholders are expected to have a higher education. Thus, all stakeholders will understand the academic language and terms used throughout this report.

1.7 Report Structure

Table 2 below is an overview of the report and contains a description of the different chapters.

Table 2: Overview of the report

Name of Chapter	Chapter	Explanation
Introduction	1	This chapter will introduce the reader to the background of the problem. In addition, a brief description of the company and the problem at hand will be discussed, followed by purpose and research questions. Focus and delimitations, target groups, and the structure of the project will also be presented in this chapter.
Methodology	2	In this chapter different research methodologies will be presented. In addition, a motivation of the chosen

		methodology will be followed by a brief explanation of the project execution. A Discussion regarding data collection and analysis will be presented. Finally, methods to increase reliability, validity and objectivity of the report will be presented.
Frame of Reference	3	In this chapter relevant theories regarding inventory control and supply chain management are presented, together with key terminology that will be used in the project. This chapter will provide a theoretical basis which the rest of the report will be connected to.
Empirical study	4	In this chapter the collected data will be presented. The chapter begins with a mapping of Duni's supply chain, followed by a discussion of Duni's products. Duni's current classification, forecasting methods and replenishment system will also be presented. The objective of this chapter is to describe how and why Duni works with the current replenishment and planning strategies.
Analysis	5	In this chapter the collected data are analysed with the help of the presented theory. The analysis will consist of explaining patterns and relationships between collected data and theory. Mathematical modelling will also be used to analyse the collected data. The analysis will be conducted according to the presented methodology. A solution will be presented.
Conclusions & recommendations	6	Results of the analysis are presented, where conclusions will be drawn based on the same results. Our recommendations to Duni are presented together with motivations of the recommendations. A discussion regarding the generalisation of the results will be presented. Suggestions for further research and reflections by the authors will be provided.
References	7	This chapter include a list of all reference used in this report. The reference list is built according to the Harvard system. When a reference is written before the punctuation that sentence comes from the same reference, although is a reference written after the punctuation the whole section is from the reference.
Appendix	8	Additional information in forms of tables and figures will be presented in this chapter.

2 Methodology

In this chapter different research methodologies will be presented. In addition, a motivation of the chosen methodology will be followed by a brief explanation of the project execution. A Discussion regarding data collection and analysis will be presented. Finally, methods to increase reliability, validity and objectivity of the report will be presented.

2.1 Research Methodology

A methodology should be selected with great caution as it is an important part of the knowledge generation regarding the studied subject. The methodology is not a manual of the execution, but a guide of how research and analysis are conducted. (Höst, et al., 2006)

2.1.1 Inductive and Deductive

There are two ways to connect empirical observations with theory; Induction and deduction. The inductive approach entails that conclusions have been drawn from empirical observations. However, it should be mentioned that this approach does not guarantee that the conclusions are correct. (Ghauri & Grønhaug, 2002)

The deductive approach means that conclusions can be drawn through logical reasoning. Existing laws and theories are used to explain or predict some observed case. Therefore, the conclusions do not need to be true, but it is logical. The deductive approach involves hypothesis based on propositions being accepted or rejected by empirics. (Ghauri & Grønhaug, 2002)

The figure below (figure 1) explains the relationship between inductive and deductive.

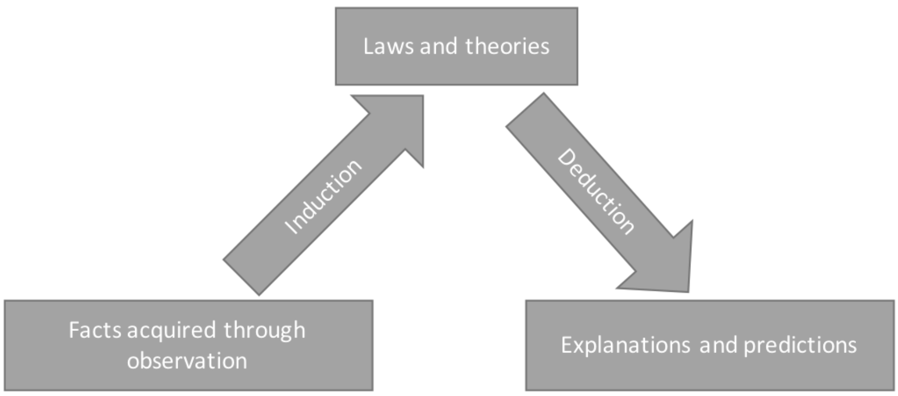


Figure 1: The relationship between induction and deduction based on (Ghauri & Grønhaug, 2002)

2.1.2 Qualitative and Quantitative Methods

There are two kinds of methods that can be used for collecting data, i.e. Qualitative and Quantitate methods. The selection of method depends on the formulation of the problem and the target of the research. Qualitative and quantitative research differs in terms of procedure, moreover the methods have different views on the objective of the research and knowledge. (Ghauri & Grønhaug, 2002)

The qualitative method is a process oriented method with focus on understanding. The most common way to collect data is through observations and interviews, which demands skills and experience from the researcher. The researcher needs to understand and interpret the respondent's answers, which means that the researcher will become subjective. In order to make a valid analysis, the researcher needs to be able to be unbiased to the subject but at the same time being able to utilize past experiences and skills. Qualitative data is rich and gives a holistic perspective that can be useful for establishing hypotheses. (Ghauri & Grønhaug, 2002)

The quantitative method emphasis on facts and reasons, the same facts and reasons are established through tests and verifications. The data is often collected individually and aggregated in order to perform an analysis. The researcher is distant to the data, which makes the researcher objective. The quantitative method is result oriented and often used to test already established hypotheses. (Ghauri & Grønhaug, 2002)

It is common to use qualitative and quantitative methods in the same study, there are researchers who claims that the two methods are complementary and cannot be used separately. However, qualitative and quantitative methods are compatible in different steps of the research. The qualitative method is often used in the early stages of research with the objective to create a hypotheses or structure a problem. A quantitative method can be applied to test the hypotheses created in the early stages, the hypotheses will be verified or rejected by the logic applied through the quantitative method. (Ghauri & Grønhaug, 2002)

2.1.3 The Selected Methodology

Both an inductive and deductive approach will be used in this project, because empirical observations will be made, in addition conclusions will be drawn from logical reasoning. Empirical observations will be generated from conversations and company visits; conclusions will be drawn from these observations. In order to make sure that the conclusions from the empirical observations are correct, logical reasoning will also be made. The logical reasoning will primarily be made through data analysis. The combination of the approaches will be iterative throughout the project, in order to reach the wanted result.

In the same manner, qualitative and quantitative methods will be used to collect data. As mentioned above qualitative methods are used to understand, by performing interviews and observations. The first part of this project is to understand Duni's material flow, product characteristics, and their current replenishment and planning strategies. The second part is to achieve a result, which will be done through testing hypothesis. In order to test the hypothesis data need to be collected and aggregated. Qualitative and quantitative methods will be used in both parts of the project, since they are complementary and will provide the general picture.

2.2 Research Strategy

The question what research strategy to use depends on the expected results and characteristics of the project. Therefore, it is crucial to choose the right research strategy to reach the project objective (Höst, et al., 2006).

2.2.1 Research Strategies

There are five different research strategies that are generally known according to Yin (2014). These five research strategies are depicted below, in table 3. The first thing to consider when deciding upon a research strategy is the research questions.

- Explanatory questions like "how" and "why" makes it more suitable to use a case, history, or experiment study.
- Exploratory questions like "what" questions are suitable for all five types of research methods. However, if "how much" and "how many" questions are used then survey methods or the archival analysis method are more suitable than the others.

There are two other conditions that should be considered when choosing a strategy, that are the extent of the control of behavioural events and the focus on contemporary events (Yin, 2014).

Table 3: Decision factors for different research strategies based on (Yin, 2014)

Strategies	**(1) Form of Research question**	**(2) Requires Control of Behavioural Events?**	**(3) Focuses on Contemporary Events?**
Experiment	How, why?	Yes	Yes
Survey	Who, what, where, how many, how much?	No	Yes
Archival Analysis	Who, what, where, how many, how much?	No	Yes/no
History	How, why?	No	No
Case	How, why?	No	yes

2.2.2 The Selected Strategy

The selected strategy for this master thesis is a case study. The research questions that have been proposed are of the types "how" and "what", which makes case study, history, and experiment suitable research strategies. The context, in this case the material and information flow, needs to be understood in order to study the object. However, an experiment requires control of the context that the phenomenon is studied in. Therefore, it is not a feasible research strategy as the real-life context should not be tampered in this study. The objects of study are replenishment and planning strategies at Duni, which are contemporary events.

Therefore, history can be excluded as a choice of research strategy as it does not entail investigation of contemporary events.

The scope of a case study can be defined according to Yin (2014) as: "A case study is an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context…" (Yin, 2014). Therefore, a case study will be conducted as it fits best the purpose of the research. The objective of the project is to find alternative replenishment and planning strategies. Existing theories includes processes that describes how this can be accomplished. The research purpose of the case study will therefore be theory testing.

2.2.3 Case Study Approach

Case studies can be used for different types of research purposes; therefore, the case study can be designed in several ways to suite the purpose (Höst, et al., 2006). Yin (2014) mentions four different types of case study designs. These designs can be divided into single-case designs and multiple-case designs.

It is appropriate to choose a single-case design when a case represents a critical test of a significant theory or an extreme occurrence. It is also appropriate to choose a single-case to represent a revelatory, or longitudinal case: studying the same single case at two or more different points in time. When a single study includes more than a single case it is a multiple-case design. The purpose of a multiple-case design is to develop theory by finding similarities or contrasts from each case.

There are several advantages and disadvantages that must be accounted for when deciding upon single- versus multiple case design. Choosing a single-case design allows rich descriptions of the existence of the phenomenon, while multiple-case design yields more robust, generalisable, and testable theory (Eisenhardt & Graebner, 2007). The disadvantage of a single-case design is the limitation to explain that conclusions are general. There are also risks of misinterpretation of a single event, and of overestimating the results from a specific case design. Multiple-cases designs are therefore more preferable and also protects against observer bias (Voss, et al., 2002). Multiple-case designs, even with two cases, provides the possibility for direct replication. Given that the cases provide the same conclusion the results will be more generalisable, which strengthens the findings from the study. Disadvantages with multiple-case design is that it requires extensive resources and is time consuming (Yin, 2014).

Moreover, Yin (2014) makes a last distinction between holistic and embedded. Single-cases and multiple-case designs can be both holistic and embedded. Embedded case studies concern cases where subunits of analysis are given attention, which allows the researcher to study the case in more detail. Holistic case studies concern units of analysis at one level only, which means that the case study is examined in a global nature.

2.2.4 The Selected Case Study Approach

The selected case study approach is an embedded single-case study. The reason for this is that the case represents significant theory, while the conclusions are expected to be specific to the case study and not applicable to other similar cases.

Furthermore, the units of analysis are the material and information flow. To study how to control these flows in more detail, the subunits will be different product characteristics, which will be defined in the case study. Therefore, embedded analysis will be considered, with a subunit of different product characteristics.

2.3 Project Execution

The project started with initial interviews with the aim of establishing the problem formulation, at the same time initial methodology research was conducted. The initial interviews took place at Duni's head office in Malmö. The interviewees were managers with insights in Duni's current replenishment and planning strategies, in addition inputs were gathered of what the project would accomplish. After the initial interviews had been conducted and analysed the problem formulation could be created and confirmed by the project supervisors at Duni and Faculty of Engineering, LTH.

The next stage was a combination of several tasks, the frame of reference was established to build a theoretical foundation which later could be compared with the empirical study. The first round of data collection consisted of interviews with the objective to find out what factors were important for Duni when characterising products, in addition a first batch of data was extracted from Duni's Enterprise Resource Planning (ERP) system. An interview guide was developed and was used in the second round of data collection, more thorough interviews were conducted in the second round than the first round which made it reasonable to create an interview guide. A first analysis was conducted in order to perform a characterisation of the products and create product groups, the foundation of the analysis was a combination of the collected data and the frame of reference.

The second round of data collection consisted of data extracted from Duni's ERP system and extensive interviews with Duni managers and employees. The second analysis was performed through mathematical modelling and spreadsheet modelling. The objective of the second analysis was to calculate parameters for the suggested replenishment strategies and tied up capital. A framework was created which enabled Duni to characterise existing and new articles into the already established classes. Thus, an alternative replenishment strategy was proposed to Duni. Final conclusions were drawn and written along with suggestions for further research. Figure 2 illustrates the different cornerstones of the project.

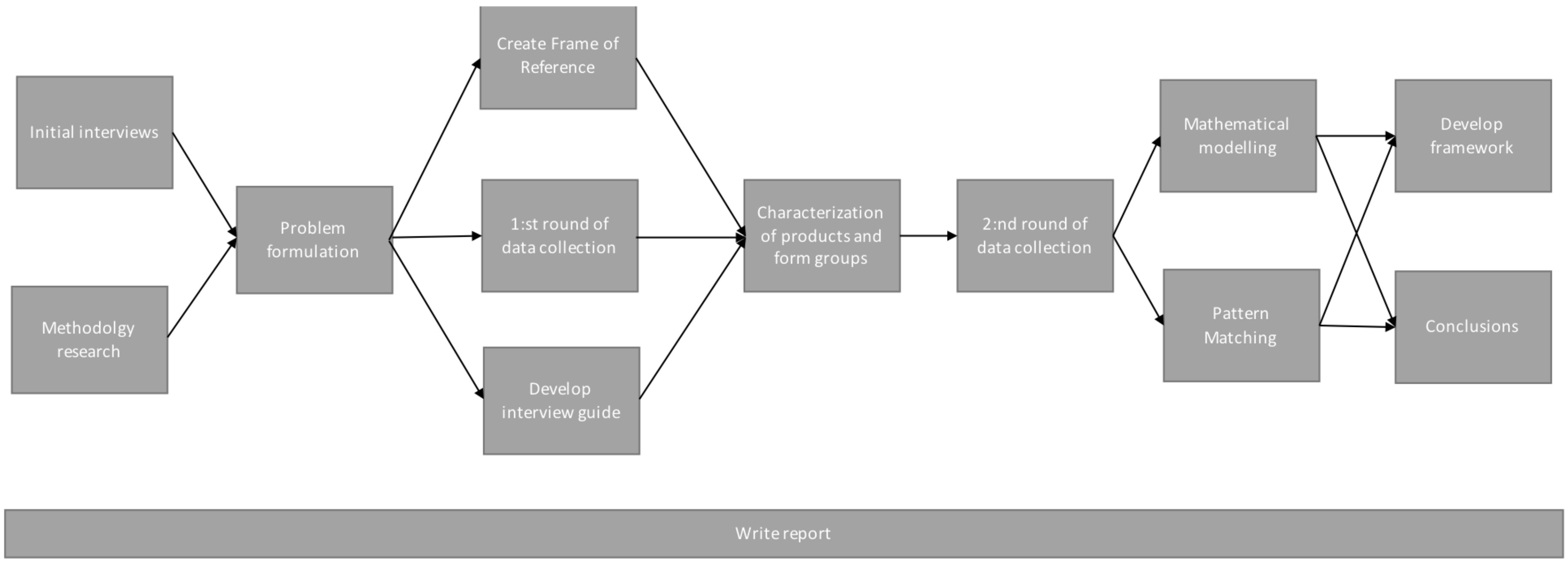


Figure 2: Project execution

2.3.1 Data Collection

There are five different tools to collect data: Observations, Communication, Surveys, Interviews and Focus groups (Ghauri & Grønhaug, 2002). These tools are used in different kind of situations and chosen based on the desired outcome.

2.3.2 Primary and Secondary Data Sources

There are two types of data sources, primary and secondary data sources. Secondary data sources should be the first data source to use, mainly because it saves time and money to the project. Secondary data sources are divided into two categories, internal sources and external sources. An internal source can be a company's annual report meanwhile an external source can be a journal article. An advantage connected to secondary data sources are that they provide a tool to understand the primary data sources. Moreover, they create a knowledge base for the researcher, which can be used to draw conclusions. Primary data sources are data that is collected by the researchers, the data can be collected from interviews, observations and surveys. Primary data sources suit the specific project but may be expensive and time consuming to collect. (Ghauri & Grønhaug, 2002)

In this project primary and secondary data sources will be used. The primary data sources that will be used are in form of interviews and observations. Furthermore, the secondary data sources that will be used are from both internal and external sources. The external sources that will be used are journal articles to establish what the current trends are in planning and replenishment. Internal sources that will be used are for example historical sales volumes.

2.3.3 Interviews

Interviews are considered as one of the best data collection methods. However, to ensure reliability of the interview, the selection of interview method is especially important. There are three types of interview methods, Structured interview, Unstructured interview and Semi structured interview. (Ghauri & Grønhaug, 2002)

A Structured interview consists of a standard form, which results in systematic sampling over predetermined areas. Furthermore, a Structured interview is comparable to a survey, the difference is that questions are asked during the interview. The Unstructured interview consists of leading questions asked by the interviewer, which the respondent is free to elaborate on in almost any direction. The objective of an Unstructured interview is to get answers to questions "how" and "why". The Semi-structured interview is a combination of the other two types. The advantage with a Semi-structured interview is that it is possible to perform in depth interviews, which grants the possibility to use open-ended questions. Thus, it is possible to get a better understanding of the respondent's view on certain areas. (Ghauri & Grønhaug, 2002)

According to Ghauri and Grønhaug (2002) objectivity is important to consider when performing and analysing interviews. When performing an interview, questions should not be formulated in a leading way. The respondent should be free to answer the questions and not be affected by the formulation of the question. Regarding the analysis of the interviews, it is important to stay objective and not interpret the interviews with the influence of the interviewees knowledge. (Ghauri & Grønhaug, 2002)

An interview guide (Available in Appendix B) will be constructed, the interview questions will be developed according to the objective of the research. To ensure that the questions are aligned with the objective of the research, the questions will be sent to our supervisor for a review. A Semi-structured interview format will be used since a case study is performed, which entails in depth interviews with the possibility of open-ended questions.

2.4 Data Analysis

After collecting the data an analysis of the gathered data needs to be conducted. It is important to understand and consider the constraints that the data gathering technique inflict on the data analysis method. If a quantitative data collection method is used then a quantitative data analysis method needs to be utilised (Ghauri & Grønhaug, 2002).

2.4.1 Qualitative Data Analysis

Yin (2014) proposes that there are five different types of analytic techniques. These should be used in a structured and suitable manner. Below is a list of analytic techniques that Yin (2014) presents.

- Pattern Matching: Compares patterns from empirical findings with patterns that were predicted prior to the data collection. This logic is focused on finding similarities and differences between the two mentioned patterns.
- Explanation Building: This is a special type of pattern matching, which is more difficult and complex. The goal with this technique is to analyse the case developing an explanation about the case.
- Time-series Analysis: Comparison of some observed empirical trend with either a theoretically significant trend specified before the investigation or some rival trend, also specified earlier.
- Logic Models: specifies and operationalises a complex chain of occurrences or events over an extended period of time. The events are staged in cause-effect patterns. The model logic is built on matching empirically observed events to theoretically predicted events.
- Cross-Case Synthesis: Aggregating data from all cases to find similarities or differences for different categories of data. The findings will then confirm or disconfirm the original expectations.

The analytic technique selected is pattern matching. By utilising the pattern matching technique the frame of reference will be compared to empirical data to see deviations and similarities. Thus, the first research question will be answered and compared with how Duni have designed their replenishment and planning strategies to control the material and information flow. This will partly lead us to research question two. However, to fit specific replenishment and planning strategies to Duni's product assortment the products needs to be categorised. To reach a categorisation pattern matching will be used again. The remaining steps involve mostly analysis of quantitative data to fit products into the different categories, find suitable replenishment and planning strategies, and design the decision framework for replenishment and planning strategies for Duni.

2.4.2 Quantitative Data Analysis

According to Law and Kelton (1991) a system is defined by all factors needed to explain the system at a certain time which are connected to the objective of the research. The quantitative data will be the foundation to the factors that are needed to explain the system. Law and Kelton's model (figure 3) will be used to answer research question 2.

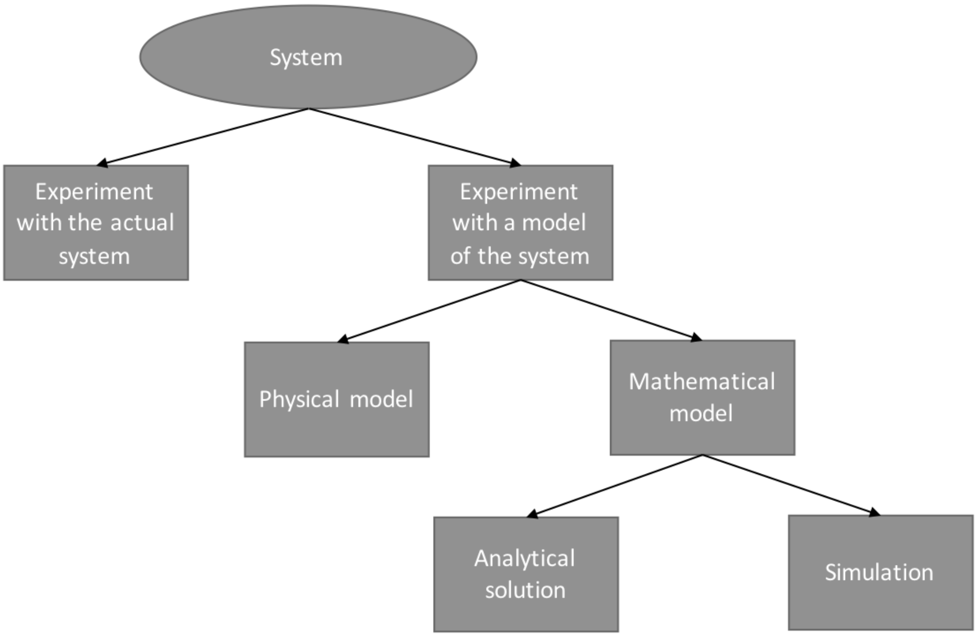


Figure 3: Way to study a system (Law & Kelton, 1991)

Once the system has been defined one need to decide whether to use an experiment of the actual system or an experiment with a model of the system (Law & Kelton, 1991). An experiment of the actual system would mean that changes would be implemented in Duni's current system and the outcome would be analysed further. However, this is not feasible. First of all, it is costly and it would jeopardise Duni's business. A model of the actual system is the logical choice and it is what will be used in the project, although questions can be raised whether the model is reflecting the actual system (Law & Kelton, 1991).

The next piece of the jigsaw is to determine whether to use a physical model or a mathematical model. An example of a physical model is clay cars in a wind tunnel (Law & Kelton, 1991). A physical model is not feasible to use in this project. However, a mathematical model suits the project. A mathematical model reflects the system and explains logical and quantitative relationships, the same relationships are then modified in order to establish how the system will respond under the modifications (Law & Kelton, 1991).

An analytical solution is feasible when the mathematical model itself is not too complex. The complexity of the mathematical model in this research will not demand a simulation model, which is used when the mathematical model is too complex. (Law & Kelton, 1991) Simulation should only be used when it is not possible to solve the problem in an analytical way, in addition results generated through simulation can only be reached with a certain statistical significance (Bertrand & Fransoo, 2002). An analytical model will be feasible for this project and numerical solution will be reached.

2.5 Credibility

It is important to establish quality throughout the research to ensure that the research has high credibility. Having credibility means that conclusions are supported, assures that research address the phenomena that is supposed to be studied, and that the results from the research are generalisable.

Credibility is built on two constructs; validity and reliability. Reliability refers to the stability of the measure, meaning that repetitive studies results in the same findings and conclusion. Validity measures how well the findings actually describes the reality (Ghauri & Grønhaug, 2002). The dart analogy can be used to describe the relationship between reliability and validity, which is presented in figure 4 (Björklund & Paulsson, 2010). In research it is important to have both high reliability and validity to ensure both that the researchers are measuring the phenomena right and that repetitive measurements are the same. Yin (2014) proposes four tests that can be conducted to increase the reliability and validity.

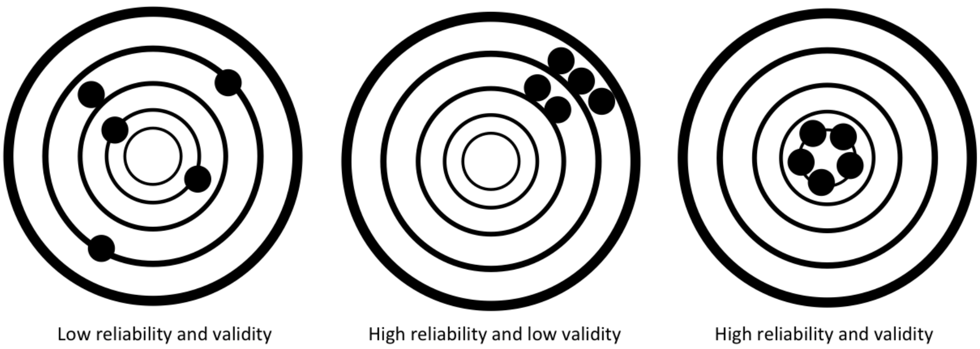


Figure 4 illustration of reliability and validity based on (Björklund & Paulsson, 2010)

2.5.1 Construct Validity

Construct validity is defined as identifying correct measures for the phenomenon. To ensure that construct validity is covered an investigator must define the case study topic in terms of specific concepts, and identify measures that match the concepts. There are three tactics that are available to ensure construct validity. The first one is the use of multiple sources of evidence to support the conclusions, thereby confirming validity. To establish a chain of evidence so that the steps in the research can be traced from conclusion to research questions and vice versa. The last tactic is to let key informants review the report to ensure that all key findings and evidence are present.

2.5.2 Internal Validity

Internal validity test is suitable for explanatory or casual studies and not for descriptive and exploratory studies. The internal validity test reflects the casual relationship between events. To ensure that there is no threat to internal validity all events need to be considered and described. There are four analytic tactics that can be used: pattern matching, explanation building, addressing rival explanations, and using logic models.

2.5.3 External Validity

External validity test is performed to measure to what extent the findings are generalisable beyond the immediate study. However, it is important to distinguish analytic generalisations and statistical generalisations. When considering case studies, the goal is to generalise theory (analytic generalisation) and not to infer probabilities (statistical generalisation). To arrive at analytic generalisations, the research questions need to be pressing on "how" and "why". To increase the external validity for a single case study appropriate theory needs to be identified, and for multiple case studies cross-case synthesis can be used.

2.5.4 Reliability

The reliability test objective is to ensure that if a later research is conducted in the same procedure described from the previous research the findings and conclusions should be the same. To accomplish high reliability means that there are few errors and biases in a study. To minimise the errors and biases in the data collection case study protocols, with detailed documentation, and case study databases can be used.

2.5.5 Credibility in the Master Thesis

In table 4 different techniques to ensure credibility that have been selected for the different steps in the case study are presented.

Table 4: How credibility will be accomplished based on (Yin, 2014)

Tests	**Techniques**	**Description**	**Phase of Research**
Construct Validity	Multiple sources of evidence	Triangulation by interviewing different people, using other sources for example, homepage and internal information	Data collection
	Chain of evidence	Make it possible to track conclusions from interviews by declaring questions and how data were analysed	Data collection
	Key informants review report	Reviewed by involved people at Duni	Composition
Internal Validity	Pattern matching	Matching theory from the frame of reference with empirical data discovered through interviews and observations	Data analysis
External Validity	Theory in single-case studies	Mapping the context of the case study	Research design
Reliability	Case study protocol	Create protocol to provide the possibility for replication of the study.	Data collection
	Develop case study database	Create database to list all interviewed people to track conclusions from the interview and the purpose of it	Data collection

3 Frame of References

In this chapter relevant theories regarding inventory control and supply chain management are presented, together with key terminology that will be used in the project. This chapter will provide a theoretical basis which the rest of the report will be connected to.

3.1 Classification

Commitment to customers consists of determining service level and accomplishments for different customers and products. Providing the same service commitment to all customers for all products will generate high costs and low service level. Furthermore, preferred customers and products with high expectations will experience a relative poor service, in opposite customers and products with low expectations will be provided a relative good service but at an unacceptable cost. The risk linked to this course of action is that profitable customers will move to another supplier and profitable products will not sell because the commitment cannot be met, evidently the existing customers and products are not profitable. Thus, differentiation is essential, focus can be on the most profitable customers and products. Differentiation is in this case usually performed through classification of products or customers. (Jonsson & Mattson, 2011)

3.1.1 Classification Based on Demand Patterns

Endless resources are spent on supply chain performance, from Electronic Data Interchange to automated warehouses. In spite of all resources spent on supply chain performance, supply chains around the world are underperforming. The reason of the underperformance is a mismatch between kind of product and kind of supply chain. In order to establish an effective supply chain strategy one need to assess the product assortment and understand the type of demand connected to the assortment. Factors to consider are for example, product variety, lead times, product life cycle, etc. Classification of products based on their demand patterns results in that they are either mainly functional or innovative. (Fisher, 1997)

Functional products are characterised by stable and predictable demand. The product itself covers often simple needs which are relative constant over time. The characteristics of the functional products enables competition. Thus, the profit margins are low. Innovative products are on the other hand characterised by unpredictable demand, the innovative nature of the product drives unpredictability, in addition the product life cycles are often short but the profit margins are high. Competitors gain their opportunity through imitation of the product, which calls for continuous introduction of new products in order to stay ahead of the competition and being able to keep high profit margins. Continuous introduction of new products drives the product assortment, which typically is large for innovative products. (Fisher, 1997)

The different products require two different supply chains. According to Fisher (1997) there are two kind of supply chains with different objectives. The physical function of a supply chain is to produce goods, from raw material to finished goods and transport the same goods through the supply chain. The market media function of a supply chain is to match demand with supply. Furthermore, ensuring that the right products are reaching the market where the demand exist. (Fisher, 1997)

Cost Effective versus Responsive Supply Chain

Regarding functional products, the market media function of the supply chain is relative easy to cope with because of the stable demand characterised by functional products. Resulting in an almost perfect match between supply and demand. Focus can be directed on the physical function with the objective to minimising costs through for example, high production utilisation and low inventory. This kind of supply chain is called cost efficient. Innovative products need another kind of supply chain, the insecurity of how the market will respond to the innovation drives costs through risk of shortages and excessive supply. The market media function carries the cost for innovative products, the cost of the physical function should not be in focus. Early sales are especially important, which enables capitalisation of the high profit margins that occurs when the product is introduced. Reacting fast to market signals and respond to demand is crucial, buffer stocks and available production slots are strategies that can be used to limit the risk of being out of stock. This kind of supply chain is called responsive. (Fisher, 1997)

In order to create the right supply chain strategy, Fisher (1997) proposes the following steps to be taken. The first thing to determine is if the products are functional or innovative. Products with unpredictable demand are generally the ones who creates logistic problems. The next course of action is to determine if the existing supply chain is responsive or functional. The matrix below (figure 5) can then be deployed, matching product type and supply chain. The same method can be used on a lower level, for example product groups. (Fisher, 1997)

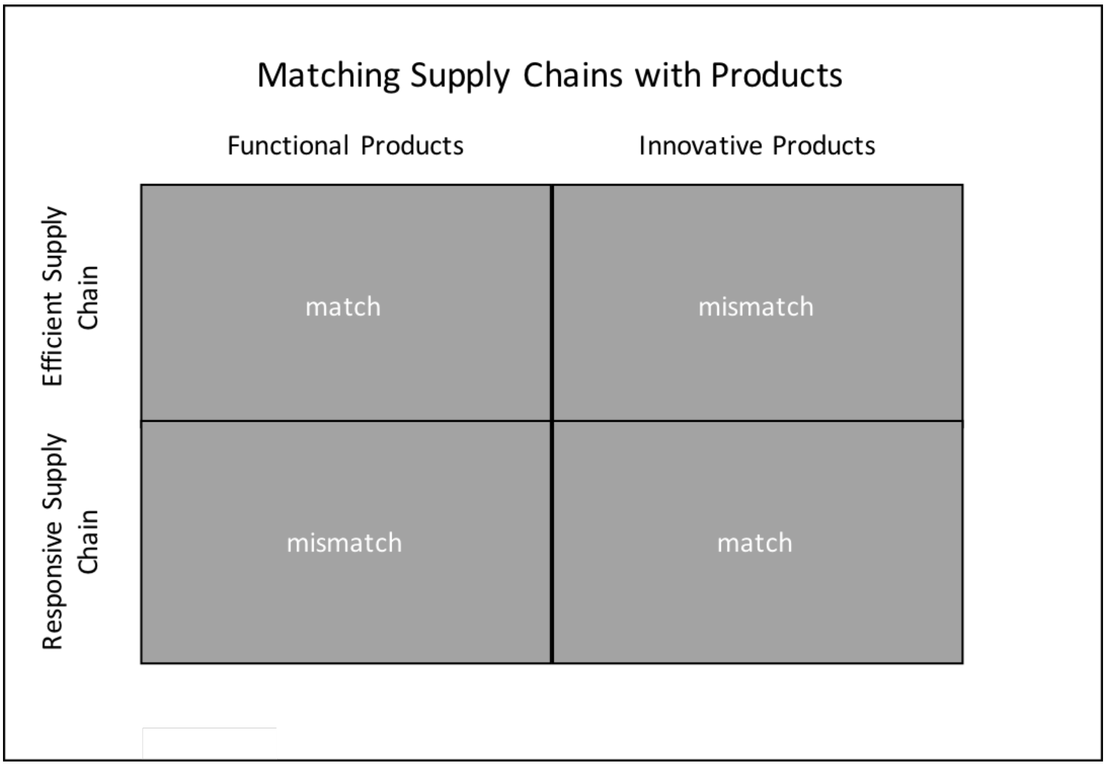


Figure 5: : Matching Supply Chains with Products (Fisher, 1997)

The Nature of the Functional Product

The end customer of a functional product purchases a product at a reasonable price and companies that supply the product gets a predictable demand in return. As mentioned earlier, predictable and stable demand makes it easier to match demand with supply, although this situation can change fast by for example, usage of price incentives (campaigns). Functional products are price sensitive and customers tend to use forward buying when prices are low, which pull the previous predictable demand to a more unpredictable nature. The cost efficient strategy cannot cope with unpredictable demand and this phenomenon is something that add cost instead of reducing it. (Fisher, 1997)

The Nature of the Innovative Product

Fisher (1997) presents four methods to handle the uncertainty generated from innovative products. The first method is acceptance; an innovative product is not innovative without uncertain demand. The forecast error will be high, trying to reduce it will not remove the uncertainty generated from the products. The uncertainty can although be reduced through for example, postponement or new sources of information. Uncertainty can be avoided through reduced lead times and increased flexibility. Lead times can for example be reduced by implementing Single Minute Exchange of Die (SMED) and flexibility can be achieved through Make-to-order. To avoid the risk of shortages of supply excess buffers can be deployed throughout the supply chain and additional production capacity could be used. The presented methods can be used together and should be applied according to current circumstances. A common issue regarding uncertainty is connected to seasonality. In Fisher's article, the company Sport Obermeyer has developed an interesting solution to this issue.

Sport Obermeier managed to shorten their lead times so that they could produce twice in one season. Aggregated forecasts steered what products and in which amounts they would produce in the first production slot. Early sales gave Sport Obermeier an indication of what kind of products that would sell most during the year, the same products could be scheduled in the second production slot and be produced once more. (Fisher, 1997)

3.1.2 ABC Analysis

ABC analysis is a method for classifying products and it was developed by Pareto (Flores & Whybark, 1988). The method has been used in the business world ever since Pareto established the method (Flores & Whybark, 1988). An ABC analysis consists of a classification of products into different classes, i.e. A B C. The factors that historically have determined the ABC analysis are percent of articles and percentage of annual dollar usage, illustrated in figure 6 (Flores & Whybark, 1988). The result of an ABC-analysis is that few products stands for a large part of the dollar usage, these products are classified as A products (Ramanathan, 2006). The amount of products increases for each category and the percentage of dollar usage decreases, the classification continues in descending order (Ramanathan, 2006). Category A products have priority over the others. The classification provides a foundation for how companies should prioritise their activities, for example, resource allocation. Different strategies can be applied on different categorises with the objective to be competitive.

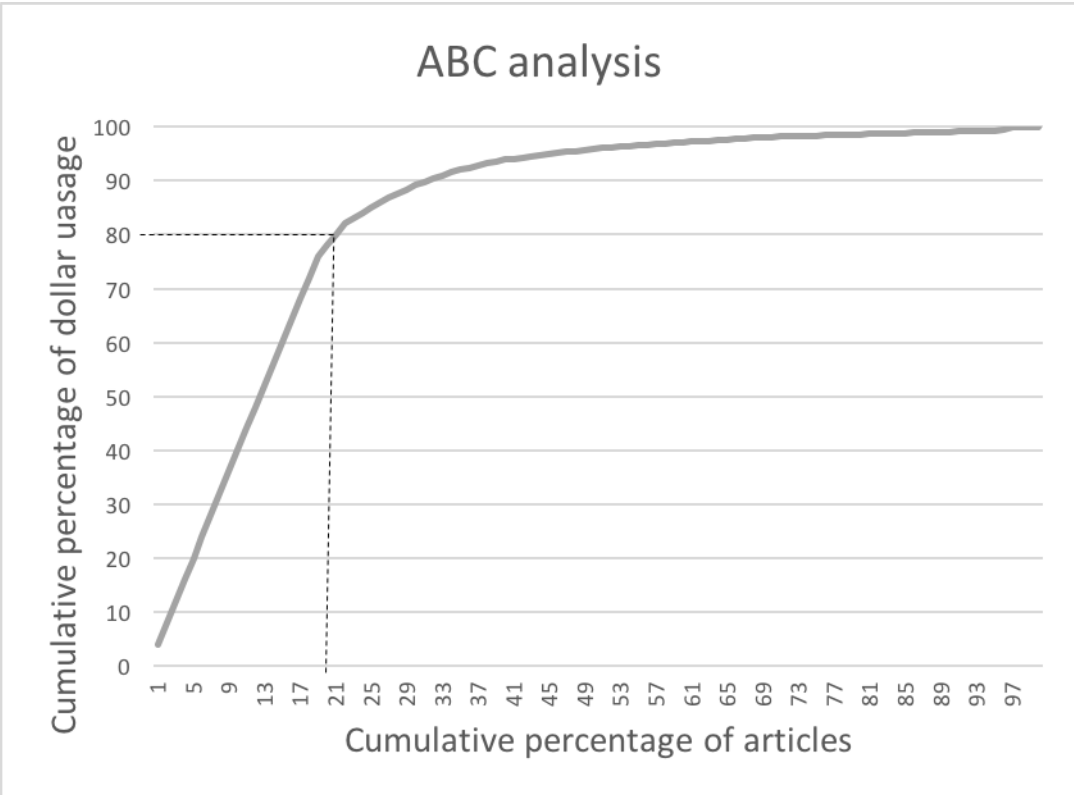


Figure 6: Illustration of ABC analysis (Chen, et al., 2008)

3.1.3 Multi Criteria ABC Analysis

According to Flores and Whybark (1988) there is a confusion regarding how to control the classified products, especially from a management perspective. Furthermore, classification of inventory items based on annual dollar usage alone may create misleading classification of products (Flores & Whybark, 1988), (Flores, et al., 1992). For example, a product can have a high annual dollar usage but the same product may have a short lead time. Moreover, customers are requesting differentiated products, which means the amount of products kept in inventory is increasing (Ramanathan, 2006). The original ABC analysis is therefore in some cases deemed to be insufficient to classify inventory items (Ramanathan, 2006), (Flores, et al., 1992). This call for multi criteria ABC analysis. Thus, products can be classified according to multi criteria and proper strategies for each group can be established.

A multi criteria ABC-analysis can consist of more categories than three. Super categories, sub categories or lower categories are recommended to create according to the developed inventory management policies and control methods. Additional categories can also be created by combining categories, for example AC, BA, etc.

3.1.4 Classification Criteria

The number of criteria to use for inventory control depends on the type of company and industry, in addition the importance of each criterion is not generic, criteria are also company specific (Flores, et al., 1992). There is a trade-off regarding how many criteria one should use when performing the classification. Too many criteria will create a disordered analysis with low value. On the other hand, too few criteria might not create a feasible solution and capture the whole complexity. Thus, the optimal classification will not be achieved (Christopher, et al., 2009). Examples of criteria to use are: lead time, criticality, obsolescence, substitutability, reparability (Ramanathan, 2006), (Flores, et al., 1992). Ramanathan (2006) continues with more examples including: inventory cost, number of requests for the item in a year, order size requirement, stockability, demand distribution and stock-out penalty cost.

Christopher et al. (2009) provides a framework consisting of five classification criteria, the criteria are: Duration of life cycle time, time window for delivery, volume, variety and variability. The reason for using these criteria is that many authors conclude that duration and steps of product life cycle are the drivers for tailored supply chain strategies. Furthermore, the timeframe has changed, forcing companies to act more responsive. Duration of product life cycle is not generic for all products and different logistics strategies need to be applied accordingly, for example transportation and manufacturing. The same argument can be made regarding volume. Variety of products creates opportunities for companies, although the results of variety is often high inventory levels and complicated production scheduling. Demand variability requires different strategies with the objective to satisfy occurred demand, nevertheless supply and process variability should also be accounted for when choosing strategy. (Christopher, et al., 2009)

3.2 Demand Models

Occurred demand over a period of time can be divided into five categories. Explanations of the different categories are available below, an illustration of the components are available in figure 7. (Olhager, 2014)

- Trend: The demand increase or decrease in a stepwise manner.
- Seasonal: A certain demand pattern that reoccurs, typically once a year. Holidays, seasons and weather may cause reoccurring patterns.
- Cyclic: This kind of pattern typically reoccurs after several years, business cycles drive often this pattern.
- Levelled: A levelled demand pattern is the average demand over time. It is characterised by countered or lack of trend, seasonal and cyclic demand.
- Random: The random category is characterised by random variation of demand. The variations cannot be connected to any specific pattern.

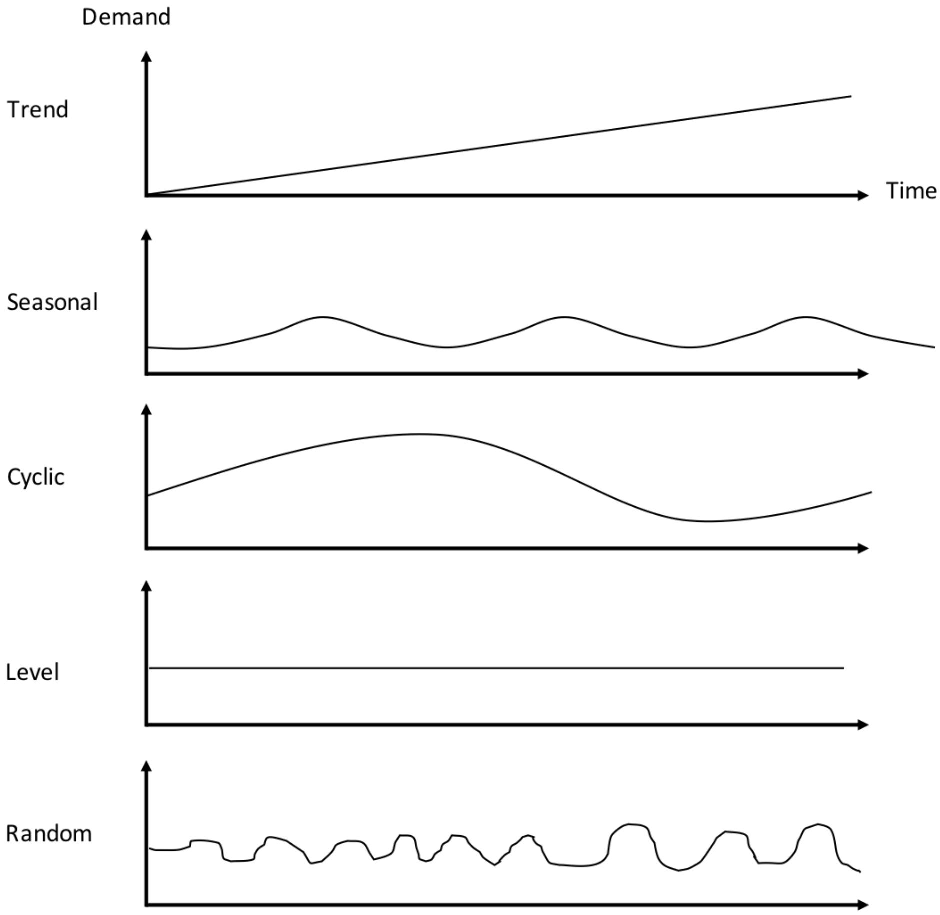


Figure 7: Five demand models from ((Olhager, 2014))

3.3 Replenishment Systems

For companies to be able to have high delivery performance some type of replenishment system needs to be used. The purpose of a replenishment system is to decide how much and when to order new goods. Hopp and Spearman (2011) mentions that the inventory control problem can be broken down into two parts (Hopp & Spearman, 2011). The first issue is to determine the order quantity, or the amount of inventory that will be purchased or produced with each replenishment. The second issue is to determine the reorder point, or the inventory level at which a replenishment will be triggered. The setup should be optimised to minimise costs of ordering, transportation, and handling, while avoiding stockouts. There are different ways the setup of a replenishment system can be configured. Axsäter makes a clear distinction on constant demand models and stochastic demand models. For each type of demand models, a continuous or periodic review can be used (Axsäter, 2006). Figure 8 will be used to differentiate between models.

Demand / Review	Stochastic	Constant
Continuous	1	2
Periodic	3	4

Figure 8 : Matrix to differentiate replenishment models

Before going in to any deeper discussion about how the replenishment system can be configured the inventory situation needs to be defined. In inventory control the stock situation can be described by the inventory position (Axsäter, 2006):

Inventory position = stock on hand + outstanding order – backorders.

Ordering decisions are based on the inventory position, however inventory costs depends on the inventory level:

Inventory level = stock on hand – backorders.

3.3.1 Continuous or Periodic Review

The update of the replenishment system can be conducted in two ways. Either the system is updated continuously or periodically. Continuous updates of the replenishment system mean that the monitoring of the system is continuous. This entails that as soon the inventory position reaches a certain level, an order is triggered. With a periodic review the replenishment system is monitored at certain points in time. Moreover, the intervals between the reviews are constant. (Axsäter, 2006)

The benefit with a continuous review is that it requires less safety stock as it entails that orders always can be triggered when needed, which means that the inventory needs to guard against variability under the delivery lead-time. For a periodic review the safety stock needs to be increased as an order might not be triggered under a certain review. This means that the order can only be triggered in the next review period and delivered after the delivery lead-time. Hence, to ensure that products are still available a greater guard against variability is crucial. (Axsäter, 2006)

Axsäter (2006) mentions that periodic review for products with high demand decreases the cost of the replenishment system, compared to continuous review. Therefore, it is common that periodic review is used for high demand products, while continuous review is used for low demand products. However, the information system at the company is a constraint which will decide how the monitoring of the inventory position can be performed. (Axsäter, 2006)

3.3.2 Ordering Policies

The most common ordering policies in inventory control are (R,Q) and (s,S) policies.

(R,Q)

When the stock level reaches R a batch of Q units is ordered. When demand is continuous and we have continuous review the inventory position will always be between R+Q – R, because the reorder point will be always hit R. How the stock level changes over time with an (R,Q) policy and continuous review is explained in figure 9. (Axsäter, 2006)

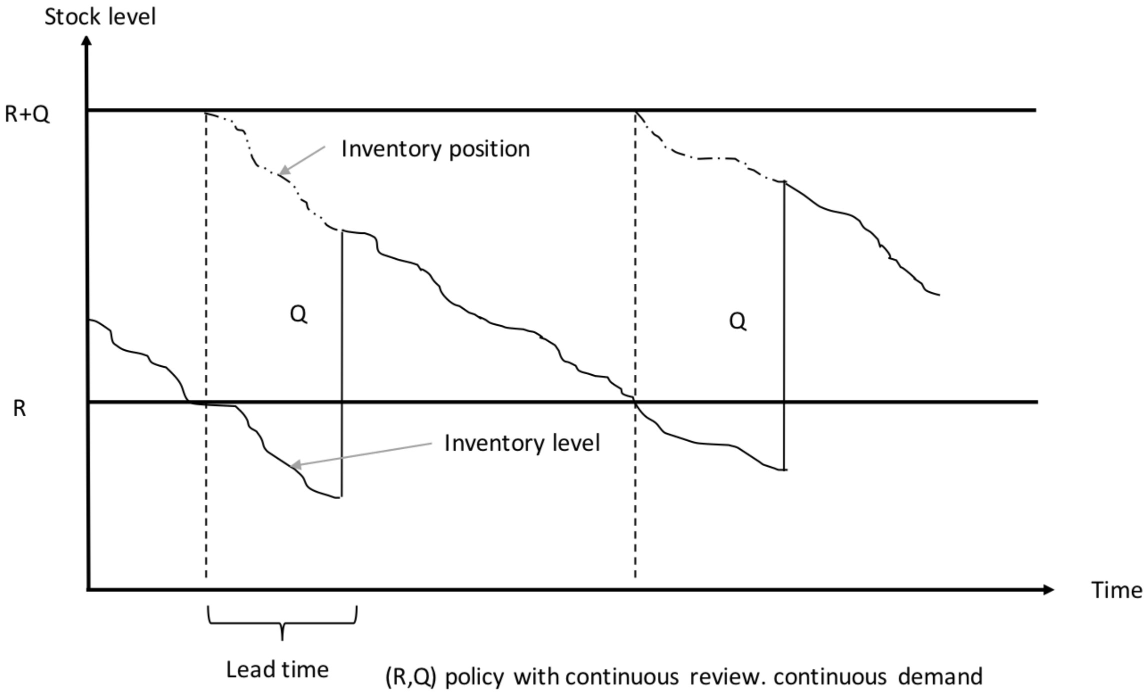


Figure 9: (R,Q) policy with continuous reviw and continuous demand

(s,S)

With an (s,S) policy the order is triggered when the inventory position reaches or goes below s, at that time an order is triggered up to the maximum level of S. An (s,S) policy is similar to an (R,Q) policy. In the case of continuous demand and review the two policies are actually the same provided that s=R and S=R+Q. However, if the reorder point is not hit exactly by the inventory position the equivalence is not valid. In figure 10 the change in stock level over time for an (s,S) policy with continuous demand and periodic review is depicted. (Axsäter, 2006)

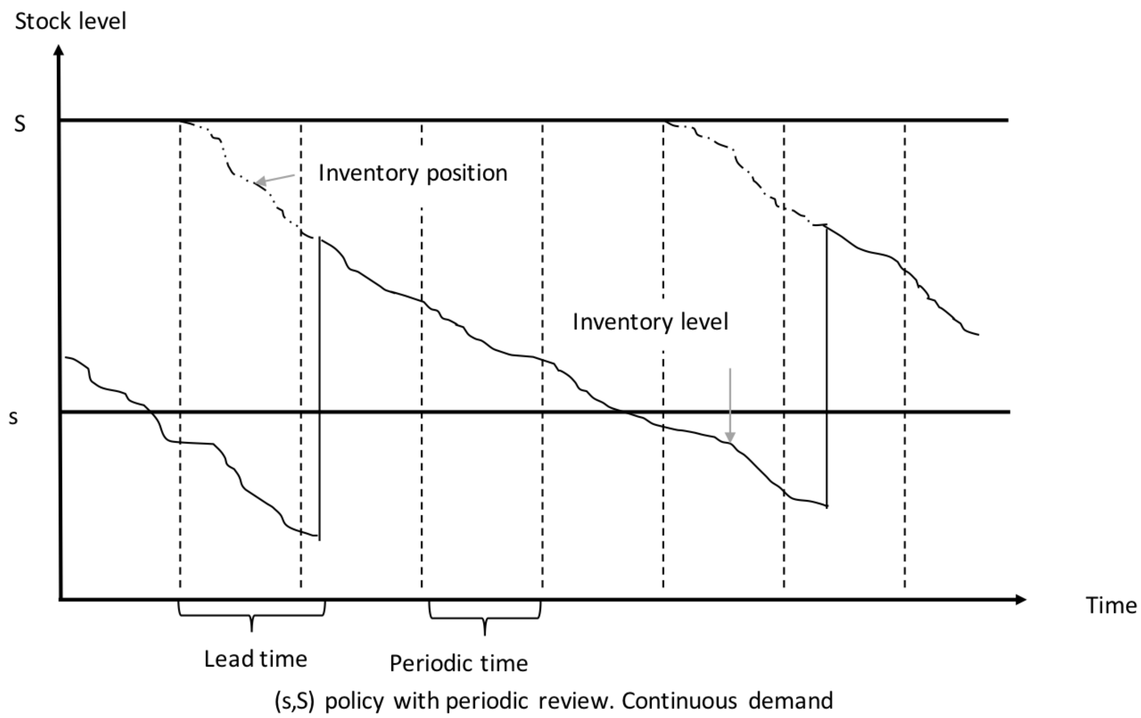


Figure 10: (s,S) policy with periodic review and continuous demand

3.3.3 Constant Demand Models

Constant demand means that the demand does not change over time. This is rarely the case in real-life, however the models based on this assumption tends to be useful nevertheless. With a constant demand model there is no regard for safety stock or reorder points as the demand is assumed to be deterministic (known in advance). The control parameter that is of interest in this case is the order quantity Q. (Axsäter, 2006)

To determine the optimal order quantity there are three well-known models that are used.
If the constant demand over continuous time the Wilson-formula can be used. However, if the demand changes over time, a continuous time model, like the Wilson-formula, is not sufficient enough. Instead the demand can be summed up in discrete time periods and to solve the lot size dynamic lot-sizing models such as the Wagner-Whitin and Silver-Meal Heuristic can be used. (Axsäter, 2006)

Wilson-Formula

Economic Order Quantity (EOQ) or the Wilson formula is the most well established model for determining lot-sizes (Axsäter, 2006). The Wilson formula is based on the following assumptions:

- Demand is constant and continuous
- Ordering and holding costs are constant over time
- The batch quantity does not need to be an integer
- The whole batch quantity is delivered at the same time
- No shortages are allowed

Hence, the model can be placed in category one in the matrix from figure 8. Before explaining the model in more detail the following notations need to be established:

Q = the ordering quantity in units
D = the demand rate
C = total replenishment cost
A = ordering cost
h = holding cost

Due to the assumptions that no shortages are allowed no safety stock needs to be deployed. Moreover, as the whole batch quantity is delivered immediately, the whole previous batch can be finished before delivery. How the inventory develops over time is explained in figure 11. (Axsäter, 2006)

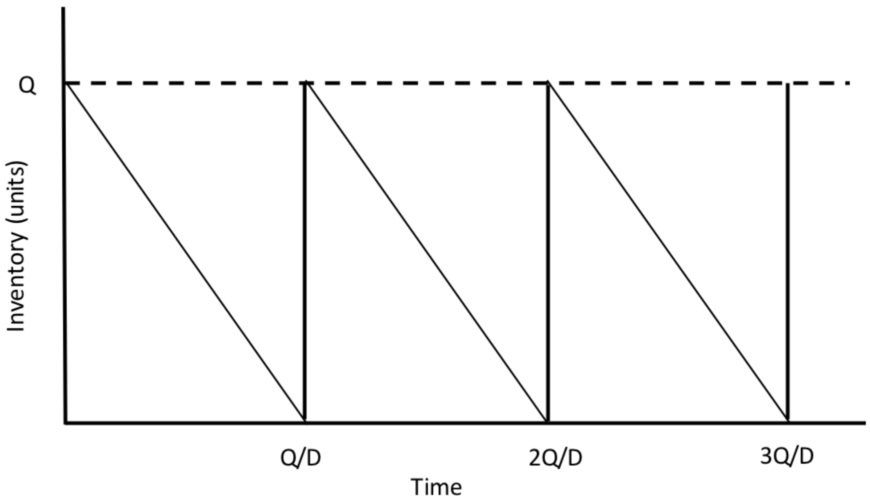


Figure 11: How inventory change over time under the assumptions of the Wilson-Formula

The two parameters that the model are based on are the costs that vary with the batch quantity, i.e., the holding costs and the ordering costs. The total replenishment cost can therefore be expressed as:

$$C = \frac{Q}{2}h + \frac{D}{Q}A$$

The costs involved in the total replenishment cost is depicted in figure 12.

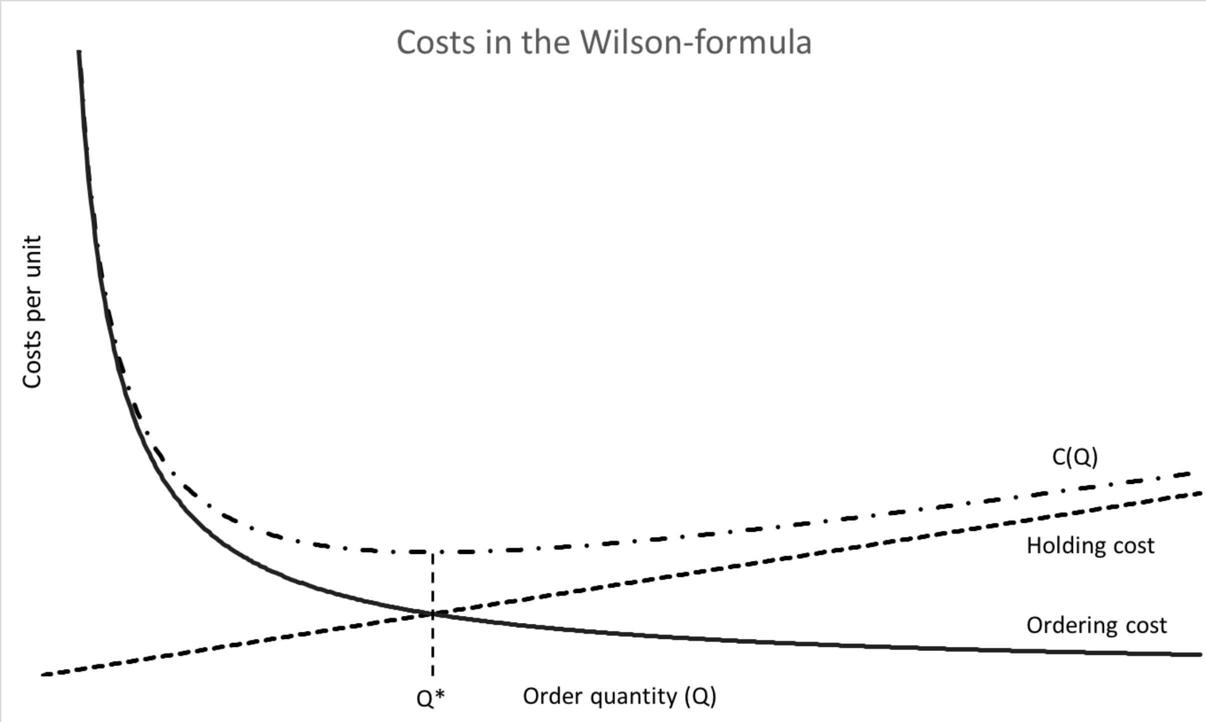


Figure 12: How costs in EOQ change with the replenishment quantity Q

As illustrated above the total replenishment cost function is convex in Q. The approach to determine the minimum for the function C(Q) is to take its derivate with respect to Q, set it equal to zero, and solve the resulting equation to obtain the economic order quantity.

$$dC/dQ = \frac{h}{2} - \frac{d}{Q^2}A = 0$$

Solving the above equation renders the optimal order quantity or EOQ = $\sqrt{\frac{2Ad}{h}}$

This gives the minimum replenishment cost = $\sqrt{2Adh}$

Silver-meal heuristic

In practise it is more common to use simple heuristic to obtain an approximate solution, and the Silver-Meal heuristic is one of the most well-known methods. This model belongs to the second category in the matrix from figure 8.

The objective is to determine the lot sizes to minimise the ordering and holding costs. The following assumptions are included in the model:

- Finite number of discrete time periods
- Demand take place in the beginning of each time period
- There is no initial stock
- The whole batch is delivered at the same time
- Holding cost and ordering cost are constant over time
- No backorders are allowed

Since the demand is time-varying the lot sizes can no longer be considered to be constant. This is a dynamic lot sizing model in the sense that both quantity and time are decided in the same model. The model is a sequential method were the the following time periods demands are considered when determining the delivery in the preceding time period. To find the optimal lot size for a period the cost for ordering materials for one, two, three, etc. time periods demands are compared. When the average per period costs increase for the first time the iterative process is finished and the optimal lot size for a period has been found. This process continues until the finite number of time periods have been planned for. (Axsäter, 2006)

The preceding description results in the following formulas:

$$A + h\sum_{j=2}^{k}(j-1)d_j \leq A + h\sum_{j=2}^{k-1}(j-1)d_j\,, \qquad 2 \leq k \leq n$$

$$A + h\sum_{j=2}^{n+1}(j-1)d_j > A + h\sum_{j=2}^{n}(j-1)d_j$$

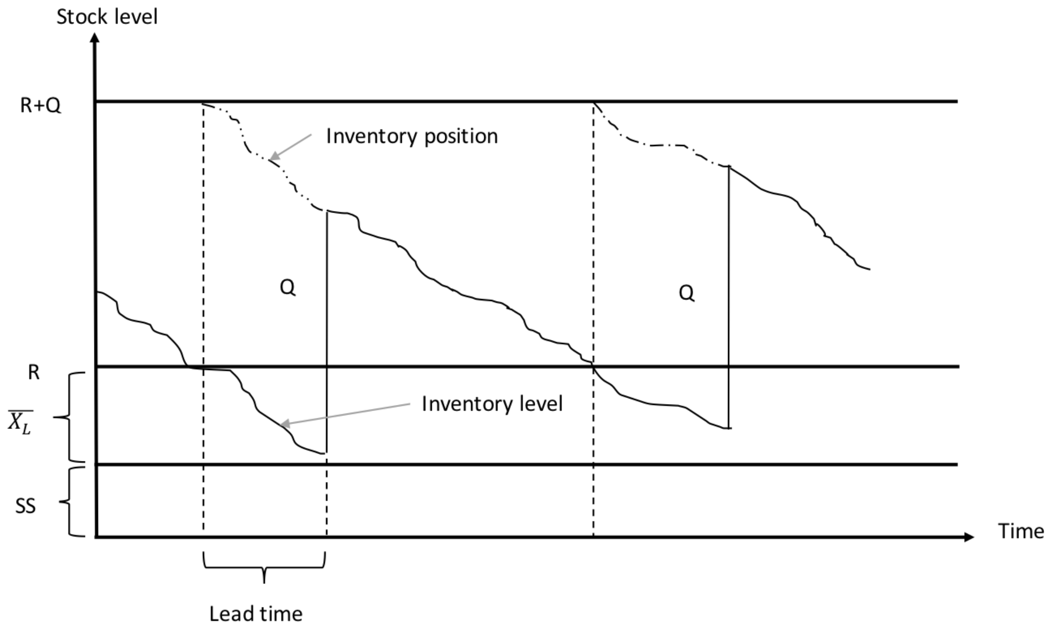
3.3.4 Stochastic Demand Models

Stochastic demand models are based on more sophisticated calculations as the demand is not deterministic and this leads to more uncertainties to be accounted for. Stochastic demand means that the demand pattern changes over time and can be explained by a probability function that describes how the demand behaves overtime. (Axsäter, 2006)

Reorder Points and Safety Stock

The constant demand models mentioned before did not need to account for any uncertainty in demand as it was assumed to be deterministic. As mentioned before in real-life it is predominantly not true that the demand is constant. Up until now the only concern has been to calculate the replenishment quantity Q. Now the reorder point R will be considered as it determines the safety stock, i.e., inventory held to avoid stock outs. The relationship between the reorder point R, mean lead-time demand μ', and safety stock SS is depicted in figure 13 and can be formulated as:

R = μ'+ SS



(R,Q) policy with continuous review. Continuous demand.

Figure 13: The relationship between reorder point, safety stock and mean lead-time demand denoted as $\overline{X_L}$

The safety stock or the reorder point is determined based on a specified service level, which will be discussed later. However, the problem is in this case two-folded. To decide the optimal reorder point for a given service level, the replenishment quantity Q needs to be determined as well. A common approach is to replace the stochastic demand by its mean and use a deterministic model to determine Q by utilising a constant demand model. Given Q, a stochastic model can be utilised to determine R. (Axsäter, 2006). However, R and Q can be decided jointly in a stochastic model.

3.3.4.1 Fixed-interval order system

Another stochastic demand model that can be used is the fixed-interval order system. The fixed-interval order system triggers an order every period by periodical inspection of inventory levels. At each inspection a batch of an arbitrary number of units are ordered to reach the order-up-to-point. (Olhager, 2014) The model is depicted in figure 14.

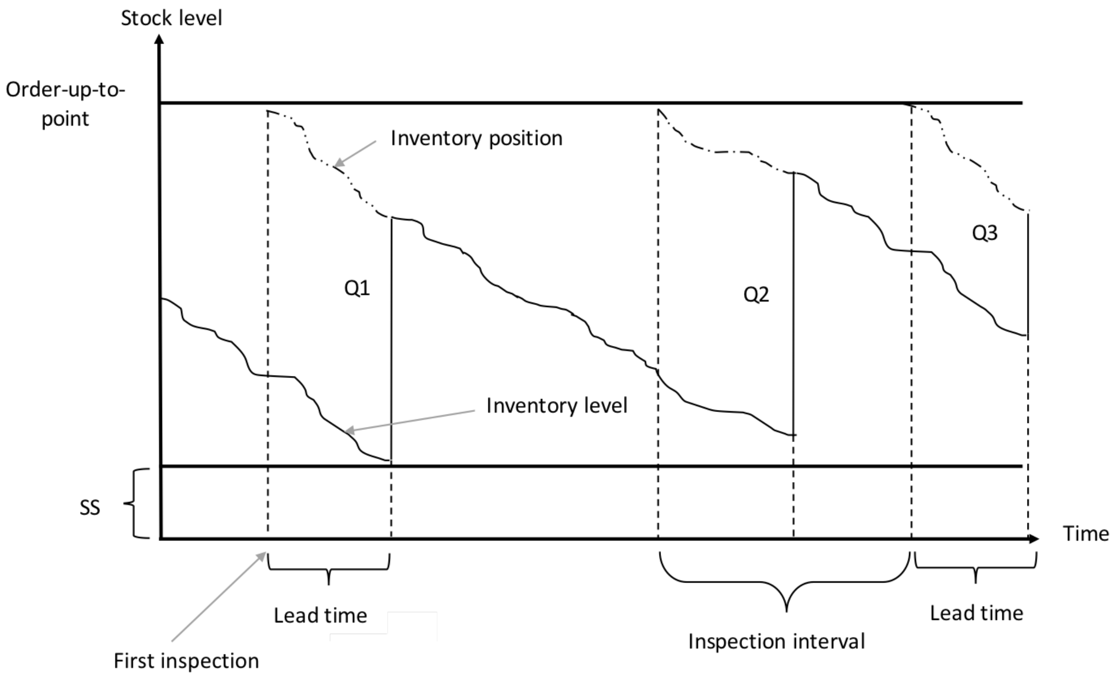


Figure 14:Illustration of the fixed-interval order system

The order-up-to-point is defined as the sum of safety stock, demand during lead-time and inspection interval. Moreover, the inspection interval can be determined by either adjusting it to production or by utilising the following relationship between inspection interval (I), mean demand for the analysed data set ($\overline{D}$), and EOQ. (Olhager, 2014)

The relationship is defined as:

$$I = \frac{EOQ}{\overline{D}}$$

Uncertainty

Uncertainty in demand is the result of deviations in lead-time and demand during the lead-time. This can be expressed as:

$$Var(X) = E[L]Var(D_t) + E[D_t]^2 Var(L) = \ell\sigma_D^2 + d^2\sigma_L^2$$

Where X represents the stochastic demand during the replenishment lead-time, L represents the replenishment lead-time (random variable), ℓ is the expected replenishment lead-time, σ_L is the standard deviation of replenishment lead-time, σ_D is the standard deviation of daily demand, and d is the expected daily demand. (Hopp & Spearman, 2011)

The standard deviation of lead-time demand can now be expressed as:

$$\sigma' = \sqrt{Var(X)} = \sqrt{\ell\sigma_D^2 + d^2\sigma_L^2}$$

However, if the lead-time is constant over time the formula above can be reduced into:

$$\sigma' = \sigma_D\sqrt{\ell}$$

Now it remains to determine which probability function that can describe the mean and standard deviation of the lead-time demand. A normal distribution can in cases of large demand be a suitable probability distribution for the lead-time demand. The agreement between observation and the model can be tested by performing a Chi Square test. A Chi Square test is a statistical test comparing the relative frequencies for the intervals/bins in a histogram with the theoretical probabilities of the chosen distribution (Laguna & Marklund, 2005). The Chi Square test is expressed as.

$$X^2 = \sum_{i=1}^{n} \frac{(O_i - E_i)^2}{E_i}$$

Where X^2 = chi square statistic; O_i and E_i are the observed and expected frequencies in the i-th frequency interval.

For low demand items a normal distribution becomes awkward as it is a continuous demand model, which means that the lead-time demand does not have to be an integer. When demand is low it is better to use a Poisson distribution. This is a discrete demand model, with only one parameter λ which represents both the variance and the mean value (Axsäter, 2006). Axsäter mentions that in practice a Poisson distribution can describe the demand if the following condition is satisfied:

$$0,9 < \frac{\sigma^2}{\mu} < 1,1$$

Service Level

Service level must be defined clearly, and it should not be misinterpreted by any function in company. There are two types of definitions for service level that should be known in inventory control. Those are:

- Service level 1 (S1) = probability of no stock out per order cycle
- Service level 2 (S2) = "fill rate" – fraction of demand that can be satisfied immediately from stock on hand

S1 is a relaxed definition of service level. This makes it relatively simple to calculate, however, it comes with a disadvantage. S1 does not consider the replenishment quantity Q. Therefore, S1 could be low even if Q covers demand for several consecutive periods. S1 is not recommended to use in practice. S2 is a better definition that gives a better understanding of the real service level but is more complex to use. As with any Key Performance Index (KPI) service level needs to be clearly defined and understood by all functions within the company. (Axsäter, 2006)

S1 is as mentioned easy to calculate. S1 is usually used when considering continuous review and continuous stochastic demand models. Therefore, assume that the lead-time demand is normally distributed with average mean, μ' and standard deviation σ'. This gives the following equation (Axsäter, 2006):

$$S_1 = P(D(L) \leq R) = \Phi\left(\frac{R - \mu'}{\sigma'}\right) = \Phi\left(\frac{SS}{\sigma'}\right)$$

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

$$SS = k\sigma'$$

Where k is a safety factor that is given for a certain service level

S2 as earlier mentioned is the fraction of demand that can be satisfied immediately from stock on hand. However, depending on the assumption how much customers may order every time they order, there are different mathematical definitions. A common assumption is that customers are only allowed to order one item in one order combined with either a normal distribution or pure Poisson distribution with continuous review respectively renders the following mathematical definition of S2 (Axsäter, 2006):

$$S_2 = P(IL > 0)$$

In the case of a normal distribution with continuous review and continuous lead-time demand S2 can expressed in more detail as (Axsäter, 2006):

$$S_2 = 1 - \frac{\sigma'}{Q}\left[G\left(\frac{R - \mu'}{\sigma'}\right) - G\left(\frac{R + Q - \mu'}{\sigma'}\right)\right]$$

The so called "loss function", G(X), is defined as:

$$G(x) = \int_x^\infty (v - x) * \varphi(v)dv = \varphi(x) - x * (1 - \emptyset(x))$$

Where,

$$\varphi(x) = density\ function\ for\ normal\ distribution$$
$$\emptyset(x) = distribution\ function\ for\ normal\ distribution$$

μ' stands for the expected mean lead-time demand, while σ' represents the standard deviation for lead-time demand. To estimate σ' for a sample population a point estimate can be used.

$$\hat{\sigma}' = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(y_i - \bar{y})^2}$$

Where $\hat{\sigma}'$ is the estimated standard deviation for lead-time demand, n is the number of observations, y_i is the observed demand in observation i and $\bar{y}$ is the the point estimate of the mean from the sample. (Laguna & Marklund, 2005)

To describe a Poisson distribution, it only requires one parameter λ as earlier mentioned. The maximum likelihood estimation (MLE) of lambda is a pure mean value from a number of observation per time unit (Laguna & Marklund, 2005):

$$\lambda_{MLE} = \frac{1}{n}\sum_{i=1}^{n} k_i$$

Where k_i is the value obtained from observation i of n observations per time unit. Moreover, only one observation per time unit is conducted. As the mean value for the lead-time demand is of interest in inventory control the lead-time has to be multiplied with lambda which renders:

$$\lambda' = L * \lambda_{MLE}.$$

The lead-time demand can now be expressed by an probability function for a Poisson distributed stochastic variable (Axsäter, 2006).

$$P(D(L) = k) = \frac{\lambda^k e^{-\lambda\prime}}{k!}$$

When the probability function for the lead-time demand is known the probability function for the inventory level can be expressed as:

$$P(IL = j) = \frac{1}{Q}\sum_{k=\max\{R+1,j\}}^{R+Q} P(D(L) = k - j) = \sum_{k=\max\{R+1,j\}}^{R+Q} \frac{\lambda^{k-j} e^{-\lambda\prime}}{(k-j)!} \qquad , j \leq R + Q$$

The service level S2, is in this case with Poisson distributed demand equal to the probability of inventory level greater than zero.

$$Serv_2 = P(IL > 0) = \sum_{j=1}^{R+Q} \left(\frac{1}{Q} \sum_{k=\max\{R+1,j\}}^{R+Q} P(D(L) = k - j) \right) = \sum_{j=1}^{R+Q} \left(\frac{1}{Q} \sum_{k=\max\{R+1,j\}}^{R+Q} \frac{\lambda^{k-j} e^{-\lambda\prime}}{(k-j)!} \right)$$

The reorder point can now be solved numerically for a given Q and a given service level. The common approach is to use bisection. This is a simple search for the smallest R giving the required service level. (Axsäter, 2006)

3.3.5 Holding Cost

Keeping stock invites an alternative cost for tied up capital in inventory, the occurred alternative cost should be compared with the return of an alternative investment. There are several costs that are pieces of the holding cost, although the major cost is the capital cost. Other costs that can be included in the holding cost are according to Axsäter (2006) material handling, storage, damage, obsolescence, insurance and tax costs. Several costs can be either fixed or variable with the inventory level. All variable costs should be included in the holding cost. A percentage of the unit value often represents the holding cost. The percentage varies depending on which product that are stored, for example the percentage is generally higher for technical products than paper.

According to Axsäter the expected cost of inventory can be expressed as:

$$C = h\left(R + \frac{Q}{2} - \mu'\right) + (h + b_1)\frac{\sigma'}{Q}\left[H\left(\frac{R - \mu'}{\sigma'}\right) - H\left(\frac{R + Q - \mu'}{\sigma'}\right)\right]$$

The function H(x) is tabulated in a normal distribution table.

3.4 Forecasting

Forecasting can be used in different settings but the overall purpose of a forecast is trying to predict future events. The purpose of forecasting for a producing company is often to predict future demand and sales. Furthermore, this information can be used to plan for future demand and sales, moreover resources can be used smarter and efficiently supplying demand. Even though there are a lot of advantages of performing forecasts one need to consider and understand the nature of forecasts. Information concerning demand from for example planned campaigns should not be ignored. Information is always more accurate than forecasts. A forecast is always an approximation of the future which means the reliability of the forecast must be questioned, a forecast is probably not correct. In order to understand and cope with the approximation the forecast should be presented together with a forecast error, a usual measurement of the forecast error is standard deviation. Another aspect that Olhager (2014) mentions is forecast accuracy, which depends on two factors, i.e. time frame and aggregation. A forecast of tomorrow’s demand is more accurate than a forecast of one year. An aggregated forecast is more accurate; the forecast error is lower if the forecast is performed on a higher level. (Olhager, 2014)

A forecast can be used as support for business decisions. There are certain aspects to consider if one wants to use forecast as support for business decisions. As mentioned above time frame and aggregation is important aspects, moreover other aspects to consider are listed below. (Olhager, 2014)

- Number of forecasting objects – What kind of products is necessary to forecast? It may be necessary to forecast a large number of products, if that is the case a suggestion is to develop a standardised forecasting process.
- Planning or control – What is the underlying reason for performing a forecast? Forecasts connected to planning is often used for identifying demand patterns, on the other hand if the forecast is used to control, it is more reasonable to use the forecast for the identification of deviations in the process.
- Stability – Can the demand be connected to a specific pattern? Successful identification of demand patterns should be used for future forecasts. If the demand cannot be identified with a specific pattern other kind methods need to be applied.
- Existing business processes – How should the forecast support the business and for whom it is useful?

The purpose, forecasting object, decision area and time frame are dependent on the period of the forecast. Olhager (2014) present three periods, short-term, average-term and long-term. It is available in the table below.

Table 5: Usage of forecasting in different periods (Olhager, 2014)

	Short-term	**Average-term**	**Long-term**
Time frame	1 day – 3 months	2 months – 1 year	Minimum 1 year
Purpose	Operational control of production and staffing	Efficient allocation of resources	Planning for acquisition of resources
Forecasting object	Products, models and articles	Product groups decomposed into products	Aggregated sales, product groups
Decision area	Production, Purchasing	Main planning, purchase planning, distribution planning	Capacity planning, facility planning Sales and business development

The order decoupling point determines the forecasting object. Olhager (2014) mentions four different order decoupling points, Make-to-stock (MTS), Assemble-to-order, Make-to-order (MTO) and Engineer-to-order. Table 9 shows what the forecasting object should be when the order decoupling point is determined. (Olhager, 2014)

Table 6: Connection between Order decoupling point and forecasting object (Olhager, 2014)

Order decoupling point	Forecasting object
Make-to-stock	Finished product
Assemble-to-order	Module, half finished product
Make-to-order	Raw material, purchased components
Engineer-to-order	Raw material, purchased components

4 Empirical Study

In this chapter the collected data will be presented. The chapter begins with a mapping of Duni's supply chain, followed by a discussion of Duni's products. Duni's current classification, forecasting methods and replenishment system will also be presented. The objective of this chapter is to describe how and why Duni works with the current replenishment and planning strategies.

The empirical study is based on interviews with Duni employees who are connected to replenishment and planning. Internal documents have also been used in order to construct the empirical study. A table including information regarding the interviews are available in Appendix A.

4.1 Mapping

A map of Duni's material flow has been constructed in order to better understand Duni's supply chain. Duni's supply chain handles approximately 9000 articles where some articles are produced by Duni and others are procured from external suppliers.

Duni owns a paper mill which is located in Dalsland, Sweden, where the raw material is produced. The production of paper runs on a [redacted] to [redacted] weeks' production cycle, and the paper mill is operational [redacted]. The paper is then transported to Duni's production facilities, which are located in Bramsche, Germany, and in Poznan, Poland. The finished products are first stocked in the warehouse in connection with its production facility. Here either the warehouse directly supplies its market or it distributes goods down the supply chain to two satellite warehouses (satellite warehouse is a warehouse with no production) and to the specific market which a warehouse holds stock for. One satellite warehouse is located in Norrköping, Sweden, and one in Riihimäki, Finland. Norrköping supplies the Norwegian and Swedish market, Riihimäki supplies the Finnish market, Poznan supplies the polish market, and Bramsche supplies all other markets and is therefore the main distribution centre. The traded goods are purchased to [redacted] from external suppliers. Goods are further transported when needed from these two warehouses. The supply chain is depicted below in figure 15.

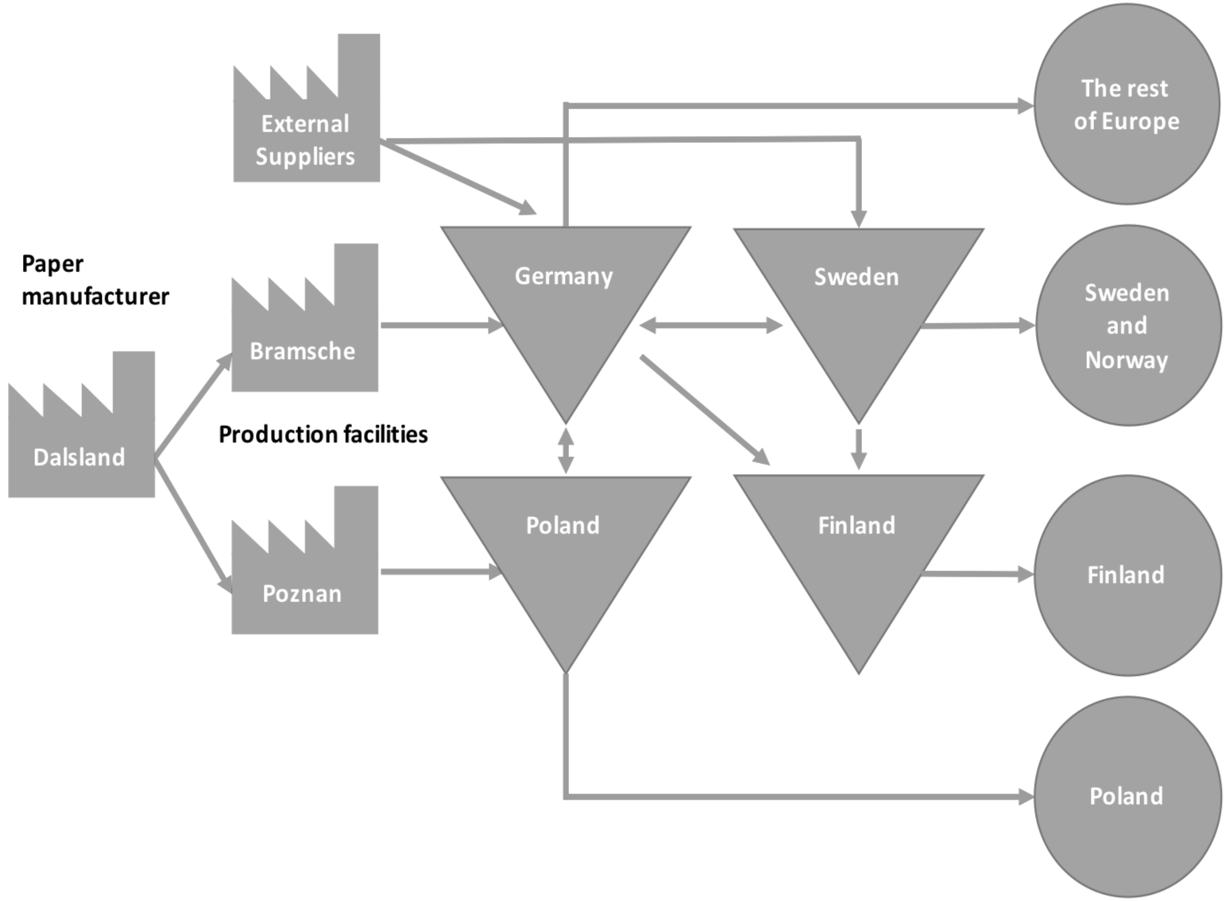


Figure 15: Duni's Supply Chain

4.2 Products

Duni's own produced articles can be divided in unicolour and design articles. Unicolour articles are one-coloured articles and design articles are printed articles hence the article can have more than one colour. Unicoloured articles are part of the standard assortment and have a longer product life cycle than design articles. The unicoloured articles have a product life cycle of [redacted] years, meanwhile the design articles have a product life cycle of [redacted] years. Duni's articles can also be divided as yeararound or seasonal. A yeararound article is sold during the entire year and a seasonal product is a designed article, intended for a specific season. For example, a red napkin with a printed Christmas tree. Yeararound articles can also be affected by the reoccurring seasons, for example the demand for unicoloured yellow napkins increase at Easter season.

Duni has distinguished its products as innovative and high quality products, in comparison to the competitors' products. Duni has as earlier mentioned relative short product life cycles (for design products), In addition Duni is introducing new products every year. The rate of product introduction is however different depending on the BA. TT has a target to exchange [redacted] percent of the assortment every year. [redacted]. The rate of product introduction for MS is [redacted] percent and a lot of the assortment are standard products and sold year around. CS are exchanging [redacted] percent of the design articles every year. TT, MS and CS are also working with campaigns.

[redacted]

4.2.1 Table Top

Products included in TT are mainly napkins, table covers and candles. These products are produced by Duni and are made of paper. Duni produces premium and basic napkins and therefore offer napkins of a wide value range. The main differences between a premium and basic napkin is the material or the mixture of raw material. [redacted]. Design articles are divided further in TT. TT distinguish between traditional and modern design articles, in addition the product life cycle is different for modern and traditional design articles. Modern design articles have a product life cycle of [redacted] years, mainly to keep up with current trends. Meanwhile, traditional design articles have a product life cycle of [redacted] years.

4.2.2 Meal Service

Products included in MS are purchased from suppliers. The products can be of different kind of materials such as plastic, bagasse, etc. Examples of products that are included in MS are: disposable cutlery, food boxes and take-away cups. In general, MS do not have seasonal products although there is a mixture of demand, the demand can differ from [redacted] stock keeping unit (SKU) to [redacted] SKUs per month.

4.2.3 Consumer

CS products are a mixture of products from the other BAs. However, CS articles have fewer pieces in each package. For example, the same napkin may be available in TT and CS but the quantity per package in TT is 50 pieces and in CS the quantity per package is 12 pieces. CS can although have unique designs that will only be offered to CS customers.

4.2.4 Supply Chain

The overall objective of Duni's supply chain is to provide reliability and availability of goods to its customers. Different information systems provided by SAP are used to increase the reliability and increasing the transparency of information throughout the supply chain. A new add on called Supply Network Planner (SNP) has been introduced, the purpose of this add on is to reduce the reaction time to the market and always be able to supply the demand.

[redacted]

4.2.5 Competitors

[redacted]

4.3 The Current Classification

Duni's classification is updated three times a year and the update is performed in January, May and September, which concur with the end of each season. The classification is based on one year of data. The classification is performed separately for each Business Area. Furthermore, splitting articles based on business area is the first differentiation. Duni uses two classification criteria, “Number of order lines cumulated of year base” and “Contribution on C3 Level”. “Number of order lines cumulated of year base” is the accumulated amount of order lines for an article during one year. “Contribution of C3 Level” is a measure of the articles contribution and is defined as:

$$Contribution\ on\ C1\ Level = Net\ Sales - \frac{1}{10} * Net\ Sales - Cost\ of\ goods$$

Sales is deducted based on rebates.

$$Contribution\ on\ C2\ Level = Contribution\ on\ C1\ level - Warehouse\ costs * Inventory\ pallets\ share - Outbound\ costs * Sales\ pallets\ share$$

$$Contribution\ on\ C3\ Level = Contribution\ on\ C2\ level - Direct\ selling\ costs * Net\ sales\ share$$

Duni is using six categories in the classification, an explanation of each category is available in the table below.

Table 7: Duni's segmentation

Category	**Contribution on C3 Level**	**Number of Order Lines**
A	High	High
B	High	Low
C	Low	High
D	Low	Low
N	-	-
O	-	-

N stands for new articles and information regarding contribution and number of order lines is not available. Articles are classified as new for one year before they are classified into category A-D. All new articles are given the same priority as A articles. O stands for discontinued articles, these articles are removed from the assortment. Duni has also established different targets of delivery performance for each category, which is presented in the table below. In case of capacity dilemmas in the production Duni has established the rule that A, B and N products will be produced and naturally are given a higher priority than the other categories.

Table 8: Delivery performance connected to category

Category	**Target for Delivery Performance**
A, N	[redacted]
B	[redacted]
C	[redacted]
D	[redacted]

4.4 Forecasting

Forecasting is an important part of Duni's operations. Today, Duni has a forecast driven replenishment system, which means that production and purchase occurs before the actual sales order is entered. To be able to do so Duni is dependent on accurate and efficient forecasting. The process of the forecasting starts at the demand planning department at Duni, which is responsible for creating and updating the weekly forecast and also analysing the forecast error and how it may be improved. In order to measure the performance of the forecast, Duni measures the forecast error by calculating the Mean Absolute Percentage Error (MAPE) on a monthly basis. The forecast is performed in two ways. Either it is performed statistically or manually. The decision rule is that when a product has two years of data, Duni evaluates if the same product can be statistical forecasted with a good result. If the result is deemed to not reach the target, the product will continue to be manually forecasted.

4.4.1 Statistical Forecasting

The statistical forecast (program in SAP) process is built on three years of historical data which is used in one of the nine statistical calculation methods that Duni has developed to determine the forecast on warehouse level. Duni's nine methods includes five old methods and four new methods, which were introduced last year. Both old and new methods are used by the statistical forecast managers. However, Duni has experienced improved forecast MAPE with the new methods. To determine which method suits which article the methods are tested by the statistical forecast manager. The manager compares the generated MAPE for each method per article in combination with professional experience of the product and the articles specific demand pattern. When the method has been decided, the program calculates the statistical forecast automatically. The statistical forecast is updated each week in the system with a horizon of three years. As only three years' historical data is used the first week in the historical data is removed and a new week in the future is added.

It is important for the statistical forecast managers to ensure that the historical data is correct for articles. As holidays such as Easter occurs in different time periods for different years, the historical data has to be moved to the time period that corresponds with the present time period. Moreover, if a campaign was launched the previous year and is not planned for the present year than that needs to be removed from the historical data as well.

4.4.2 Manual Forecasting

The manual forecast process is performed in practise for all new products which has not been sold for more than two years. The manual forecast is carried out on warehouse and Business Unit (BU) level for these articles. BU entails that a specific BA is forecasted against a specific region. For example, there is a forecast for the warehouse in Bramsche for TT articles in the Great Britain region. The manual forecast is performed initially for new items when the phase out and phase in list is released, which is a list of all the new articles that will be sold. When the initial forecast has been created the manual forecasting managers has to wait for information and feedback regarding best-sellers and slow movers to be able to update the forecast.

4.5 Replenishment System

Duni's replenishment is as earlier mentioned based on forecasts, the forecast is first sent to SNP where the system calculates what should be purchased or produced. The replenishment strategy is to use Material Requirements Planning (MRP) to control inventory. The system takes several aspects into account when calculating purchase or production requisitions. The following aspects are taken into account: inventory level, "open" production or purchase orders (meaning that the same article has been ordered but not received in the warehouse), forecast and safety stocks. The system then generates a production or purchase order, these orders are suggestions which are sent to production planners or purchasing who are analysing the suggestions and refine them before the actual orders are created. Factors that are frequently taken into account are for example lead times, Minimum Order Quantities (MOQ) and bundling. A MOQ in the production is set by Duni and is the minimum quantity that is profitable to produce, other factors may influence the MOQ. A MOQ in purchasing is negotiated between Duni and the supplier, which means that it is the smallest quantity Duni can order from a supplier (for example one pallet). The next step in process is goods received.

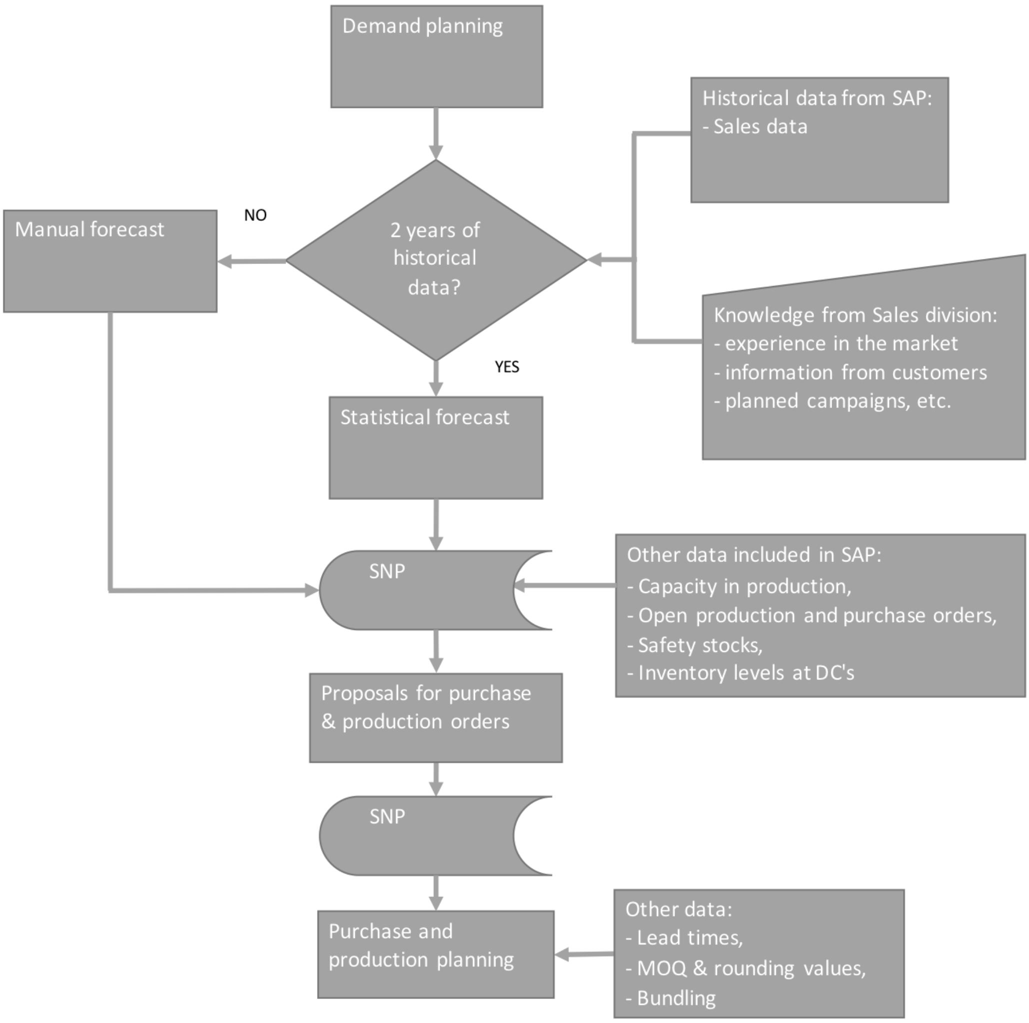


Figure 16: Illustration of Duni's replenishment system

Warehouses are replenished based on deployment runs, a deployment run consists of input from the forecast and transportation lanes. Transportation lanes are established for all warehouse combinations, for example, from Bramsche to Norrköping. The transportation lanes consist of several parameters, transportation lane lead time, safety time, goods receiving time, rounding values (for example, the number of SKUs must equal pallet or layer). The deployment run is then transformed into a shipping plan. Each warehouse also has safety stock settings on article level. Replenishment of warehouse is therefore based on forecasts, sales orders and safety stock.

The methods that are used to control inventory are a report consisting of the development of DOI per business area and analysis of pallet place utilisation. The development of DOI per business area are overviewed on a monthly level with time horizon of 12 months. DOI are used to find root causes for increased stock of an article. Pallet place utilisation is overviewed on a monthly level.

Duni uses MTS for major part of the assortment. There are cases when MTO and Make-To-Contract (MTC) are used. MTO is used in those cases when the article is not selling [redacted]. MTC is used in the same manner in all BAs, the general rule is that a predefined quantity is produced over a number of months. For example, an MTC order may be 800 SKUs over a period of 4 months.

4.5.1 Safety Stocks

Duni uses a tool to determine safety stocks, the input is historical data and the tool is using an algorithm to calculate the safety stock settings. For example, if 97 percent service level is wanted, the system proposes how many Days of Cover (DOC) the article should have in the specific storage location. The proposed DOC is then discussed with people involved in replenishment, for example, production planners and call off, it may be that the proposed DOC is unrealistic and then the current safety stock setting is kept. Production planners and call off includes other factors such as supplier performance, machine breakdowns and forecast error. There is higher safety stock setting for A articles and level of safety stock is descending according to the segmentation. For traded goods lead time is an important factor when deciding safety stocks, there are some supplier with relative long lead time.

4.5.2 Service Level

Service level is calculated based on the requested number of SKUs delivered on time, for example, if an order consists of 100 SKUs and 90 SKUs are delivered on time, the service level is 90 percent The KPI is comparing the requested delivery date and the actual delivery date. [redacted]

5 Analysis

In this chapter the collected data are analysed with the help of the presented theory. The analysis will consist of explaining patterns and relationships between collected data and theory. Mathematical modelling will also be used to analyse the collected data. The analysis will be conducted according to the presented methodology. A solution will be presented.

5.1 Introduction

To be able to increase the planning efficiency and find suitable replenishment strategies a general classification has been made, which can be applied for Duni's warehouses. The first concern was to find suitable factors for the classification. The classification will be used to determine how articles can be differentiated so that the most suitable strategy can be applied for each class. When the different classes were established service levels could be defined for each class. Once service levels had been defined replenishment strategies were decided by analysing two or three representative articles from each class respectively. Three representative articles were used for classes consisting of a high number of articles, in order to be able to capture the complexity of the class.

The data used for the analysis were transactional data, description of articles and stock levels in the warehouses. The analysis is based on data from 2015 and were extracted from Duni's database with the help from an employee at Duni. As mentioned in the introduction, all articles in Duni's assortment are not considered. The excluded articles are produced or purchased outside Europe, private label articles, profile print articles, display articles, and articles intended for campaigns. This resulted in 4916 out of 8847 articles that will be in the focus for the analysis.

As earlier mentioned Duni has characterised their articles as yeararound or seasonal. The shares of articles in each category are visualised in figure 17. The yeararound articles stand for the major part of the analysed assortment. Produced and purchased yeararound articles are characterised by long product life cycles and are sold during the entire year. Unicoloured napkins are part of the yeararound assortment and are an example of articles with a long product life cycle. The seasonal articles are characterised by a short product life cycle and a short sales period. The rate of product introduction is higher in the seasonal assortment than the yeararound assortment, although there is continuous product introduction in both assortments.

The major part of yeararound assortment consists of articles with predictable and stable demand. In addition, the characteristics of the yeararound articles indicate that the articles are functional and therefore demands a cost effective supply chain.

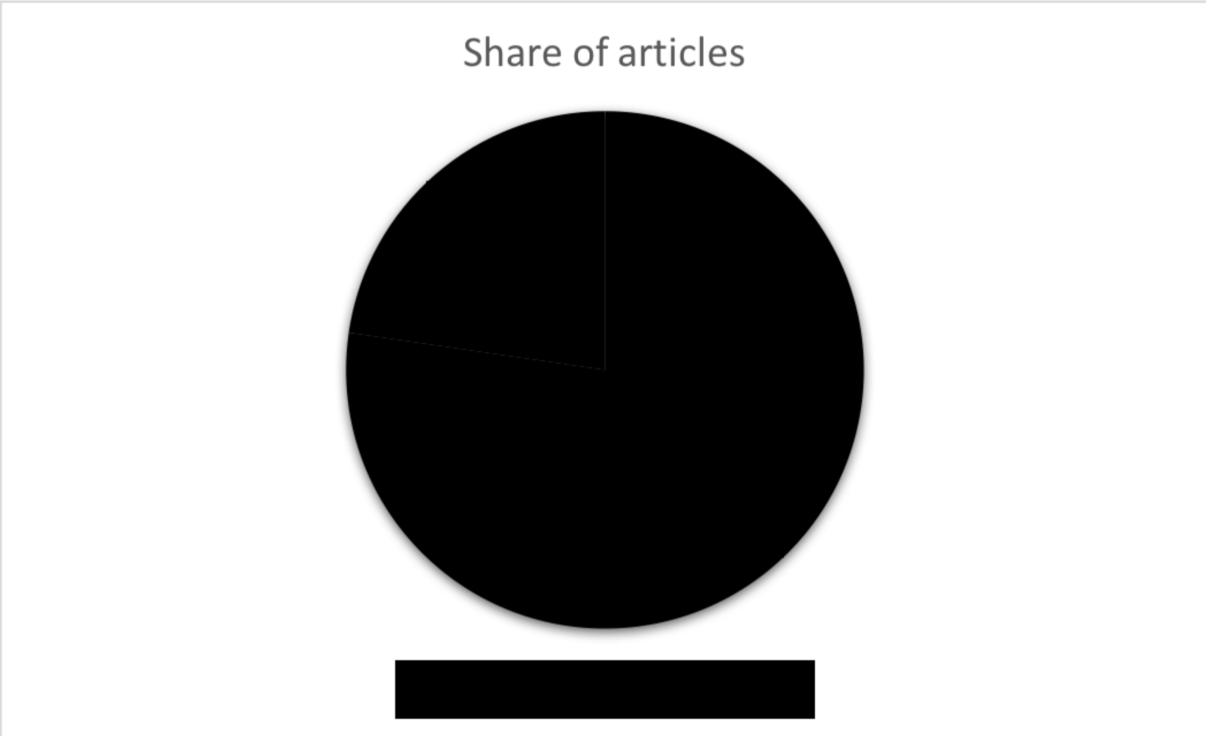


Figure 17: Share of yeararound and seasonal articles

A differentiation between yeararound and seasonal articles is suitable for the assortment, there are several reasons for this differentiation. The sales period between yeararound and seasonal assortment differ which demand different strategies. The characteristics of the articles differ, which requests different replenishment strategies in order to spend less resources and to reach the wanted service levels. The differentiation would also make it possible to target the most valuable articles and increase the profit through proper steering and inventory control.

An analysis of annual euro volume has been conducted in order to understand what impact yeararound and seasonal articles have on the bottom line. The share of annual euro volume for yeararound articles is above [redacted] percent, which is illustrated in figure 18. Yeararound articles have a bigger impact on [redacted] than seasonal articles, although one should recognise that yeararound articles also represent [redacted] percent of the assortment. However, in order to target the valuable articles and capture the whole complexity, more classes will be used for the yeararound assortment.

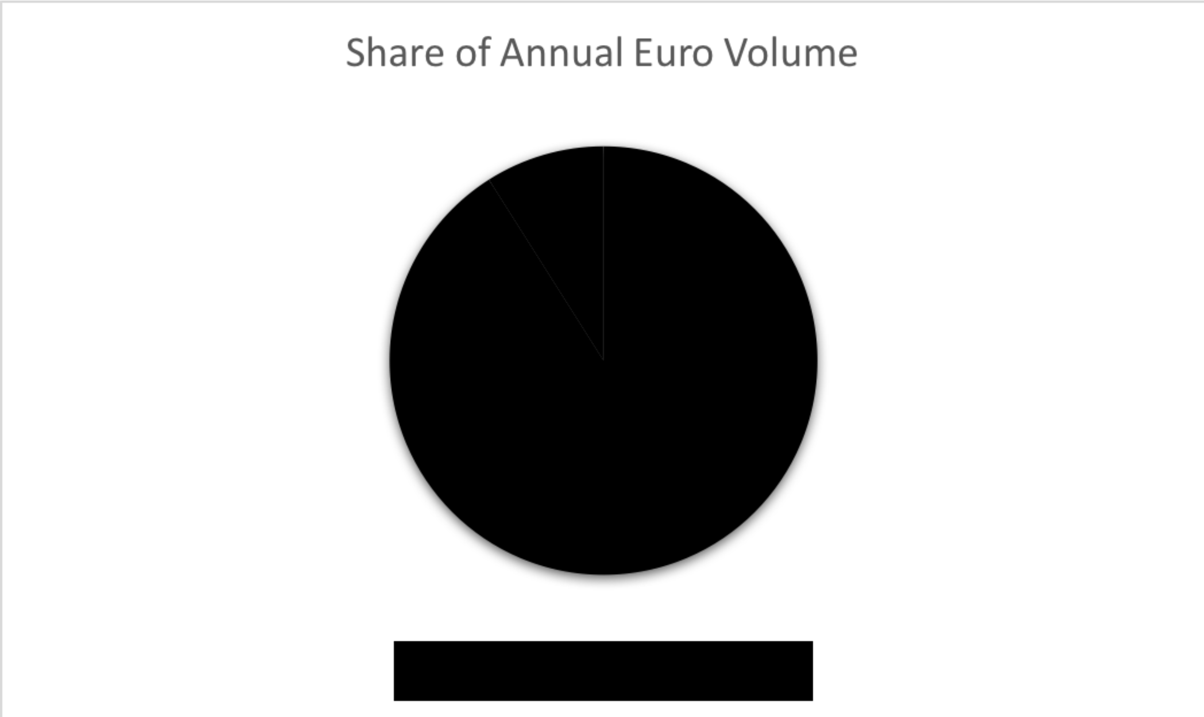


Figure 18: Share of annual euro volume between yeararound and seasonal articles

5.2 Yeararound

The solution for the yeararound assortment will be presented in this section.

5.2.1 Classification

A common criterion to use when classifying products is annual euro volume. (Flores & Whybark, 1988) (Flores, et al., 1992). The authors have used euro instead of dollar since the gathered data has euro as currency. Although classifying articles based on this criterion alone may be misleading. However, annual euro volume was deemed as an insufficient criteria based on the dispersion of value among analysed articles. The dispersion was not large enough as shown in figure 19. In order to use annual euro volume as a criterion a rule of thumb is that the dispersion of value should be 20-30 times. In the analysed assortment the dispersion of value is maximum [redacted] times.

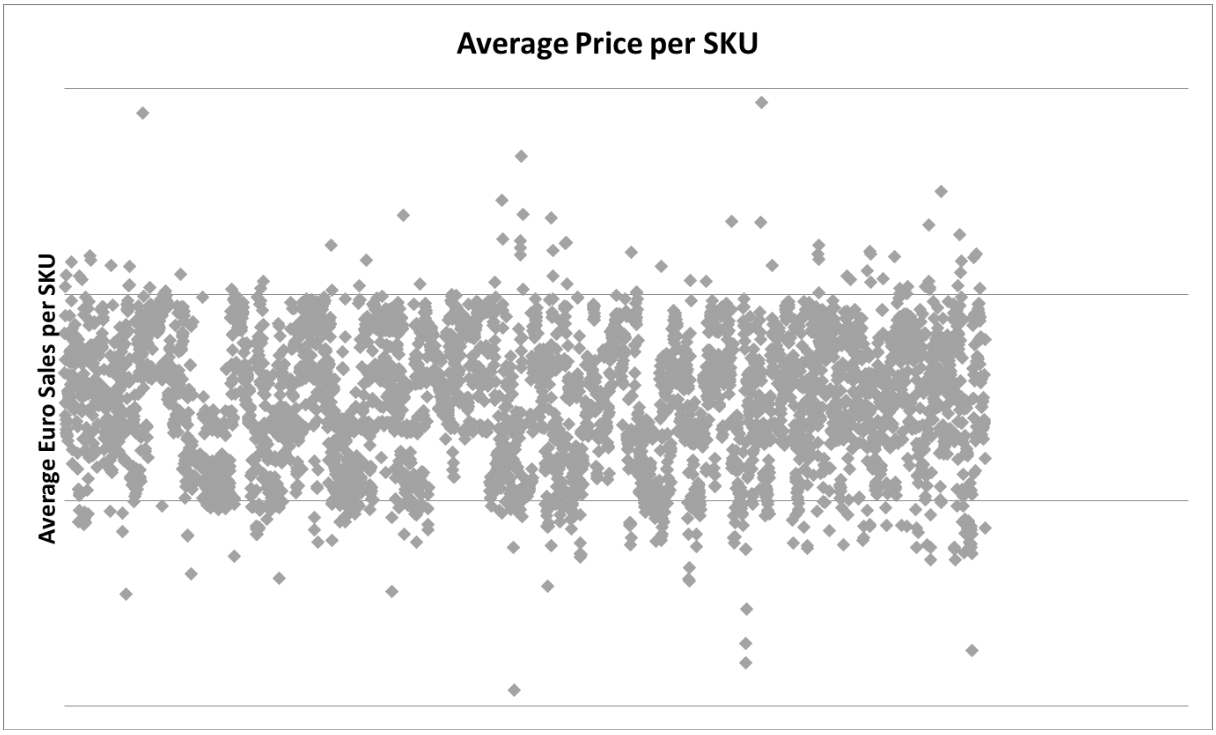


Figure 19: Illustration of the dispersion of value among the articles

Coefficient of variation is a criterion which illustrates the variation in demand in relation to the average weekly demand of SKUs. Coefficient of variation is defined as the standard deviation divided by the mean value. Coefficient of variation has been used as a criterion for the yeararound assortment illustrated in figure 20. Coefficient of variation illustrates the complexity of the assortment and natural inflection points have been identified. The average weekly demand and variation in demand differ among articles in the yeararound assortment and have created a dispersion which can be used for a differentiation of the articles. As seen in figure 20, four groups have been established. The vertical line which divide the average weekly demand has been set at the median of the average weekly demand for analysed articles. The median of the analysed articles was [redacted] SKUs per week. The horizontal line was set at one coefficient of variation, mainly because it is common to suggest MTS for articles with coefficient of variation below one. Coefficient of variation is a known criterion which researchers have used. D'Alessandro and Baveja (2000) used coefficient of variation as a criterion in their article: Divide and Conquer: Rohm and Haas' Response to a Changing Specialty Chemical Market.

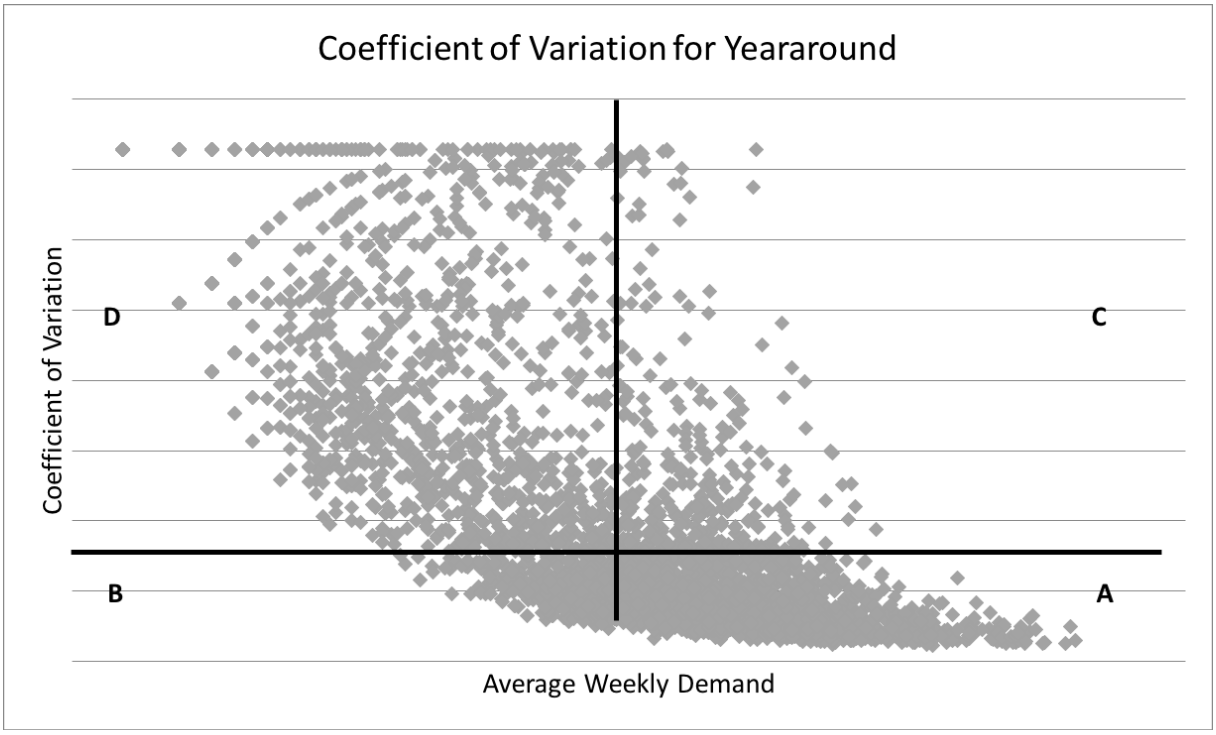


Figure 20: Analysis of coefficient of variation and average weekly demand

[redacted], although annual volume in number of SKUs has shown to be a sufficient factor to use. [redacted], the volume indicated which articles were contributing to the bottom line and were of importance. In addition, Christopher et al (2009) mention volume as a valid criterion to classify products. Natural inflection points were identified for the yeararound assortment and the 80-20 rule was applied. 20,8 percent of the articles were accountable for 82 percent of the volume, 31,7 percent of the articles were accountable for 15,7 percent of volume and 47,5 percent of the articles were accountable for 2,3 percent of the volume. The dispersion of volume among the yeararound assortment is shown in figure 21.

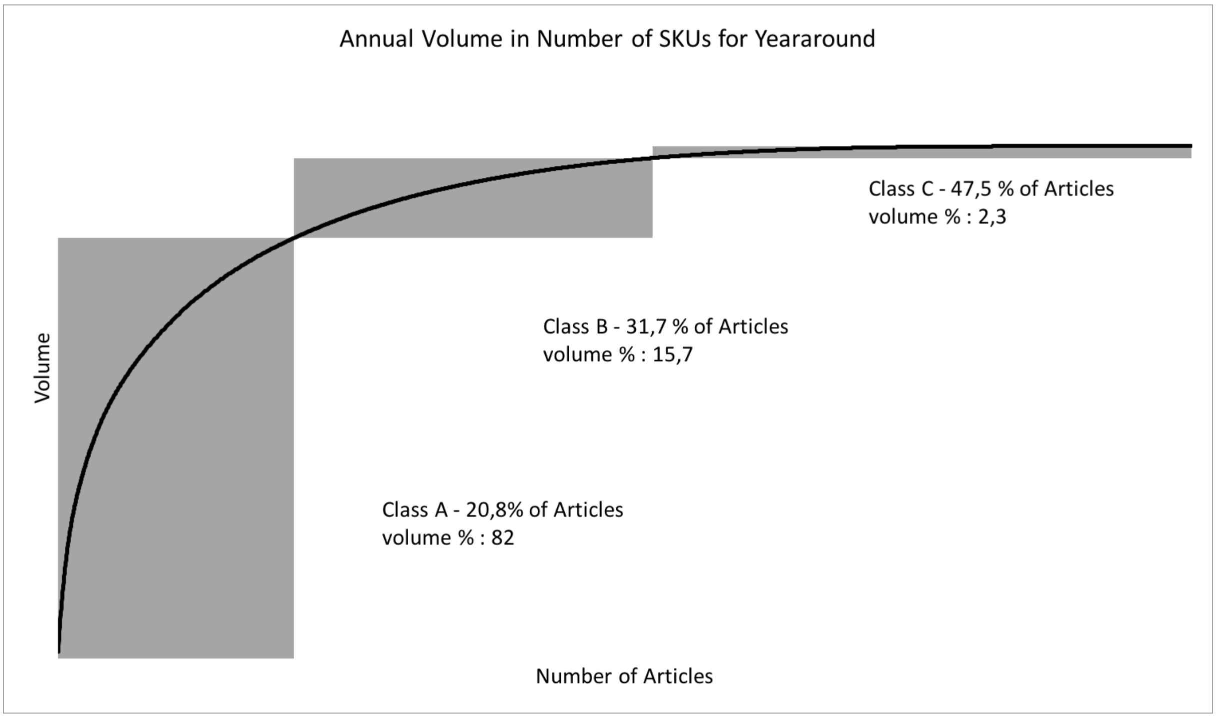


Figure 21: Analysis of annual volume in number of SKUs for the yeararound assortment

In order to establish classes, the chosen criteria were combined. The order of when to use each criterion were important to consider. As mentioned above, a split between the yeararound and seasonal assortment was made and motivated earlier, which also was the first used criterion in the classification. Regarding the yeararound assortment, two criteria were used. A common way to decide the order between two criteria is to use the criteria with most amount of groups first. Coefficient of variation consisted of four groups and volume consisted of three groups which meant that coefficient of variation was used before volume, as shown in figure 22.

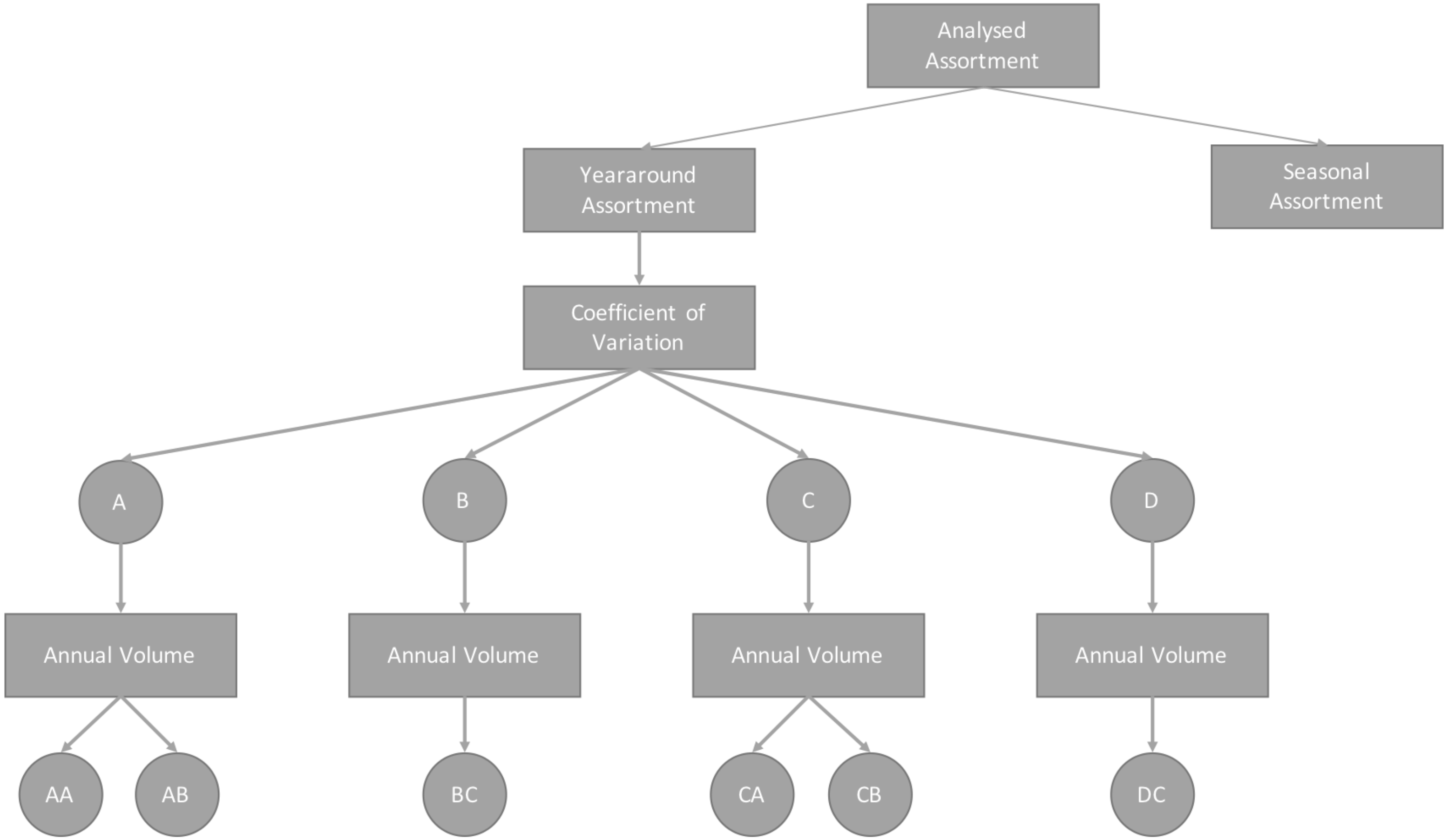


Figure 22: Illustration of the classification

5.2.2 Service level

When the classification had been established the service level for each class had to be decided. Serv1 was used to calculate the service level and was deemed to be a suitable measure. The overall target service level was decided in collaboration with our supervisor at Duni and the target was set to [redacted] percent. To reach the overall target, different service levels were determined for each class depending on variability and volume of demand. The classes below one in coefficient of variation have a stable demand which makes it is easier to maintain a high service level, while it is increasingly difficult to maintain a high service level for the classes that exceed one in coefficient of variation. Concerning the classes below one in coefficient of variation, it was decided that the class which represents the articles with the highest average weekly demand (AA) should be given the highest priority, as shown in table 9. Therefore, also the highest service level. In order have a distinctive priority and suitable service levels for the classes, the target of [redacted] percent was improved and the overall service level was set to [redacted] percent.

Table 9: Defined service level for each class

Class	Service level
AA	[redacted]
AB	[redacted]
BC	[redacted]
CA	[redacted]
CB	[redacted]
DC	[redacted]

5.2.3 Replenishment and planning strategies

As earlier mentioned representative articles were the starting point for the analysis of replenishment strategies. The representative articles were chosen in collaboration with our supervisor at Duni, a directive from Duni was to choose representative articles based on the distribution of articles from each BA in the classes. An analysis was made to investigate the share of articles from each BA in each class, which is illustrated in table 10. If one BA had a major share of the articles in the class, representative articles were chosen from this class. If two BAs stand for the same share of articles, one article from each BA were chosen. Concerning the classes AA, AB, CB and DC, initially three representative articles were chosen in these classes. Although one article in CB and DC were deemed to be insufficient since both articles were introduced in November 2015. A table of the representative articles is available in appendix C.

Table 10: Shares of articles from each BA in the classes

Class/Business Area	Table Top (TT)	Meal Service (MS)	Consumer (CS)
AA	[redacted]	[redacted]	[redacted]
AB	[redacted]	[redacted]	[redacted]
BC	[redacted]	[redacted]	[redacted]
CA	[redacted]	[redacted]	[redacted]
CB	[redacted]	[redacted]	[redacted]
DC	[redacted]	[redacted]	[redacted]

To decide replenishment strategies for the six different classes the authors analysed the classes position in figure 23. Moreover, replenishment strategies were chosen in collaboration with our supervisor from LTH. Class AA, AB and BC represents articles with stable demand, which means that they are easy to control. This also indicates that the demand pattern is levelled (Olhager, 2014). These classes can therefore be controlled by simple inventory control methods such as stochastic demand models achieving high service levels without deploying large safety stocks. Moreover, to decide what type of stochastic demand model that should be used for AA, AB and BC the demand needs to be considered. Regarding class AA, fixed production batches are suitable for articles with high and stable demand. Moreover, this type of demand is commonly controlled with a (R,Q) policy with continuous review under the assumption of normal distributed demand, as it is a simple and accurate method for inventory control.

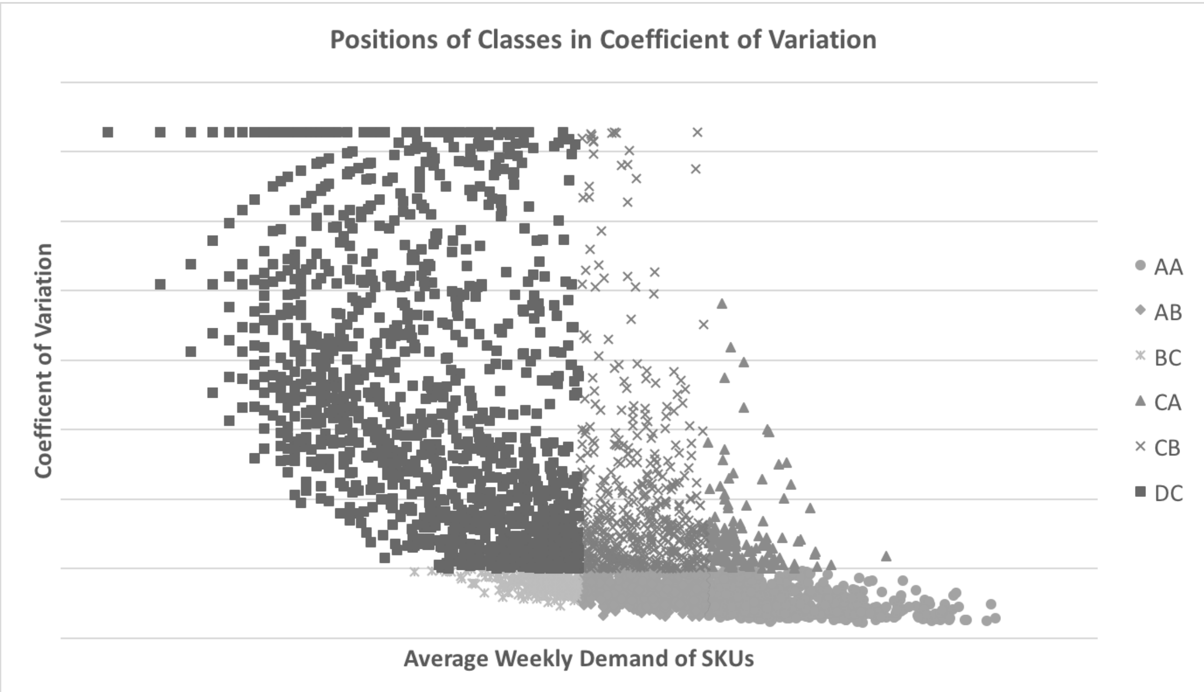


Figure 23: Illustration of the Positions of classes in coefficient of variation

Class AB, and BC has lower volumes than AA. However, it was decided that the assumption of normally distributed demand could be used for these classes as well. Moreover, due to the low volume a (R,Q) policy might not be feasible since it will not enable Duni to coordinate procurement of articles supplied by one supplier.

To be able to increase the lot sizes periodic review can be used, since updating inventory level and position for predetermined time periods can give the possibility for coordinating several purchase orders to one supplier. Therefore, a fixed-interval order system could be used for both AB and BC. As AB has higher volume than BC the periodic review time period can be set to a lower level. It was decided that for AB the periodic review should be set to one week, and for BC it should be set to two weeks. The suggested strategies are both easy to use and decreases the nervousness in the system since there is a fixed batch quantity in the case of (R,Q) policy and a fixed periodic inspection interval in the case of fixed-interval order system.

Regarding the calculations of the (R,Q) policy and fixed-interval order system, most parameters were calculated based on the collected data or gathered as they were predefined by Duni. However, the parameters set up and ordering cost were not defined by Duni. In order to perform the calculations, the set up cost and ordering cost were set based on industry standard in collaboration with our supervisor at LTH. In order to not overestimate the results, the parameters were set at the highest industry standard. For example, industry standard of the ordering cost was between 50-100 euro. Thus, the set ordering cost were to 100 euro.

Finally, class CA, CB, and DC were deemed to have a coefficient of variation that exceeded what is feasible to control with stochastic demand models as it would require large safety stocks to cover the uncertainty in demand. It would be suitable to have MTO on all articles above three in coefficient of variation as it is more efficient to not keep stock and only produce when a customer order is released. [redacted]. Therefore, the only option is to try controlling inventory with MRP as Duni does today. The different replenishment strategies for each class are summarised in table 11.

Table 11: Suggested Replenishment strategies

Class	AA	AB	BC	CA	CB	DC
Replenishment strategy	R,Q policy	Fixed-interval order system	Fixed-interval order system	MRP	MRP	MRP
Review	Continuous	1 week	2 weeks	-	-	-
Service level	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

The result from the calculations that have been made for each class is presented in Appendix D, were all parameters necessary to control the calculations are available.

5.3 Analysis of the warehouses

To be able to decide a replenishment strategy for a specific warehouse an article has to be classified depending on the demand that occurs at that warehouse. Therefore, all articles were re-classified per warehouse. This was done as an article in the general classification does not necessarily entail that it is classified in the same class as per warehouse. However, the general classification contributed with general strategies and settings for the different classes by analysing a representative article on an aggregated level. To decide a replenishment strategy per warehouse level it is therefore only a matter of analysing how the articles are classified per warehouse and matching it with the proposed strategy for that class in the general classification. The logic is presented in figure 24.

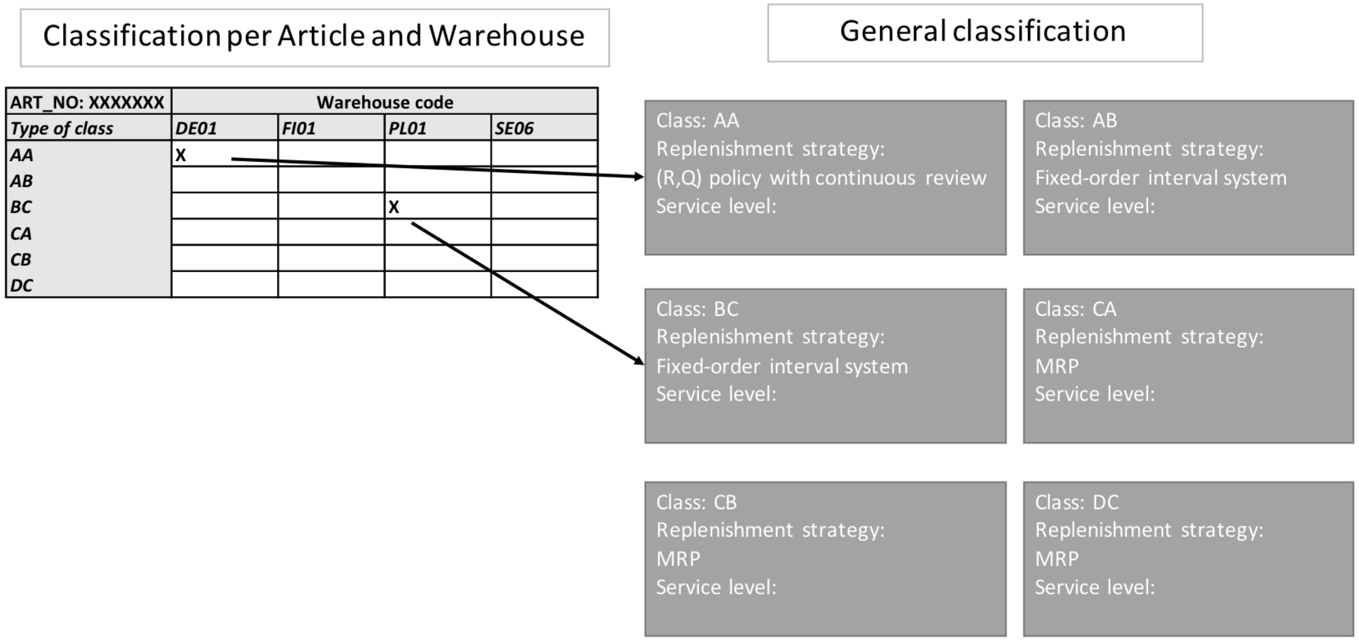


Figure 24: Logic of the warehouse solution

5.4 Planning efficiency

Regarding the suggested alternative replenishment strategies, there is no need for Duni to use the current forecast for articles in these classes. From a replenishment point of view, a total of 1566 articles can be removed from the current forecasting process. The replenishment systems are more or less self-sustaining and replenishment will occur according to the set policy. However, the demand may change over time which calls for an update of the parameters, which is a type of forecast. Our suggestion is to update the parameters R, Q, I and Order up to point once a year, which will require analysis of the sales data from the previous year.

Concerning Duni's current replenishment strategy, which is kept for three classes. Since the other classes will be removed from the current forecasting process, capacity to improve the forecasts exists and focus should be on improving the forecasts. Forecasts should also be performed on warehouse level because aggregated forecasts are more accurate and the classification is based on warehouse level. This suggestion is however somewhat contradictive since the authors originally suggested MTO for the major share of the concerned articles. A MTO strategy from a replenishment point of view means that forecasts are not necessary. Another aspect is that these articles are difficult to forecasts since the variation is high, [redacted]. However, in order to further improve the service level, which is one of Duni's goals the forecasts need to be improved.

Introduction of new articles is an important aspect, which need to be acknowledged. Today, new introduced articles are segmented as A articles in one year. As shown in figure 25, there is a significant share of new articles is to the left. A pattern that one can determine through the figure is that the articles are either moving upwards or to the right. New articles that move to the right are potential high runners and should be kept and reclassified accordingly. Articles that move upwards should be reviewed to either be removed or reclassified as D. The process of introducing new articles is far too long and ties up capital, especially since the articles are classified in the A segment. A reasonable goal is to decrease the length of this process to two to three months. After two or three months enough information regarding the articles sales figures and demand pattern exist to decide whether an article should be kept or removed from the assortment. Evaluation of early sales figures is essential so that resources can be allocated to the successfully introduced articles. Furthermore, new introduced articles should initially be controlled through the MRP, initial forecasts and monitoring of new introduced articles are important.

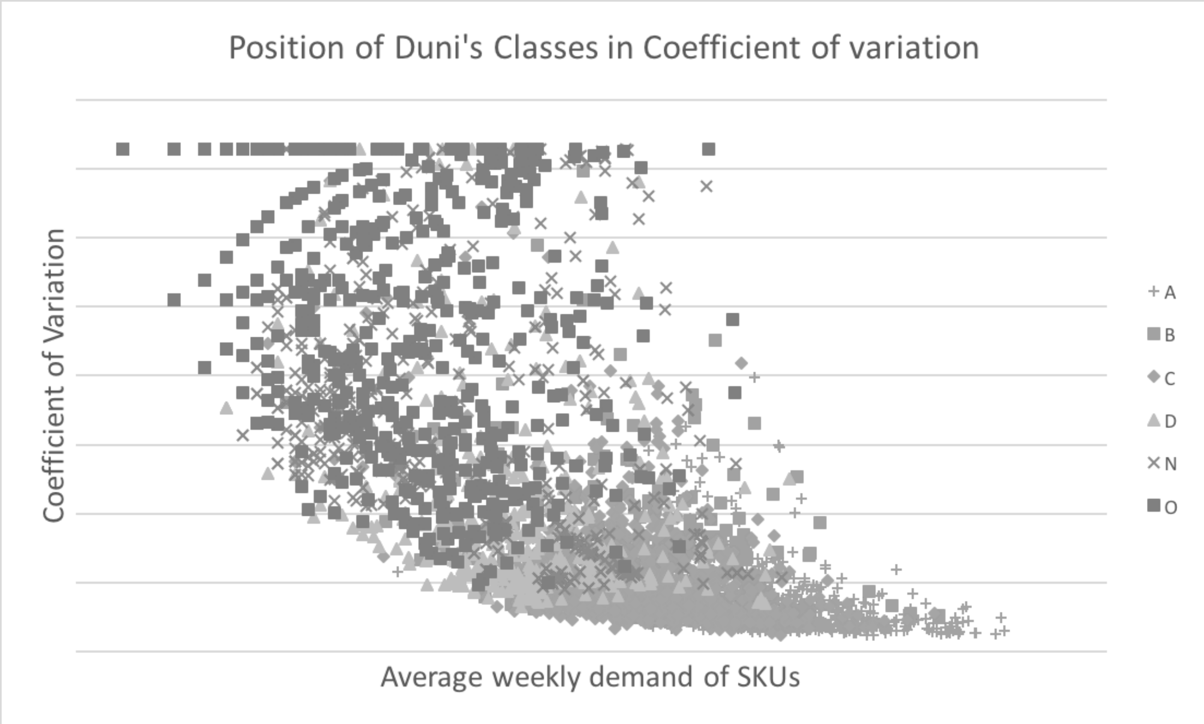


Figure 25: Illustration of the positions of Duni's classes in coefficient of variation

5.5 Cost analysis

An analysis of the costs affected by the suggested replenishment strategies has been made. However, the presented savings below can only be realised with the made delimitations. There are also other factors that affect the presented savings, these factors are mentioned in the conclusion. The focus of the analysis has been tied up capital in stocks, which is the most significant cost. However, there are more costs that are affected by other strategies and a short discussion will be provided.

Data of tied up capital in stocks have been provided from Duni, the data consisted of average stock levels for each month during 2015. This data was combined with the defined holding cost from Duni. The holding cost was defined as [redacted] and month. The expected inventory on hand was calculated for each representative article. The expected inventory on hand consists of expected inventory level and expected amount of backorders. The expected amount of backorders was deemed to be insignificant and did not affect the result. The expected inventory on hand for each representative articles was compared to the average stock levels for 2015, which gave the reduction in inventory in percentage. A mean percentage of the reduction in inventory was calculated for each class which could be compared to the total tied up capital in stocks, the result of the reduction in tied up capital is illustrated in table 12.

Table 12: Savings that can be realised through the suggested replenishment strategies

Class	Current inventory cost per year	New Inventory cost per year	Savings in percent per year	Savings in euro per year
AA	[redacted]	[redacted]	[redacted]	[redacted]
AB	[redacted]	[redacted]	[redacted]	[redacted]
BC	[redacted]	[redacted]	[redacted]	[redacted]
CA	[redacted]	[redacted]	[redacted]	[redacted]
CB	[redacted]	[redacted]	[redacted]	[redacted]
DC	[redacted]	[redacted]	[redacted]	[redacted]
Total (all classes)	[redacted]	[redacted]	[redacted]	[redacted]

As shown in the table above, there are savings that can be realised through applying the suggested replenishment strategies. The classes save almost the same share in percentage per year although there is a substantial difference of the savings in euro per year, which can be explained by the number of articles in each group and the volume of the articles. Class AA has not the highest number of articles but a high annual volume, compared to the other classes. Furthermore, the largest savings in euro is in class AA. Class AB has the largest amount of articles and have a higher annual volume than class BC, which explains the larger savings in euro per year. The reason why the total savings in percent is lower than the illustrated savings in the classes is that the authors assumes that the inventory cost will be on the same level for class CA, CB and DC. The inventory cost of class CA, CB and DC is therefore independent of the replenishment strategies for the other classes. A total saving of [redacted] percent indicates that the suggested replenishment strategies will provide an improved inventory control for Duni. In addition, the overall service level target has been increased by [redacted] percent.

Due to the fact that the representative articles in class AA have a relatively low setup time [redacted], the authors performed a sensitivity analysis of how the savings in percent per year would change if the set up time was increased. The relationship between increased setup time and savings in percent per year is illustrated in figure 26. It is evident that even if the setup time would [redacted], Duni would still save [redacted] percent per year with the suggested replenishment strategies.

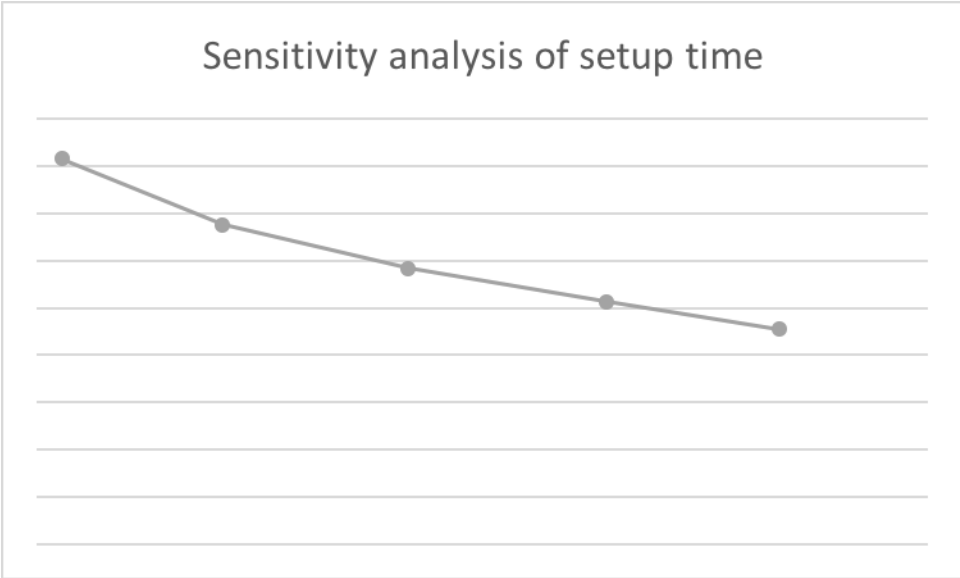


Figure 26: Illustration of how the savings decline with an increased setup time

There are other costs that are associated with a decreased inventory level. Staffing and administration costs are costs that Duni should be investigating. A decrease in inventory implies that the workforce in the warehouses could be decreased. As earlier mentioned, the [redacted]. The largest savings in tied up capital and space can be made in warehouse in Germany, since most of the products flow through this warehouse and the warehouse itself supplies the biggest market. Duni should investigate if it is necessary to [redacted].

5.6 Seasonal

Duni has four different seasons, which are active during different time periods. To be able to define how long the different seasons are the authors analysed how many SKUs were sold each week. Starting from the first week of the year the volumes were aggregated, this rendered a pattern that illustrated between which weeks most of the volume was sold. From this information it was possible to define the start and end of a season (see appendix E). The result is presented below in table 13.

Table 13:Definition of the length of each season

Season	Start week	End week	Length of season
Christmas	36	50	15
Autumn	31	50	20
Spring/Summer	1	38	38
Easter	1	12	12

The seasonal assortment is in general difficult to plan in terms of forecasting and replenishment. Currently, the analysed seasonal articles are manually forecasted by Duni, which was expected due to the defined process of forecasting at Duni. Moreover, because of the short life cycle and selling period it is difficult to estimate how volatile demand will be for a future time period. Therefore, coefficient of variation could not be used as a parameter to steer planning and replenishment. In collaboration with our supervisor at Duni, it was concluded that it would be possible to estimate the volume sold during the season for an article and the number of weeks an article will be sold, which will be referred to as sales weeks henceforth. Another parameter that the authors thought would be interesting to analyse was the lead time, especially the ratio between lead time and sales weeks.

As earlier mentioned, volume is a differentiating factor for the yeararound assortment which also can be applied to the seasonal assortment. The ratio between lead time and sales weeks will indicate how often one will be able to produce or procure a product during a season. Volume and the ratio between lead time and sales weeks are illustrated in figure 27.
The figure above illustrates a classification model which makes it possible to prioritise articles and determine their flexibility. The priority of the articles is decided based on volume and the flexibility is decided based on the relation between lead time and sales weeks. High flexibility is deemed as less than 50 percent in terms of relation between lead time and sales weeks, low flexibility is therefore deemed to be above 50 percent of the same relation. Therefore, the interaction point on the x-axis is set at 0,5 (50 percent). Regarding the volume, the interaction point was set at [redacted] SKUs sold per annum as [redacted] percent of the articles are accountable for [redacted] percent of the total volume and [redacted] percent of the articles are accountable for [redacted] percent. This resulted in four classes.

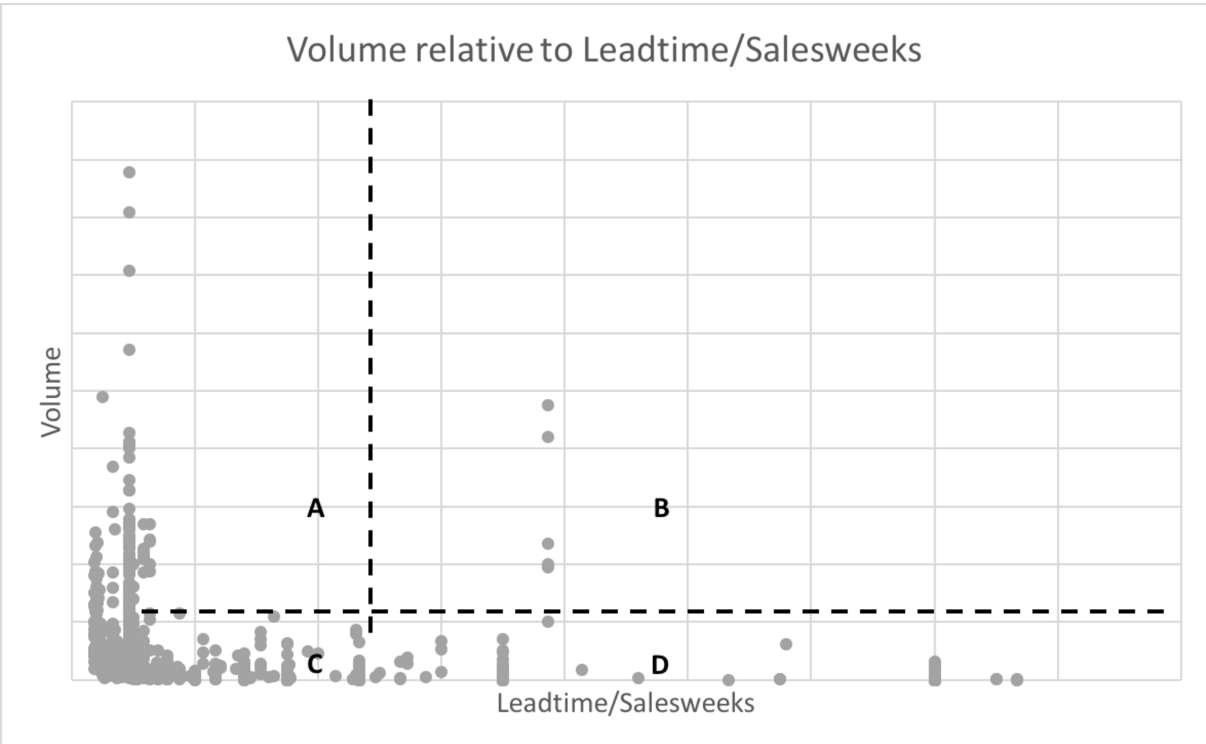


Figure 27: Suggested classification model for the seasonal assortment

Regarding articles in Class A, 50 percent of the forecasted volume should be produced before the season starts. In Fisher's example SportObermeier, the company are producing 50 percent of the volume before the season. Producing the articles before the season starts will make it possible to evaluate early sales figures in the beginning of the season. Class A articles are characterised by high volume and high flexibility. Due to the high flexibility it is possible to hedge against uncertainty such as volatility in demand by producing or purchasing a number of additional times during the season and it is therefore possible to keep a lower level of inventory. To be able to decide if there will be a surge or a decline in demand, it is essential to evaluate early sales figures. By analysing early sales, it is possible to re-allocate resources from articles that will not sell more during the season to articles that are projected to have increased demand, this is an opportunity to decrease the risk of excess supply. To conclude, class A need to be monitored in the season by early sales analysis to get indications regarding demand. Moreover, an initial forecast needs to be performed to determine the amount of stock that needs to be kept before the start of the season. As the life cycle for the seasonal assortment is short there is no time to sell off excess supply for class A.

The other three classes, B, C and D, should have a lower priority. Regarding class B and D there is less opportunity to hedge against uncertainty as the low flexibility entails that it is not possible to produce more than once before the season. Class B and D articles could be produced in the full quantities that are forecasted for their corresponding periods. Class C represents articles with low volume and high flexibility Due to the low volume, there is low feasibility to produce more than once, since the setup cost would probably exceed the cost of lost sales or excess supply. Moreover, even if it is possible to produce more than once during the season for class C articles, efforts should be on following up the early sales figures of class A. Therefore, there might not be resources to follow up sales for class C articles. As class B, C and D articles only will be produced once an initial manual forecast is only required.

The illustrated classification is unfortunately not correct due the fact that the lead time is not accurate. Duni uses a symbolic number for the lead time of produced products, the symbolic number of the lead time may deviate from the actual lead time. A classification is dependent on correct data and in this case the lead time is a deciding factor for the application of different strategies. However, the chosen factors and recommended strategies for the different classes are valid with a correct lead time.

6 Conclusions & recommendations

Results of the analysis are presented, where conclusions will be drawn based on the same results. Our recommendations to Duni are presented together with motivations of the recommendations. A discussion regarding the generalisation of the results will be presented. Suggestions for further research and reflections by the authors will be provided.

6.1 Answers to the research questions

The following paragraphs answer the research questions. In addition, both research questions contain the authors recommendations to Duni.

6.1.1 What kind of replenishment and planning strategies suits Duni's product assortment?

From the analysis it was concluded that there are opportunities to control inventory and plan demand in several ways depending on the characteristics of the product. From the analysed characteristics it was possible to find theoretical replenishment and planning strategies. For yeararound articles with low volatility, a theoretical potential was found in using stochastic demand models to control inventory performed better than the current MRP solution. As these articles will be controlled with stochastic demand models the forecast of demand does not need to be updated more than once a year. For articles with high volatility in demand was more difficult to find a suitable replenishment strategy. In most cases articles with high volatility and low demand should according to the authors not be kept in stock and only be made once a customer order is released. In this case both authors were convinced that a MTO strategy should be suitable for Duni. However, as discussed earlier [redacted]. Therefore, the proposition was not believed to be feasible in the current setup. With that in mind, the most suitable replenishment strategy according to the authors is the current MRP solution for all articles with high volatility independent of volume. Forecasts for articles with high volatility in demand can only be performed manually. However, the authors found that it is better to forecast these articles per warehouse, as aggregated forecasts are more accurate and then classification is performed on warehouse level.

Concerning seasonal articles, articles with high flexibility and high demand should according to the authors be produced in advance in a batch size that covers half of the forecasted demand. This means that Duni can hedge against uncertainty in the manual forecast. By analysing early sales figures Duni can also decide which articles that will need to be produced again to better supply demand. For articles with high or low flexibility and low demand, and for articles with low flexibility and high demand it is suitable to replenish the whole forecasted demand in advance of the season, because the costs involved with an additional replenishment will be to great due to small batch sizes for low volume articles and infeasible for articles with low flexibility. For all seasonal articles it is suitable to aggregate the initial manual forecast per warehouse, as it is more accurate.

6.1.2 How should a decision framework be designed for replenishment and planning strategies at Duni?

The decision framework consists of the presented classification and strategy for the warehouses. The classification contains factors that can be applied to yeararound articles. Furthermore, factors for new introduced products can be decided within a couple of months after the introduction, according to the authors. Concerning the validity of the factors, both factors have previously been used in research and are recommended to use in the presented frame of reference. Moreover, according to the analysis, the factors provide an adequate differentiation. Our recommendation is to perform a differentiation between yeararound and seasonal products, based on their characteristics. Regarding the yeararound assortment our recommendation is to use coefficient of variation and volume as factors. The variation illustrates the stability of the demand, which is necessary to know when choosing between MTO and MTS. [redacted] differentiates articles based on their [redacted], since [redacted] can be neglected. The combination of the two factors make it possible to choose suitable replenishment strategies. The application of these factors generates six classes and four different replenishment strategies.

Concerning the seasonal articles, a classification has been performed and replenishment strategies have been suggested accordingly. However, due to inaccurate lead times it is not feasible for Duni to use this classification. Although, the chosen factors and recommended replenishment strategies are valid. The authors strongly recommend Duni to launch an investigation to determine correct lead times of both seasonal and yeararound articles. Correct data of lead times can be used to support important business decision and the application of strategies, even beyond the reach of planning and replenishment.

Duni has as earlier mentioned four warehouses and our recommendation is to use the same classification for all warehouses. It is possible to use the same classification for all warehouses since a general classification has been made and replenishment strategies have been suggested for the different classes. Furthermore, classifications for each warehouse have been performed with the same interaction points as the ones in the general classification. Moreover, the demand for each warehouse have been used in the separate classifications, which makes it possible to apply the general classification to all warehouses.

6.2 What conclusions can be drawn from the results and analysis

From the results and analysis, it can be concluded there is theoretical potential that could be realised through diversified replenishment and planning strategies as its articles differ in characteristics. It can also be concluded that dividing articles in classes and adapting strategies depending on their characteristics gives improved control of inventory and gives the possibility to allocate resources to articles that have a greater impact on the bottom line. Duni could by implementing the proposed decision framework theoretically be able to increase the service level with [redacted] percent, reduce inventory cost by [redacted] percent, and increase planning efficiency and accuracy.

6.3 Limitations and criticism

This project has been time limited, which has forced the authors to make delimitations and to not consider all factors that affect the results. Furthermore, this project is in the field of supply chain management where parts are connected to each other and affected by changes, both up- and downstream the supply chain. The results can only be realised through a proper analysis of factors that may affect the results. Examples of factors that need to be evaluated are: production capacity, practicalities in the production and raw material planning. Regarding production capacity, one need to perform a production capacity analysis to evaluate if the production can support the suggested replenishment and planning strategies. There are also several practicalities in the production that affect the results, for example the paper-rolls in the machine might need to be consumed in one production run, which impose constraints to the smallest feasible batch quantity. The raw material planning process are connected to the Duni's replenishment system. If one would consider to use the suggested replenishment and planning strategies, an analysis of the raw material planning process need to be performed and changed according to the suggested strategies.

This project illustrates the potential of the suggested replenishment and planning strategies at Duni with certain delimitations. However, in order to evaluate what the real savings may be from the suggested strategies all factors need to be taken into account. The authors strongly recommend Duni to investigate all affected factors to determine if the suggested replenishment and planning strategies are feasible and what the real savings will be.

There are two parameters that were decided in collaboration with our supervisor from LTH and were based industry standards. The decided parameters were setup and ordering cost, which were used to calculate EOQ. Given that these values were based on industry standards, the calculated savings may be uncertain. Moreover, lead times have been set to constant in all calculations which means that uncertainty in lead time has not been considered. This may have a high impact on the result if there is high volatility in lead time.

When analysing the seasonal assortment, it was concluded that the lead time for produced articles were set to a standard level for all produced articles. Therefore, the authors are not certain that the articles are in the right position in the classification model for seasonal articles. However, since no further analysis on article level was performed, the model is still relevant, and can be used once the lead times per article have been established.

Service level has been defined as the probability of no stock out per order cycle known as Serv1. Measuring service level by Serv1 is not as accurate as Serv2. To improve the accuracy of the service level Serv2 should be used instead. However, using Serv2 as a measurement for service level requires extensive knowledge in inventory control as it is more complex to calculate.

6.4 Generalisation of the results

Parts of the results can be generalised to other industries. The approach of the classification and the suggested alternative replenishment strategies could be generalised to a similar industry, such as the paper industry. However, the more valuable the products gets the more questionable it is generalising the classification. In connection to the classification, using the current MRP solution for classes with high variation cannot be generalised to other industries or markets. Other companies would have used a MTO solution, which also the authors originally suggested.

Regarding the seasonal assortment, the suggested strategies and classification can be generalised and applied to other companies and industries to some extent. The overall strategies and classification work in different settings. However, all companies that are challenged by seasonality face different issues and complexities. Adjustments according to the ruling issues needs to be performed and customisation of the replenishment is necessary.

6.5 Suggestions for future studies

Silo-thinking is a known and common problem, [redacted]. The authors believe that working across the BAs and functions would increase the efficiency of the company. Resources could be used more efficiently and the information sharing would be improved. The process of introducing articles is also an area that are suitable for improvements. A discussion regarding the introduction of products has been made and articles should be reclassified after a couple of months, from a replenishment point of view. However, [redacted]. The BAs have different processes for introducing products. It might be of interest to investigate if it is possible to use a common process for the introduction of products.

7 References

This chapter include a list of all reference used in this report. The reference list is built according to the Harvard system. When a reference is written before the punctuation that sentence comes from the same reference, although is a reference written after the punctuation the whole section is from the reference.

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Appendix

Additional information in forms of tables and figures will be presented in this chapter.

Appendix A – List of interviews

The table below includes information regarding interviews conducted in the master thesis.

Table 14: List of interviews

Interviewee	Title	Date
Interviewee 1	Supply Chain Director	March 14 & February 3, 2016
Interviewee 2	Supply Chain Planner MS	March 17, 2016
Interviewee 3	Statistical Forecast Manager MS & CS	March 18, 2016
Interviewee 4	Statistical Forecast Manager TT	March 14, 2016
Interviewee 5	Category Manager within TT	March 18, 2016
Interviewee 6	Manual Forecast Manager within CS & TT for Germany, Switzerland and Austria	March 15, 2016
Interviewee 7	Manual Forecast Manager CS for Germany	March 16, 2016
Interviewee 8	International Demand Manager	February 4, 2016
Interviewee 9	Director Value Chain	February 4, 2016

Appendix B – Interview Guide

The interview guide is constructed to answer the research question: What kind of replenishment and planning strategies suits Duni's product assortment?

General Questions

1. What is your name?
2. What do you work with?
3. What are your responsibilities?

Products and Supply Chain

4. How would you describe Duni's products in terms of characteristics?
5. What kind of Supply Chain has Duni?
6. What is the primary objective of the Supply Chain?
7. Who are the competitors and how many are they?
8. What is the main purpose of Duni's classification?
9. What is the result of the classification used for?
10. What factors do you think one should consider when performing a classification for Duni?
11. Is there something else that you think is relevant under these circumstances?

Forecasting

12. What kind of statistical forecasting methods are used today?
13. How does the statistical forecasting work?
14. How do you perform the manual forecasting?
15. What is the information generated by forecasts used for?
16. Are there any products that should not be forecasted?
17. Are you satisfied with the forecasting process?
18. Do you believe the forecast could be used in a different way compared to today?
19. Is there something else that you think is relevant under these circumstances?

Replenishment System

20. Describe the replenishment process (the different stages)
21. What methods and tools are used to control inventory?
    a. Are there different inventory control methods for different product characteristics?
        i. MTO/MTS
22. How are the replenishment quantities determined for FGW?
23. How is safety stock determined?
24. How is service level measured?
    a. What service level is promised to the customers?
25. Are you satisfied with current replenishment system?
26. Is there something else that you think is relevant under these circumstances?

Final question

27. Do you believe that there are products that should not be forecasted and/or kept in inventory?
    a. Which products?
    b. What characterise these products?

Appendix C – Representative articles

The table below contains the representative articles, which have been used in the master thesis. The articles that are crossed over have not been used since both articles were introduced in November 2015.

Table 15: List of representative articles and corresponding classification parameters

Article number	Class	Description	Business Area	Coefficient of variation	Average demand per week	Volume
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Appendix D – Summary of calculations

The three tables below contain a summary of the performed calculations, the most essential parameters are illustrated.

Class AA

Table 16: Parameters for representative articles in class AA

Article number	[redacted]	[redacted]	[redacted]
Service level	[redacted]	[redacted]	[redacted]
Lead time demand	[redacted]	[redacted]	[redacted]
Standard deviation of lead time demand	[redacted]	[redacted]	[redacted]
Safety stock	[redacted]	[redacted]	[redacted]
Reorder point (R)	[redacted]	[redacted]	[redacted]
Batch quantity (Q)	[redacted]	[redacted]	[redacted]
Expected stock on hand	[redacted]	[redacted]	[redacted]

Class AB

Table 17: Parameters for the representative articles in class AB

Article number	[redacted]	[redacted]	[redacted]
Service level	[redacted]	[redacted]	[redacted]
Standard deviation of the inspection interval	[redacted]	[redacted]	[redacted]
Safety stock	[redacted]	[redacted]	[redacted]
Inspection interval demand	[redacted]	[redacted]	[redacted]
Order up to point (S)	[redacted]	[redacted]	[redacted]
Expected stock on hand	[redacted]	[redacted]	[redacted]

Class BC

Table 18: Parameters for the representative articles in class BC

Article number	[redacted]	[redacted]
Service level	[redacted]	[redacted]
Standard deviation of the inspection interval	[redacted]	[redacted]
Safety stock	[redacted]	[redacted]
Inspection interval demand	[redacted]	[redacted]
Order up to point (S)	[redacted]	[redacted]
Expected stock on hand	[redacted]	[redacted]

Appendix E – Length of the different seasons

The four figures below each represent the length of a specific season. The length of a season is defined within the dashed lines.

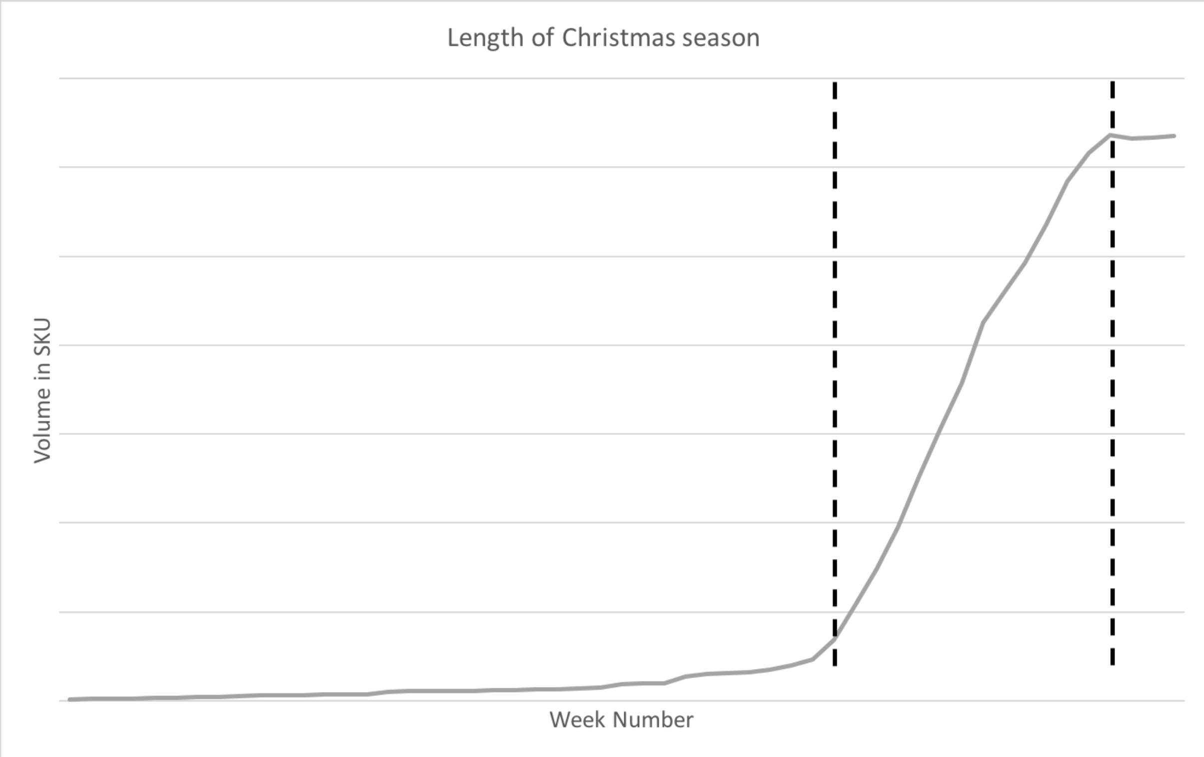

Figure 27: Illustration of the length of the Christmas season.

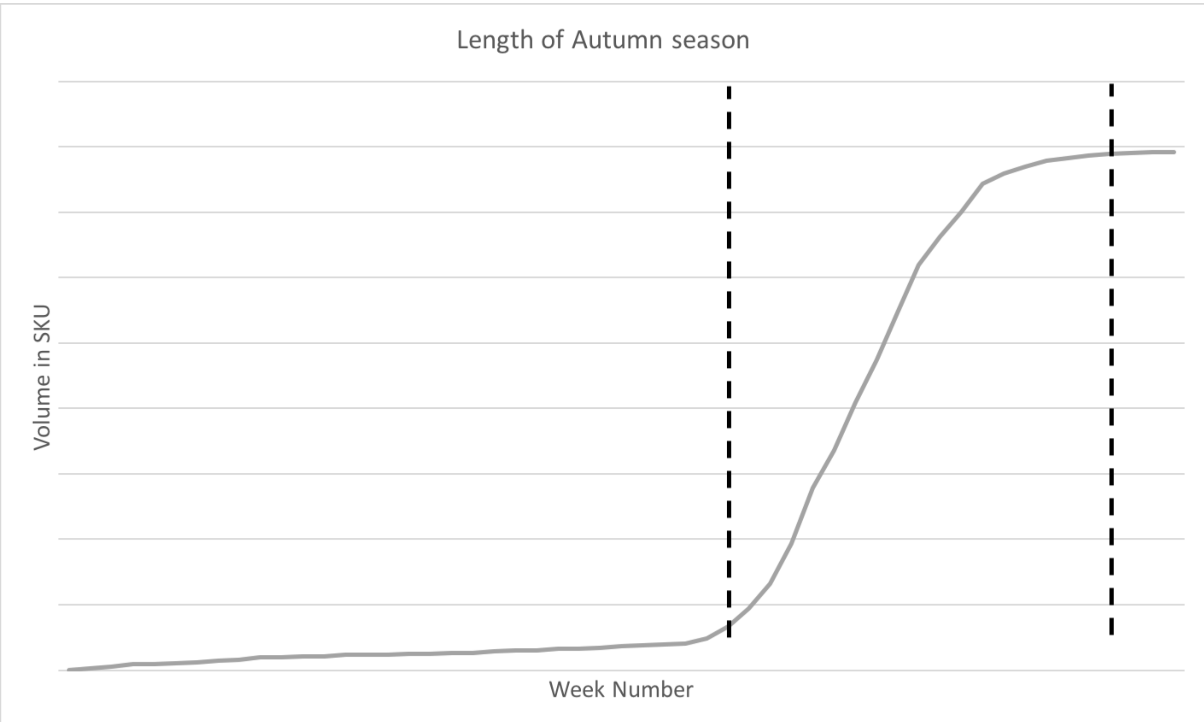

Figure 28: Illustration of the length of the Autumn season.

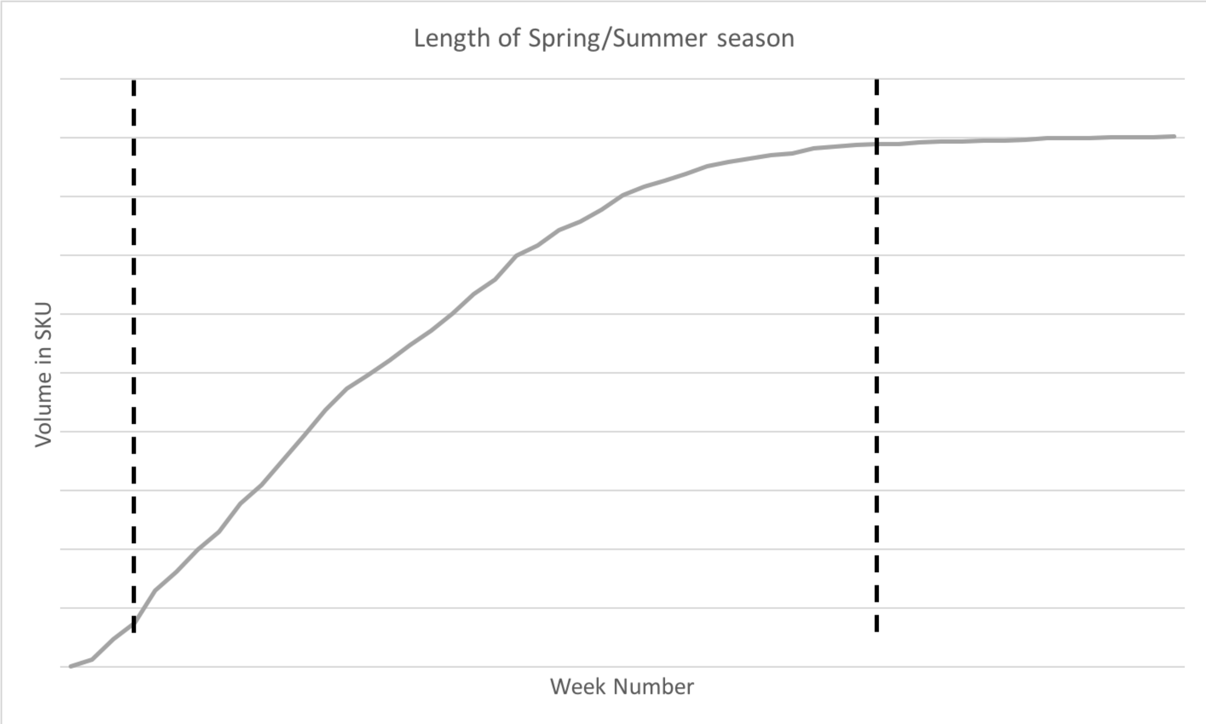

Figure 29: Illustration of the length of the Spring/Summer season.

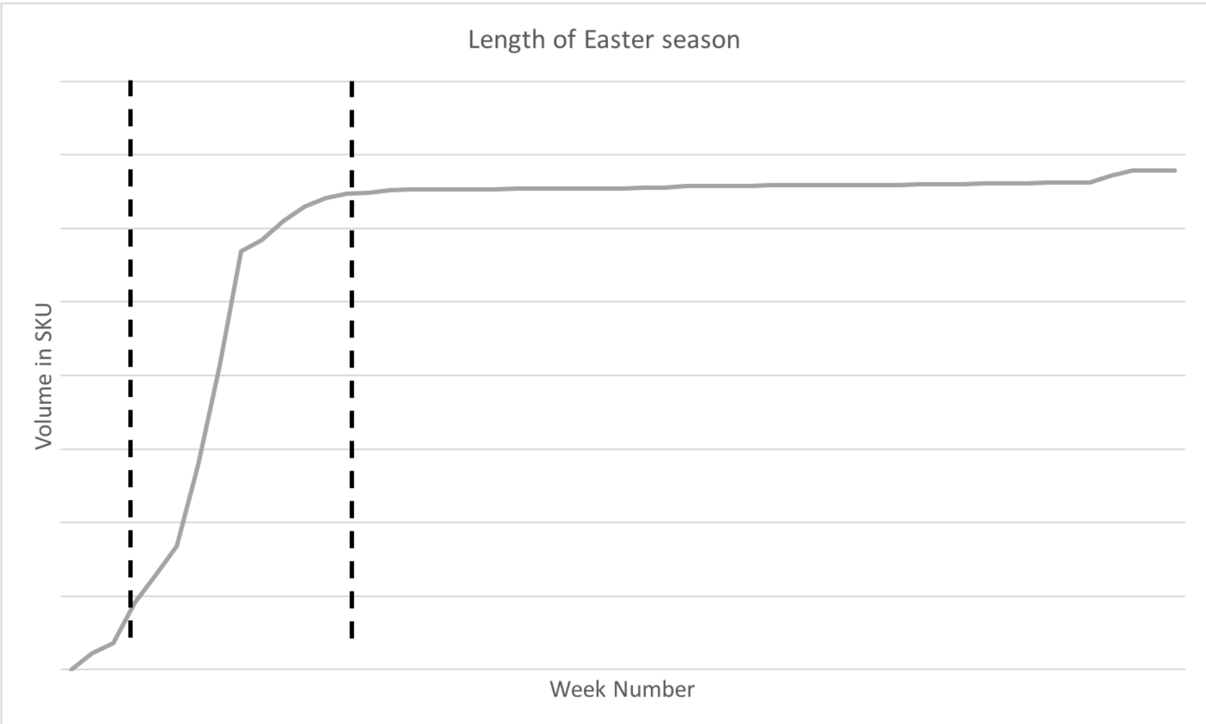

Figure 30: Illustration of the length of the Easter season.