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Development of a Decision Support Tool for the Process of Deciding Inventory Levels

A Study at The Absolut Company

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Keywords: Inventory level, decision support tool, spreadsheet model, inventory control, factors affecting inventory levels

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Preface

This master thesis was written during the spring of 2014 as the final part of our education in Industrial Engineering and Management at Lund University, Faculty of Engineering. The project was conducted at The Absolut Company, Åhus, together with the Department of Industrial Management and Logistics, Faculty of Engineering, Lund University.

We would like to express gratitude to The Absolut Company for giving us the opportunity to conduct our master thesis there and to the employees for participating in numerous interviews and answering all of our questions. Especially we would like to thank our supervisor, Johan Ström, at The Absolut Company for his efforts in guiding us through the project. Moreover, we would like to thank our supervisors at Lund University, Eva Berg and Joakim Kembro, for all of their support and feedback.

Lund, May 2014

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Abstract

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Background: Supply Chain Management is receiving increased attention as companies are trying to remain competitive in a global and challenging environment. An important topic to consider when managing the supply chain is inventory control. Companies today have enormous investments in inventories, which means that there are potential improvements regarding tied up capital in raw materials, work-in-progress and finished goods. There are a variety of tools available in the theory to support the process of determining inventory levels, but these general tools are not suitable for every company.

Problem description: This master thesis was conducted at The Absolut Company (TAC) – a large spirits manufacturer. They are responsible for the production of Absolut Vodka, a premium vodka brand. As for any manufacturing company it is crucial that the production constantly has material available to avoid stoppages in the lines. The inventory of the bottle cap, which is one of the materials used in the production process, has historically been kept high to ensure constant supply, but now TAC has started to question if these is managed correctly. Hence, there is a desire from TAC to develop a better understanding of what is affecting the inventory levels. There is also a need for an analytical tool that supports the decision making process related to the inventory levels of the bottle caps.

Purpose: The purpose of this master thesis is to investigate which factors affect the inventory levels of bottle caps at TAC and to develop a decision support tool for the process of determining appropriate inventory levels for the bottle caps.

Research questions:

1. What factors are affecting the inventory levels at TAC?

2. How do the identified factors affect the inventory levels of bottle caps at TAC?

3. How should a tool for deciding appropriate inventory levels of the bottle caps at TAC be designed?

Methodology: The research approach for this thesis is a systems approach and the research is performed inductively. A case study has been chosen as research strategy and the design of the case is single case and single unit of analysis. The system is studied by analyzing both qualitative (interview and observations) and quantitative data (operational data from TAC's ERP system). The quality of the research is evaluated based on the dimensions reliability and validity.

Conclusion: During the analysis it was concluded that the factors affecting the inventory levels at TAC come from the cycle and safety inventory. The identified factors associated with the cycle inventory were supplier lead time, purchase batching and production batching, while the factors affecting the safety inventory were forecast accuracy, quality defects, delivery reliability and delivery dependability. From the analysis it was concluded that the factors purchase batching, forecast error and delivery reliability contributed the most to the inventory levels at TAC.

The decision support tool was designed to suggest appropriate inventory levels and to give the user an overview of how much each factor contributes to the inventory. In the tool a baseline scenario, reflecting the current situation, and two alternative scenarios are presented. One scenario shows appropriate inventory levels to cover for the mean error and the other scenario is calculated to cover for the maximum error. The tool also gives the user an overview of all the factors affecting the inventory levels of caps that can be used to spread the information in the company and create understanding across departments. Furthermore, the decision support tool can be used to analyze how improvements or deteriorations of the factors affect the inventory levels, to support TAC's supply chain department in deciding which improvement project should be prioritized.

Keywords: Inventory level, decision support tool, spreadsheet model, inventory control, factors affecting inventory levels

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1 Introduction

In this chapter an introduction of the thesis will be presented, describing the background of the research topic to motivate the purpose and research questions.

1.1 Background

Supply Chain Management is getting increased attention as companies are trying to remain competitive in a globally challenging environment. It is defined as “an integrative philosophy to manage the total flow of a distribution channel from the supplier to the ultimate user” (Cooper & Ellram, 1993, p. 13). Companies have to deliver products with high delivery accuracy with ever-shorter lead times, while at the same time being efficient and keeping the costs low (Mattsson & Jonsson, 2003). There is also increased focus on lowering the tied up capital within the entire supply chain. In order for companies to manage this competitive environment, the material flows and the value adding resources have to be controlled in an effective manner (ibid).

An important topic to consider when managing the supply chain is inventory control. In companies today there are enormous investments in inventories, which means that there are potential improvements of the tied up capital in raw materials, work-in-progress and finished goods (Axsäter, 2006). The use of scientific methods for inventory control can target this problem and give companies a significant competitive advantage (ibid.). There are several reasons for a company to carry inventory, for example to avoid interruptions in production or to satisfy the customer’s demand of short lead times. The main factors that influence the size of the inventory are: batching/economies of scale, variability and obsolescence (Axsäter, 2006; Hopp & Spearman, 2001). However, the goal with inventory control is not simply to reduce the inventory levels; instead the focus lies on meeting the purpose with the inventory at the lowest possible cost (Hopp & Spearman, 2001).

There are a variety of tools available in the literature to support the process of determining inventory levels, e.g. ABC analysis and economical order quantity model (Onwubolu & Dube, 2007). Factors affecting inventory levels have also received the researchers’ attention. For example, Greis (1994) investigated the relationship between customer service and the expected cost in achieving it. Disney (1997) used a generic algorithm to reduce the inventory levels by investigating the amplification created by the production orders. Kogan & Rind (2011) conducted research within the field of inventory levels for crucial components, such as spare parts for the cooling system in a nuclear plant, and investigated what was needed to assure that the service level was met. Another research area that has received attention is the total inventory in a supply chain. The aim with this research is to find the optimal distribution of inventory in the different stock locations in the supply chain; see (Beheshti, 2010; Petrovic, 2001; Smith, 2003). Furthermore, the optimal order quantity or the optimal order-up-to which are related to each other have also been researched for individual stock locations; see (Petrovic, 2001; Walker, 2000). The company Procter & Gamble has developed a model to support the decision making process of setting inventory targets. The model takes several factors into consideration, such as the forecasted demand, forecast accuracy, lot sizes and lead time (Farasyn, Perkoz, & Van de Velde, 2008). After analyzing the input factors the model suggests appropriate service levels based on the characteristics and constraints of the supply chain (ibid).

To summarize the current research in the field of determining inventory levels it can be concluded that there are several general methods for determining inventory levels, but these general tools are not suitable for every company. This thesis investigates methods for determining the inventory levels at a company with case specific factors. An interesting case, connected to the master thesis company, is how an article’s inventory level is affected by factors such as lead time, delivery reliability and quality defects, when the article is supplied by two suppliers. Furthermore, it is investigated in this thesis how a holistic understanding of the factors affecting the inventory levels can be created at the same time as it is communicated to what extent each factor affects the inventory levels.

1.2 Problem Description

This master thesis was conducted at The Absolut Company (TAC) – a large spirits manufacturer. One of the products that TAC produces is the Absolut Vodka, which is a well-known brand of premium vodka. Absolut Vodka is their biggest product based on sales and is produced in two production sites in Åhus, in southern Sweden. As for any production line, it is crucial for TAC that the production lines function without unscheduled interruptions. Therefore it is important not to run out of the materials needed for the production process. The bottle cap, which is one of the materials used in the production process, constitutes only of a small part of the total production cost, and it has a low inventory holding cost; therefore the stock levels for caps has historically been kept high, in order to ensure constant supply. However, the company has been questioning how the caps are managed. TAC believes that the stock levels are too high, which affects the tied up capital and the need for storage space. Furthermore, TAC is currently only basing their decision regarding the inventory levels of the caps on the staff’s experience and on historic inventory targets. Hence, there is a desire from TAC to develop a better understanding of what is affecting the inventory levels. There is also a need for an analytical tool that supports the decision making process related to the inventory levels of the bottle caps.

1.3 Purpose

The purpose of this master thesis is to investigate which factors affect the inventory levels of bottle caps at TAC and to develop a decision support tool for the process of determining appropriate inventory levels for the bottle caps.

1.4 Research Questions

There are numerous reasons for a company to keep inventory of raw materials, as well as many factors affecting how much inventory needs to be kept in the raw material warehouse. In order to investigate what factors affect the inventory levels of bottle caps at TAC, research question 1 (RQ 1) has been formulated. This research question aims at reviewing the current literature to find factors that affect the inventory levels of raw material, but also to investigate if they are relevant to TAC's inventory of bottle caps.

RQ 1: What factors are affecting the inventory levels at TAC?

The next step in this master thesis is to create understanding of how the factors identified in RQ 1 are affecting the inventory levels of bottle caps; therefore RQ 2 has been formulated. This research question tries to quantify the effects of the identified factors by analyzing how each factor contributes to increased inventory levels. The analysis will be based on the factors' historical impact.

RQ 2: How do the identified factors affect the inventory levels of bottle caps at TAC?

With the understanding of what factors affect the inventory levels and to what extent, a tool for helping the material planners at TAC can be developed. The tool should be used as support for managing the inventory levels of bottle caps. In order to know how the tool should be designed, RQ 3 has been formulated. The tool should use the knowledge gained in RQ 1 and RQ 2 to show the user how each factor affect the inventory levels of bottle caps, and to give the user an approximation of how much capital is being tied up in stocks.

RQ 3: How should a tool for deciding appropriate inventory levels of the bottle caps at TAC be designed?

1.5 Focus and Delimitations

Firstly, the thesis will only focus on factors that affect the inventory levels of raw materials and consequently the availability of raw materials. Hence, the thesis will not consider aspects related to the finished product, such as physical distribution or service levels towards the end customer. Secondly, the thesis will only consider factors that directly affect the inventory levels of bottle caps, such as poor delivery accuracy or a long lead time, and not factors that are affecting the inventory levels indirectly, like the suppliers availability of raw materials. Thirdly, only four types of bottle caps at TAC will be considered – the four with the biggest purchased volume. Lastly, topics connected to the purchasing tasks of selecting supplier and negotiation contracts will not be considered in this thesis. In Figure 1 the scope of the thesis is illustrated. It is within the functions and processes of this scope the factors affecting the inventory will be identified.

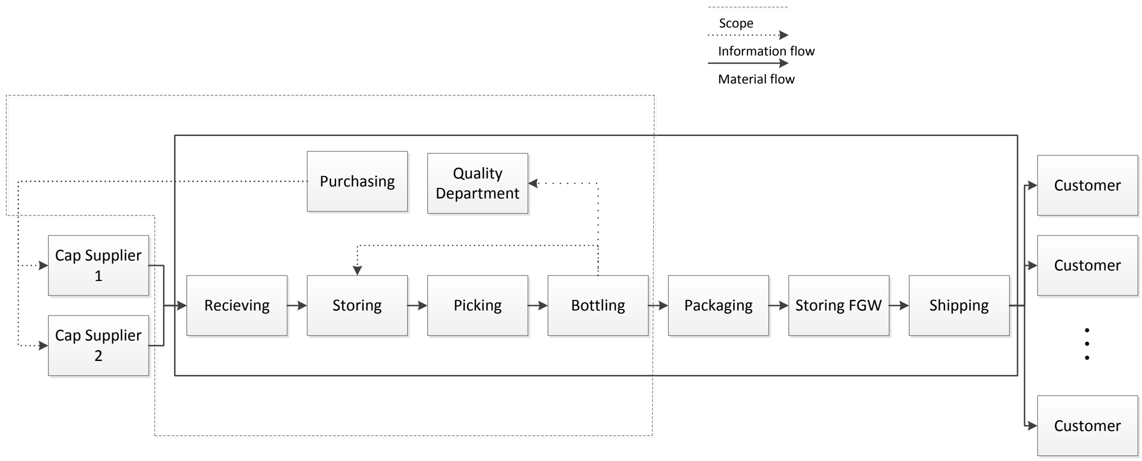


Figure 1. The scope of the master thesis.

1.6 Target Group

This thesis is primarily of interest for the staff at TAC involved in handling the material and information flow of the bottle caps, but the thesis could be also of interest for people outside of TAC with an interest in logistics.

1.7 Outline of the Thesis

An outline is presented below to give the reader an overview of what will be included in the coming chapters.

Chapter 1 – Introduction
The first chapter aims at giving a background of the problem in focus, followed by a problem description and the corresponding purpose and research questions. Also presented in this chapter is the focus and delimitations of the study and what the thesis is supposed to achieve.

Chapter 2 – Methodology
The methodology chapter explains how the research has been conducted and how the research questions will be answered. Included here is also a discussion of the quality of the research.

Chapter 3 – Frame of Reference
The frame of reference chapter consists of the theory needed for the analysis of the empirical data. Presented here are factors that affect inventory levels of raw material, how the cause of the factors can be determined, and general inventory control.

Chapter 4 – Empirical Data
In this chapter all the data collected at the focal company will be presented. Included here are a more detailed presentation of the company, a current state map describing how the processes in the company are linked together and an explanation of how caps are ordered. Also presented in this chapter are the parameters related to the suppliers and a description of how the inventory is managed today. The historical data of the factors will also be presented in this chapter.

Chapter 5 – Analysis

In this chapter the empirical data will be analyzed with the framework created in the frame of reference chapter. Factors that affect the inventory levels of bottle caps at TAC will be identified, followed by an analysis of how they affect the inventory levels.

Chapter 6 – Designing the Decision Support Tool

The design of the decision support tool will be presented in this chapter, including the structure, the scenarios and the theory used for designing the tool.

Chapter 7 – Conclusion

The final chapter will connect back to the purpose and the research question to investigate if they have been answered. Furthermore, recommendations for TAC will be introduced and what implications these will bring. Lastly, a concluding discussion will be presented.

2 Methodology

This chapter presents the methodology of the master thesis. The chapter outlines how the purpose and the research questions of the thesis will be addressed. It begins with a description of the research approach, followed by the research strategy, the research design, the research quality and the research process.

2.1 Research Approach

Choosing the appropriate method when performing research is important, because different methodological views make different assumptions about the reality they try to explain and/or understand, which means that the data collected depends to a large extent on the view chosen (Arbnor & Bjerke, 2009). Gammelgaard (2004) argues that logistics research has almost solely used the positivistic approach, resulting in research questions derived from the same methodological approach, and thus tending to produce similar questions and answers. The positivistic approach is only one way of performing research and logistics research would benefit from adopting more methodological approaches (Gammelgaard, 2004). Arbnor & Bjerke (2009) have created a framework consisting of three methodological approaches for conducting scientific research: analytical approach, actors approach and systems approach.

2.1.1 Analytical Approach

The analytical view focuses solely on trying to explain reality, a reality that is seen as a summative of parts that can be considered in isolation of each other (Arbnor & Bjerke, 2009). This means that the different parts can be added together in order to get the whole picture. Using the analytical approach implies to decompose reality into the smallest possible parts, so as to form concepts and reveal cause-effect-relations by testing hypotheses (Gammelgaard, 2004).

2.1.2 Actors Approach

The actors view says that the whole can be understood by the characteristics of its parts; reality is seen as a social construction, and is not independent from the researcher (Arbnor & Bjerke, 2009). It is not relevant, according to the actors view, to understand the systemic characteristics; it is the individual members who act, not the organization itself (Arbnor & Bjerke, 2009).

2.1.3 Systems Approach

In contrary to the analytical approach, the systems view considers that reality is formed in such a way that the whole differs from the sum of its parts – which infers that the relation between parts is important (Arbnor & Bjerke, 2009). The systems approach is seen as a holistic view, in contrary to the atomistic and fragmentary view of positivism. Instead of observing a decomposed reality, the systems approach says that the world must be understood by seeing things in terms of mutually dependent "components" (Gammelgaard, 2004). The goal with the system approach is to try to understand a given part of the world by identifying the system parts, links, goals and feedback mechanisms so as to improve the system (Gammelgaard, 2004). The systems approach is contextual rather than universal, and should thus be used to compare cases instead of attempting to find universal cause-effect-relations, when gaining knowledge (Gammelgaard, 2004).

2.1.4 The Research Approach in this Thesis

The system approach is considered to be better than the analytical approach for handling complex situations and should be favored when performing logistics research (Senge, 1997). Furthermore, Gammelgaard (2004) says that the systems approach strives to create a holistic view, and it is well suited when studying logistic processes and Supply Chain Management. Dividing the processes concerning the bottle caps into smaller parts could be done, but a holistic view is seen as crucial for this project, in order not to sub optimize the analyzed processes. The overall goal of this thesis is to create understanding of the factors that influence the inventory levels of caps at TAC and to investigate how a tool for supporting the process of determining inventory levels can be designed. The approach for these tasks can be seen as holistic, since all relevant factors regarding the inventory levels will be taken into account together. There are also synergy effects between different parts in the process, which can be hard to derive to a specific cause. Based on the line of thought above, the systems approach was chosen.

2.1.5 Deductive and Inductive Research

When using the inductive approach the researcher develops propositions from observing the real world and generates theory from the observations (Dubois & Gadde, 2002; Kovács & Spens, 2005). The inductive approach is explained in Figure 2. As an alternative the deductive approach can be used, which works the opposite way; the researcher develops the propositions from the existing theories and makes them testable in the real world, which means that the researcher's perspective originates from the theory (ibid).

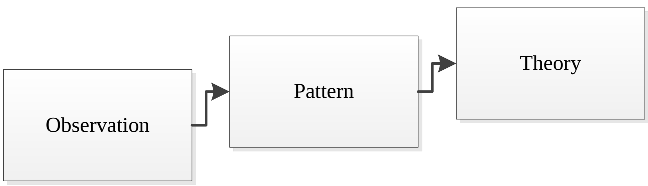


Figure 2. Illustration of the inductive approach.

To fulfill the purpose of this thesis, designing a decision support tool, an inductive approach will be taken. It will be used to identify which factors are affecting the inventory levels and to what degree they are affecting it. The factors will be identified from interviews and historical data and based on these factors patterns will be identified. The identified factors will then be compared with the theory and if there is a mismatch between the theory and the observations further analysis will be conducted to assure the validity of the factors.

2.2 Research Strategy

Höst, Regnell, & Runesson (2006) say that the research strategy describes the fundamental way to work through a study. The research strategy concerns the broad approach to the research, such as aims and design principles (Denscombe, 2010). Höst et al. (2006) have identified four strategies which they claim suitable for a master thesis: (i) survey, (ii) experiment, (iii) case study, and (iv) action research. Höst et al. (2006) describe these four strategies as follows. (i) A survey is a description of the current state of the studied object or phenomenon. The purpose of a survey is often to describe a broad question; a research question could for example be to describe how many people in a company uses a specific computer program. The design of a survey is fixed, which means that it is not possible to change questions when the survey has begun. (ii) When it comes to case studies the purpose is to study the research object or phenomenon more in depth, in order to understand how it works. The design of a case study is not fixed, which means that questions can be changed during the course of the study. One cannot make generalizations from a case study, which means that the results and conclusions are case specific. (iii) The purpose of an experiment is often to find the cause and explain what the studied phenomenon depends on, and the methodology used is often more regimented than when doing a survey or a case study. An experiment often consists of comparing two options with each other. Parameters can be studied by changing them and then repeating the experiment, in order to understand how they affect the studied phenomenon. Experiments have a fixed design; nothing can be changed when it has started. (iv) Action research is about studying something and improving it at the same time. The research begins with observing the research object, in order to identify problems and improvement possibilities. For this process a survey or a case study can be used. The next step is to suggest improvements and implement them and lastly to evaluate the solution.

The choice of research strategy depends on the purpose of the study; unless it is clear what the study is supposed to achieve, it is impossible to understand what strategy might be useful or appropriate (Denscombe, 2010). Table 1, which is adapted from Denscombe (2010), describes a framework to choose an appropriate research strategy depending on the purpose of the study.

Table 1. How the choice of research strategy is linked to the purpose of the study (Denscombe, 2010).

Strategy	Purpose of research
Survey	• Measure some aspects of a social phenomenon • Gather facts in order to test a theory
Case study	• Understand the complex relationship between factors as they operate within a particular setting
Experiment	• Identify the cause of something • Observe the influence of specific factors
Action research	• Solve a practical problem • Produce guidelines for the best practice

The chosen research strategy for this thesis is case study. The reason for this is twofold. Firstly, this master thesis will examine how the factors affect the inventory levels of the bottle caps at TAC, which corresponds well with the purpose stated for case studies in Table 1. Secondly, Yin (2007) argues that the choice of research strategy depends on the stated research questions. Case studies are preferred when the research questions are “how” and “why”, as opposed to a survey strategy when the research questions are “which”, “what”, “where”, “how many”, and “how much”. In this thesis “how” and “why” are more closely linked to the chosen research questions, which favor case study as a research strategy. However, the first research question is a “what” question, but this question is only formulated to gain the knowledge needed to proceed with question two and three. Meaning that research question one is answered within the case study and that the main focus in this thesis lies on the two latter questions that is examining the impact of the identified factors and developing a decision support tool; therefore the chosen research strategy in this thesis is a case study.

2.3 Research Design

Yin (2007) says the research design is the logical sequence or plan that connects the research questions with the empirical data and the conclusions. The research design can be seen as a plan of how to collect relevant data and analyze it. According to Yin (2007) there are four possible designs of a case study. The study focuses either on a single unit of analysis (holistic view) or multiple units of analysis (embedded view). Moreover, these two concepts can either consider a single case or multiple cases. In this thesis there is only one unit of analysis, which is presented in 2.3.1 below, and a single case studied.

2.3.1 Unit of Analysis

The unit analysis in this master thesis will be the material flow, and the information sharing connected to the material flow, of four types of caps for the Absolut Vodka bottle. TAC produces bottles with 15 different bottle caps and out of these the four largest in volume will be focused on. They are the ones with the diameter 28 mm, 33 mm and 35 mm, and the Non Refillable Cap (NRC). Throughout the rest of the thesis the four caps will simply be referred to as the caps.

2.3.2 Methods for Studying a System

The theoretical hypothesis created in the chapter Frame of Reference regarding RQ 2 and RQ 3 will be studied on TAC’s inventory system. A system is defined as a group of units, workers and machines that act and interact together toward the completion of some logical end (Law & Kelton, 1991). Law & Kelton (1991) present an approach for determining an appropriate method to study a system. There are many methods for studying a system, some of which are presented in Figure 3 (1991).

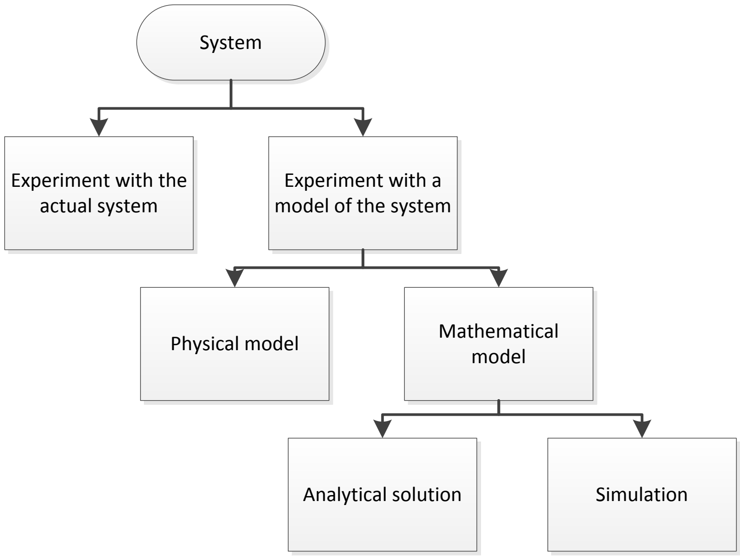


Figure 3. Ways to study a system (Law & Kelton, 1991).

The first choice when studying a system is to either experiment with the actual system or experiment with a model of the system (Law & Kelton, 1991). If it is possible and cost-effective to alter the system physically it is probably desirable to do so, as there then would be no doubts regarding the study's relevance. However, it is rarely feasible to experiment with the actual system as it would often be too costly and would possibly disrupt the system (ibid). This is also the case in this study; therefore experiments with a model will be carried out.

The second choice is to either study a physical model or a mathematical model. Examples of physical models are clay cars in wind tunnels, cockpits disconnected from their airplanes or miniatures of system. A mathematical model represents the system in terms of logical and quantitative relationships, which are then manipulated and changed to see how the model reacts (ibid). A mathematical model will be used in this thesis as an inventory system is too complex to model with a physical model.

The third and last choice is to use either an analytical solution or a simulation (ibid). The analytical solution is suitable if the model is simple enough to work with its relationships and quantities in order to get an exact analytical solution. However, if a system is complex the system is best studied with the use of simulation; that is numerically exercising the model for the inputs in question to see how they affect the output measures of performance (ibid).

To study the second research question in this thesis, how the identified factors affect the inventory levels, simulation will be used. Each factor will be studied separately leading to a simple simulation model that can easily be transferred to RQ 3. To answer RQ 3 a decision support tool will be designed, as mentioned earlier, which should be built to include simulation as a feature. This means that the user should be able to change input values to analyze the impact of each factor, and to compare different scenarios. Simulation is appropriate as the mathematical model requires several input factors creating a complex mathematical model. Furthermore, the tool should be easy to understand. This is another reason for choosing simulation, as an analytical solution for the tool would become too complex while simulation will be easier to comprehend.

2.3.3 Simulation

Simulation offers the user the possibility to evaluate different control methods in advance by testing the methods in a mathematical model that represents the real system (Axsäter, 2006). To enable a model to mimic real supply chains it often needs to be large and complex; therefore the use of computers can help considerably, particularly when the computer simulation can be built out of a series of elements where each step is of manageable and understandable proportion (Disney et al., 1997). Axsäter (2006) states that with the use of simulation it is generally possible to evaluate the development during several years in a few seconds and that it is easy to make various test runs with different inventory control techniques. Technically it is quite easy to simulate an inventory system and it can be done by the use of special simulation software or by developing a model using standard programming language (Axsäter, 2006). However, a simulation model is essentially associated with the same limitations as all other mathematical models and can never give a complete illustration of the real system, but Axsäter (2006) states that simulations can give more valuable information compared to other mathematical models if the simulation model illustrates the real system well.

A simulation model can be static or dynamic (Law & Kelton, 1991). A static simulation model represents a system at a particular time whereas a dynamic simulation model represents a system as it evolves over time (ibid). This thesis will use a static simulation model, as the support tool developed should only present the appropriate inventory levels at a particular time. The simulation model can be of deterministic or stochastic dimension (ibid). In a deterministic simulation model the output is determined by the set of input quantities and relationships that have been specified and there are no probabilistic events involved. A stochastic simulation model uses random input components, to some extent. Most queuing and inventory systems are modeled stochastically, since the input variables often act as probabilistic components. This master thesis will however use a deterministic dimension, as this is judged to be able to fulfill the purpose of this particular project. This is partly because the tool should be easy to understand and easy for users to develop after implementation, and partly because of a lack of data to ensure the credibility of the distributions of the variables needed to perform a stochastic simulation.

Spreadsheets Models

Spreadsheet software can be used effectively for analyzing logistics and supply chain issues (Smith, 2003). Spreadsheets allow analysis from many different perspectives and can be modified and enhanced to reflect new situations and options, making each spreadsheet model specific for the analysis purpose. Smith (2003) states that the methodology used for developing an integrated spreadsheet model is similar to modeling with specialized software. When using spreadsheet models the user develops a baseline model reflecting current operations and creates alternative scenarios that can be compared to the baseline scenario. An advantage with the spreadsheet model is that non-quantifiable factors and soft costs are also considered to develop a complete analysis, and that the user can analyze the impact of business decisions on any number of variables (ibid).

When developing a spreadsheet model there are generally three steps to consider (ibid):

1. Create a baseline model that mimics the current state giving an as-is model of the current setup.
2. Develop scenarios, which explore the variables affecting the model.
3. Analyze how the different values of the identified variables affect the model.

When creating the baseline model it is critical that this reflects the current state well, in order to create value when comparing the baseline with the alternative scenarios (ibid). Smith (2003) states a number of categories that generally are considered in creating the baseline model: labor and benefits (direct, indirect and supervision), inventory (cost, volume), plant and equipment (lease, deprecation, maintenance, etc.), transportation and third party expenses (driver, fuel, maintenance, monthly changes), and IT-cost related to logistics. Smith (2003) recommends that the data included in the model should be dynamic, which means that all static data that does not change over time, such as the existing number of pallet positions, should be excluded from the model. Once the baseline model has been created, its validity as a representation of the current state must be tested (ibid). The second step for using spreadsheet models is to develop alternative scenarios. When doing this it is important that the scenarios follow the same logic as in the original model; they should for example be constructed for the same time horizon (ibid). The last step when using the spreadsheet model is, according to Smith (2003), to determine and analyze the difference (delta) in total cost between the baseline model and the scenario models. In addition to the total cost, care must be taken to ensure that the scenario is fully explored, for example that all costs are identified and that the model is physically implementable.

Examples of how spreadsheet model can be used are found in Beheshti (2010) and Smith (2003). The main objective of Beheshti (2010) was to develop an optimization technique for a multi-level supply chain. He presents a decision support model for improving a supply chain’s performance and to facilitate the decision-making process performed by the business partners in the supply chain, by analyzing inventory placement in the supply chain. The article shows how a spreadsheet model with optimization techniques can provide a powerful tool when developing decision support for supply chain decisions. Smith (2003) gives an example of a major food manufacturer that has used a spreadsheet model to reduce the company’s transportation costs. The article analyzed the cost reduction of direct shipping to their largest customers by bypassing its distribution system of third party logistic operators. The spreadsheet model was used to calculate which volumes were suitable for the new scenario, and the cost of the new scenario was subsequently compared to the cost of the current situation.

In this master thesis a delimited spreadsheet model will be used to answer RQ 3. The spreadsheet model will use the factors identified in RQ 1, which have been quantified in RQ 2, together with the forecast of the production demand, to create a baseline model of the inventory levels. The factors affecting the inventory levels will be increased and decreased in different scenarios to investigate how improvements in the factors will affect the inventory levels.

2.3.4 Data Collection

This thesis will primarily use three methods of data collection: interviews, observations and operations data from TAC's ERP system BaaN. A primary focus during the data collection will be to collect first hand data to increase the reliability of the analysis.

Primary and Secondary Data

During the data collection phase it is important that the researcher classifies the collected data as either primary or secondary data. Primary data is information that is gathered particularly for the researched purpose and is collected from the source (Björklund & Paulsson, 2003). Secondary data is information that is written for another purpose or information that is collected from a secondary source (ibid). When using secondary data it is important that the researcher critically reviews the data, as it has been collected for an often unknown purpose, to assure the transferability to the researcher's purpose. The second hand data collected in this thesis will be critically reviewed and the original collector will be interviewed to understand the intended purpose.

Quantitative and Qualitative Research

Data collection can be performed through two distinct methods: quantitatively and qualitatively. The choice of method for data collection is closely linked to the purpose of the researched area and what analysis that is supposed to be made. Qualitative research primarily uses four data collection methods: observations, textual analysis, interviews and audio and video recording (Silverman, 2011). The data collected with a qualitative method primarily consist of words and descriptions (Höst et al., 2006; Silverman, 2011). Quantitative research uses experiments, surveys and statistical methods to collect the data. Quantitative data consist of data that can be counted and classified, for instance numbers, proportions and colors (Höst et al., 2006).

In this thesis qualitative data will initially be used to understand and analyze the current material and information flow, in order to identify the factors affecting the inventory levels and to answer the RQ 1. The qualitative data will be collected through interviews and observations. The findings from the qualitative methods will then be validated and further analyzed by a mixed approach with both qualitative and quantitative data to understand to what extent each factor affects the inventory levels. This will answer RQ 2. The quantitative data will be collected from TAC's ERP system and from data already collected by the employees at TAC. For the last RQ a mixed approach will also be used – quantitative data will be used to calculate the factors that can be quantified while the factors that cannot be quantified will be defined with qualitative data as constraints. The data requested from TAC's ERP-system can be viewed in Table 2.

Table 2. Data requested from TAC's ERP-system.

Requested Data	Attribute 1	Attribute 2	Attribute 3	Attribute 4	Attribute 5

Delivery reliability 2013-present	Order number	Cap type	Supplier	Ordered quantity	Delivered quantity
E.g.	3426321	28 mm	CS1	1 000 000	900 000

Delivery dependability 2013-present	Order number	Cap type	Supplier	Planned delivery date	Actual delivery date
E.g.	3426321	28 mm	CS1	140325	140330

Purchase orders 2008-20013	Date	Supplier	Cap type	Amount purchased
E.g.	140325	CS1	28 mm	400 000

Quality defects 2013-present	Cap type	Supplier	Type of defect	Defect quantity
E.g.	28 mm	CS1	Scratches	100

Warehouse transactions 2008-2013	Date	Cap type	Transaction size	Transaction type
E.g.	140325	28 mm	400 000	Receiving

Production forecast 2013-present	Month	Product type	Forecasted quantity
E.g.	14-jan	blue 1 liter	5 000 000

The following data was also requested from other sources:

1. Stocktaking report for period 2008-2013
2. Purchase price of the caps

Interviews

There are several ways to conduct an interview and in this paragraph the three most commonly used approaches will be presented; structured interview, semi-structured interview and unstructured interview. In a structured interview, all questions and the order of the questions are determined in advance and the interviewer is not allowed to deviate from the interview guide (Björklund & Paulsson, 2003). A semi-structured interview is based on pre-decided topics and the questions can be formulated during the interview to suit the respondent's answer or reaction on previous questions (ibid). The outcome of a semi-structured interview is highly dependent on the researchers experience and knowledge of conducting an interview, as it is the researcher's responsibility to lead the interview in the direction of the topic to make as much information as possible available. An unstructured interview has the structure of a conversation and questions are covered as they arise (ibid). The number of questions and the time dedicated for each interview can vary considerably.

The method of collecting data through interviews will have an important role in this thesis. To familiarize the researchers with the company a number of initial interviews will be conducted. These interviews will be held with personnel associated with the processes connected to the material and information flow of the bottle caps. For each identified process or function a person will be identified, together with the supervisor at TAC, as the process owner and chosen for interview. Regarding the processes where the owner is not the main practitioner additional interviews will be conducted with the personnel performing the activities in the process. An example of this is the incoming goods inspection where the quality control function owns the process but do not perform the actual inspection. The interviews will be conducted in a semi structured or unstructured way, depending on the respondent's role.

When the literature review has been conducted and a theoretical framework has been created the researchers will conduct additional interviews with people that have tasks linked to the purpose of the thesis. Then the respondents will recommend people for further interviews, also known as the snowball approach (Esaiasson, Gilljam, Oscarsson, & Wängnerud, 2010). These interviews will mainly be conducted during the data collection phase but can also be conducted during the analysis phase for clarification or validation. During the data collection phase the interviewees where not asked if they have experienced specific factors from the theory but they were rather asked to describe which factors they thought affected the inventory levels.

Table 3 the interviews conducted during this master thesis are presented. Included in the table is the name of the interviewee, the job title of the interviewee, the type of interview conducted, duration, main areas discussed, and the method chosen to document the interview. In this table the supervisor at TAC, Johan Ström, is not mentioned, but he has continuously answered questions throughout the project and acted as a sounding board. No records have been kept of when certain areas were discussed due to practical reasons.

Table 3. List of persons interviewed during this master thesis.

No.	Date	Name	Job Title	Type of Interview	Duration (min)	Areas Discussed	Method of Documentation
1	24 Jan 2014	Ingela Lennartsson	Master planner	Semi-structured	60	Master planning, production lines, articles	Notes
2	24 Jan 2014	Alf Fajersson	Category manager purchasing	Semi-structured	40	Purchasing strategy, supplier performance, supplier relations	Sound recording and transliteration
3	29 Jan 2014	Dan Andersson	Material planner	Semi-structured	100	Material planning, inventory levels, article characteristics, forecast, information sharing with suppliers, supplier performance, supplier relations, ordering process	Sound recording and transliteration
4	29 Jan 2014	Fredric Turner	Supervisor bottling Satelliten	Unstructured	60	Satelliten's production facilities, warehouses, current situation	Notes
5	3 Feb 2014	Christian Persson	Forklift driver	Unstructured	30	Incoming goods inspection, receiving, storing, picking	Notes
6	21 Feb 2014	Elin Nilsson	Material planner	Semi-structured	50	Material planning, inventory levels, forecast procedure, supplier performance, supplier relation, ordering process,	Notes / sound recording and transliteration
7	21 Feb 2014	Peter Olsson	Supervisor bottling	Unstructured	15	Main production facilities, warehouses, current situation	Notes
8	21 Feb 2014	Anders Persson	Quality technician	Unstructured	20	Quality error procedures	Notes
9	28 Feb 2014	Petter Andersson	Supplier quality engineer	Semi-structured	45	Quality performance, measurements, incoming inspection, order	Sound recording and transliteration

						batching	
10	28 Feb 2014	Elin Nilsson	Material planner	Semi-structured	60	EDI-system, cost of purchasing caps, supplier relations, ordering process, forecasts	Notes
11	28 Feb 2014	Dan Andersson	Material planner	Unstructured	30	Inventory levels, supplier performance, strategy material planning	Notes
12	12 May 2014	Peter Neiderud	Supply chain director	Semi-structured	80	Validating the identified factors and their impact	Notes

Observations

The researcher can collect data through observing the problems, activities or processes that are investigated (Denscombe, 2003). Observations in this thesis will be conducted to understand the processes of TAC; therefore the method for observation will be participation. To validate the reliability of the collected data an observation schedule will be decided before each observation opportunity. The observations schedule will determine which activities the observers shall focus on and ensure that the observer registers data systematically and thoroughly. At the end of each observation the observers will compare notes to ensure the reliability of the data.

2.3.5 Data Analysis

In order to answer all of the research questions the data analysis will be conducted in three steps, one for each research question. The first step consists of analyzing which of the factors affecting the inventory levels identified in the theory that can be found at TAC. Also in this step an Ishikawa diagram analysis will be performed to analyze where the factors originate from. In the second step the factors found at TAC will be analyzed to see how much they contribute to the need for inventory, that is to see how much extra stock each of the factors are causing. This analysis will be performed with simulation (described in section 2.3.3) based on historical data. The last step of the data analysis will be performed by analyzing the factors' combined impact on the inventory levels and, based on this analysis, design a decision support tool for TAC to use when setting inventory targets for the bottle caps. Also in this step a simulation will be made based on historical data, in order to validate the calculations made in the decision support tool.

2.4 Research Quality

The quality of the research in this master thesis has been assessed based the dimensions reliability and objectivity, which are important to consider when performing research (Höst et al., 2006).

2.4.1 Reliability

Reliability refers to the possibility to repeatedly get the same results when the same data is analyzed. A good reliability means that variations in the results are not dependent on the research instruments, that is the variations are only dependent on the variation in the thing being measured (Denscombe, 2010). In order to produce the same results repeatedly it is important that the research procedure is well documented in the report. In this report, the methods used for collecting data have been described in detail, in order for another person to be able to execute the same thing again. The methodology has also been peer reviewed by fellow students, currently writing their thesis at the Department of Industrial Management and Logistics, Faculty of Engineering, Lund University, and reviewed by the supervisors at the university.

Interviews are always unique and cannot be repeated in the exact same way, but a description of how the interviews were conducted and the topics discussed can be viewed in

Table 3. It is also described, in the same table, how the interviews were documented, either in the form of a recording and transliteration or by taking notes. The interviews were recorded when key people were interviewed. There were always two interviewers during the interviews, so when notes were taken one focused on asking questions and the other interviewer wrote down the conversation. Afterwards the interview was discussed between the two interviewers to make sure that both had the same view of what had been said. Regarding the collection of quantitative data, the data request made to collect data from TAC's ERP system is also documented in this report, seen in Table 2.

2.4.2 Validity

Validity concerns how appropriate and accurate the data used in the analysis is. If the validity is high, then the data reflects the truth and covers the crucial matters (ibid). Validity also involves the choice of methods; that is if the suitable indicators are measured and how accurate the produced results are (ibid). One way to improve the validity is through triangulation. In research triangulation refers to using several different methods for collecting data, in order to decide where the "truth" lies (Denscombe, 2003). In this project several sources have been used to improve the validity. Observations, interviews and written documents have been used in parallel. During the interviews, another form of triangulation has been used. In some cases the same question was asked to several interviewees and their respective answers were compared. A weakness in the documentation of the interviews is that the notes or transliterations were not sent back to the interviewees for validation of facts, but clarifying questions were asked by e-mail or in person when facts from the interviews were ambiguous or unclear. The literature review made for this master thesis also affects the validity. In order to increase the validity of this thesis only well-known databases were used when searching for literature and the articles used come from international journals.

To further specify how the validity of the results were assured the specific measures taken are described more in detail below. To assure the validity of the identified factors affecting the inventory levels at TAC, interviews were conducted were the answers where compared and triangulated. The identified factors where then compared with the theory and when a mismatch was found the factor was further investigated and discussed with the supply chain department at TAC. To validate the calculations conducted on each factors impact the head of the supply chain department at TAC where introduced to the factors and their impact to assure that they reflected the reality. To assure the accuracy of the empirical data, collected from the ERP system, the authors compiled summaries of the used data and validated them by getting them approved by TAC. In the case where the data did not reflect the reality the data was reviewed together with TAC. In order to avoid personal opinions and inaccurate information, interviews have been held with as many persons as possible. By doing so, the accuracy of the information gathered has been increased by including several persons view on the matter. Unfortunately, this was not possible for all discussed topics and for these the risk of inaccurate information is greater.

2.5 Research Process

Before the purpose and the research question of the study at TAC could be defined a pre-study was made. The pre-study started with exploratory interviews and observations over the entire material and information flow of the caps. To support the pre-study a brief literature review of mapping techniques was conducted. In the pre-study a wide scope was used to get an understanding of the caps' material and information flow, but also to find out how TAC works with their suppliers and customers. During the pre-study an initial data collection was conducted to establish what data was available. The research questions were defined based on the findings in the pre-study. The procedure for the pre-study is illustrated in Figure 4.

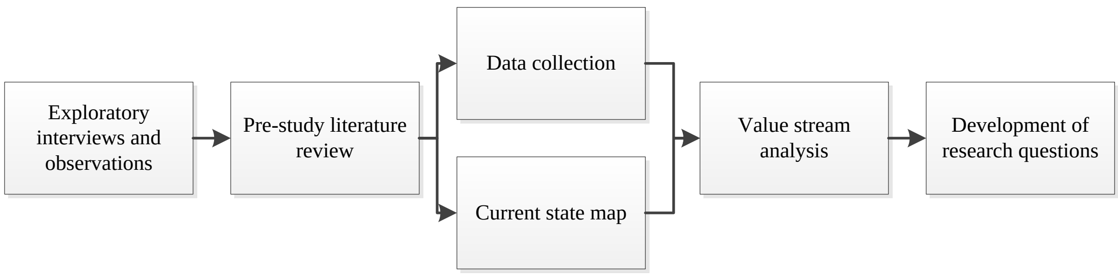


Figure 4. Pre-study procedure.

From the findings in the pre-study a case study was designed. The first step in the case study was to conduct a literature review to establish a theoretical framework. To be able to compare the collected theory with the situation at TAC additional empirical data was collected. The collected data was then used to analyze which factors at the company corresponded to the factors identified in the theory, and to answer RQ 1. When these factors had been identified the impact of each of the factors were analyzed to answer RQ 2. Based on this analysis a decision support tool was developed to answer RQ 3. The tool was then tested on historical data and validated based on discussion with people at TAC. With the use of the decision support tool a conclusion and recommendation was presented. The case study procedure can be viewed in Figure 5.

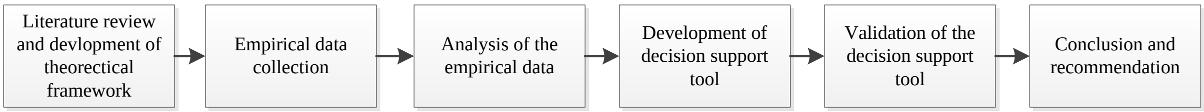


Figure 5. Case study procedure.

2.5.1 Literature Review Case Study

All research should start with a literature review. In addition to collecting information the literature review should assure the reader of the study's validity. According to Denscombe (2003) the literature review should assure the reader that the authors are aware of the previous work that has been conducted in the field that is studied. The literature should also give guidance to the reader of what the authors consider being the main problem areas, the critical questions and if there are any gaps in the previous conducted research (ibid). The literature review should also clarify whence the authors have collected their theory and principles (Denscombe, 2003; Esaiasson et al., 2010).

The literature review concerning the case study was conducted in order to develop an analytical framework for analyzing the empirical data, as stated previously. The literature search was divided into two phases, based on the research questions. Firstly, the literature review focused on factors that affect inventory levels and methods for identifying factors that affect the inventory levels at a specific company. Search phrases such as *factors affecting inventory levels*, *reasons for holding inventory* were used. The findings were used to identify factors that contribute to TAC's need of holding an inventory of caps. The factors found were then used when performing the second phase of the literature review. In this phase the focus was on developing deeper knowledge in how the different factors can affect the inventory levels. Different methods or tools for determining appropriate inventory levels were also investigated during this phase. Search phrases such as *inventory control*, *forecast error*, *quality defects*, *delivery accuracy*, *lead time*, *safety stock* and, *determining inventory levels* were used during this search.

Both phases of the literature review search were performed mainly in the database Web of Science, but also in the databases Emerald Insight and Lund University's online library Lovisa. Moreover, the literature used in previous courses during the authors' studies (MS in Industrial Engineering and Management, at Faculty of Engineering, Lund University) was used to complement the literature found in the previous searches.

2.6 Summary of the Methodology

A summary of the methodology has been made (seen in Figure 6) in order to give the reader an overview of what has been presented in this chapter.

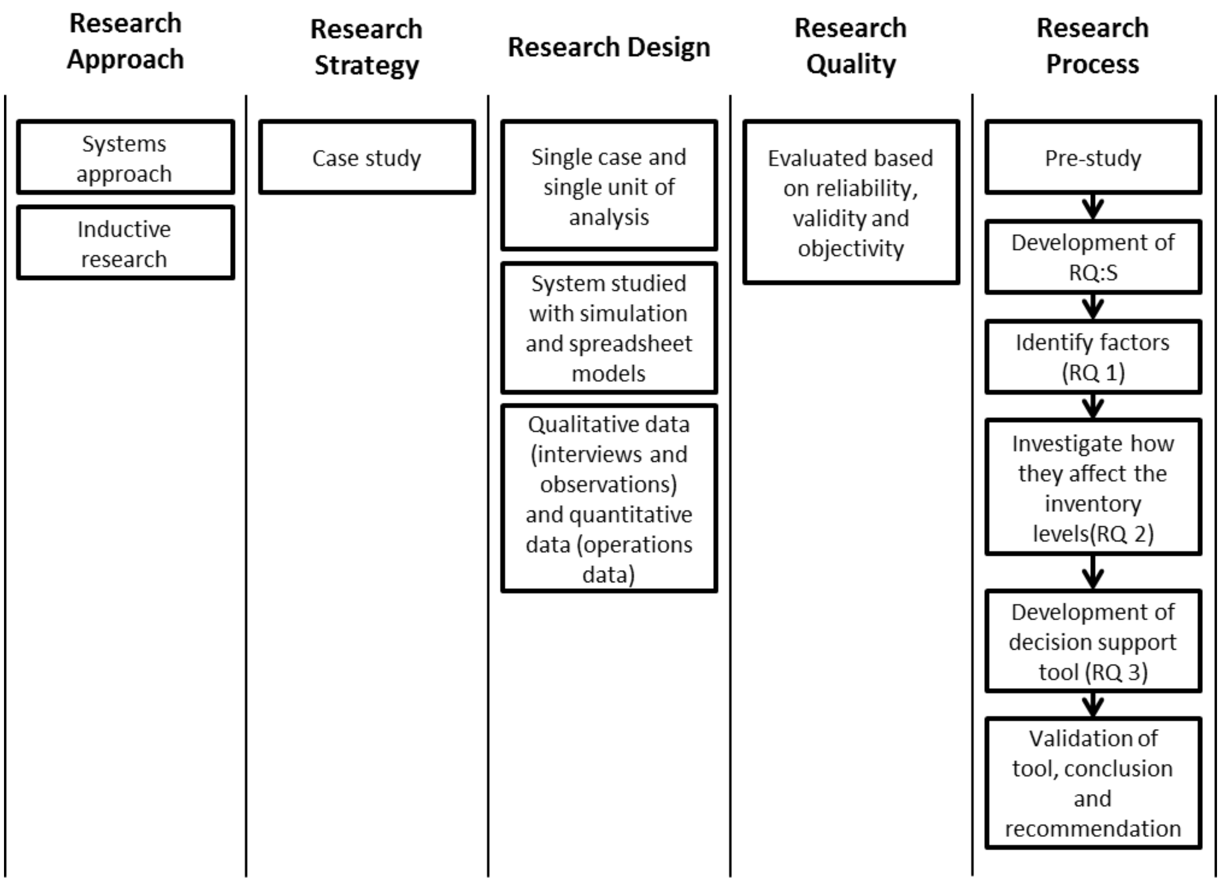


Figure 6. An overview of the methodology chapter.

The research approach for this thesis is a systems approach and the research is performed inductively. A case study has been chosen as research strategy and the design of the case is single case and single unit of analysis. The system is studied through both qualitative (interview and observations) and quantitative data (operational data from TAC's ERP system). The quality of the research is evaluated based on the dimensions reliability, validity and objectivity. The research process starts with a pre-study followed by the development of the three research questions, then the questions are answered, and lastly the tool is validated and conclusion and recommendation are presented.

3 Frame of Reference

This chapter presents the theoretical framework which is later used when analyzing the empirical data and designing the decision support tool.

3.1 Introduction

The theory presented in this chapter consists of factors that affect the inventory levels in a manufacturing company and theory regarding inventory control. These two will in a later stage of the thesis be combined into a decision support tool, as illustrated in Figure 7. Theoretical factors will be identified from the literature and out of these a framework will be created, in the form of a list of factors that can be compared with the predominant factors regarding caps at TAC. As a starting point for the identification of factors, four authors' views of the reasons for holding inventory are presented. These reasons or main factors will then be merged into five groups of factors that are considered to affect the inventory levels of raw materials for a manufacturing company. The theory regarding inventory control will present tools, concepts, costs and models that will serve as a basis for the calculations performed in the decision support tool.

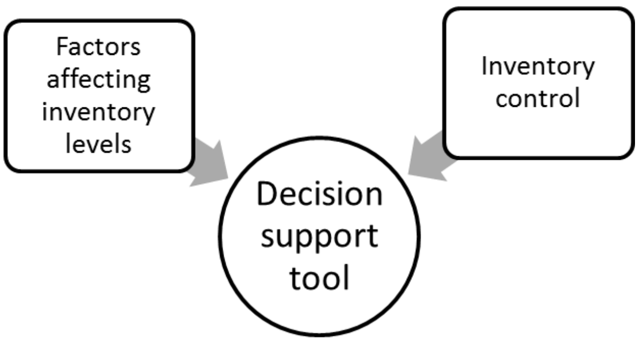


Figure 7. How the theory will be combined into the decision support tool.

3.2 Factors Affecting the Inventory Levels of Raw Materials

Inventory have been divided in several different ways in the literature, but the components raw materials inventory, work-in-process (WIP) and finished goods inventory are commonly used concepts (Gattorna, Day, & Hargreaves, 1991; Hopp & Spearman, 2001; Howard, 1984; Mattsson & Jonsson, 2003; Nahmias, 2009). This thesis will focus on factors affecting the size of the inventory for raw materials. Included in the raw materials inventory are the resources required in the production or processing activity of the company (Nahmias, 2009). Examples of included inventory are raw materials, details, purchased components and sub-assemblies (Mattsson & Jonsson, 2003). As mentioned in the introductory chapter, there are several reasons why a company needs to keep an inventory of raw materials. If the raw material would arrive literally just-in-time, it would not be necessary to keep any inventory, but since this is not possible all manufacturing systems carry stocks of raw material (Hopp & Spearman, 2001).

Hopp & Spearman (2001) have identified three main factors that affect the size of these stocks. The first factor is *batching,* which can occur for example when discounts are given from the supplier when ordering bigger batches, when the plant's purchasing function has a capacity limitation of how much order processing they can handle, or when the company takes advantage of economies of scale in deliveries. The second factor that has been identified is *variability*. This could for example be that more is produced than expected, the supplier gets behind schedule, or quality defects causing excessive scrap loss. The third factor is *obsolescence*, which is when material in stock is no longer needed in the production. Hopp & Spearman (2001) have also identified factors that affect the size of the finished goods warehouse, but the factors are also in some cases affecting the size of the raw materials warehouse directly or indirectly. Firstly, they mention *customer responsiveness*, which is how responsive the supply chain is towards the customer. It includes choices such as the customer order decoupling point (make-to-stock, assemble-to-order, make-to-order or engineer-to-order) and desired level of customer service. The second factor is *batch production* – the output of production does not match the pre-specified quantities (batches) and the excess inventory goes to the finished goods inventory. As the third factor they state *forecast error,* which is the stock built when the sales are less than anticipated. The fourth factor is *production variability,* for example variability in production timing or variability in production quantity. Lastly, they mention *seasonality* as an approach for dealing with demand that varies with season; stock is built during the off-season to meet demand during peak season.

Chopra & Meindl (2013) discuss four major inventory-related decisions that need to be considered when determining inventory levels. The first one is *cycle inventory,* which is the stock needed to satisfy the demand between supplier shipments. Its size is affected by production, transportation and purchasing in large lots. Companies are taking advantage of economies of scale, which affect how big the batches will be for production, transportation and purchasing. The second inventory-related decision is *safety inventory*. It is used to counter variability in demand, or more specifically to safeguard against demand that exceeds expectations. The third decision is *seasonal inventory,* which is used to counter predictable seasonal variability in demand. Some companies find it beneficial to build up inventory when the demand is low and use it when demand is higher than the plant's capacity. The fourth and last decision is *level of product availability*. If the level of product availability is set to be high it will result in bigger stocks and vice versa. A high level of product availability provides high responsiveness, but will also result in high inventory holding cost.

Silver, Pyke & Peterson (1998) have divided the inventory into four components: cycle stocks, safety stocks, frozen stocks and anticipation stocks. They define the four components in the following way. *Cycle stocks* are the result of items produced or purchased in batches. *Safety stocks* are supposed to protect against uncertainty in demand and supply during the lead time. *Frozen stocks* are lead times in the supply chain and process constraints, such as goods awaiting clearance from quality inspection. *Anticipation stocks* are sometimes created in order to cover for demand peaks that exceed available production capacity.

Nahmias (2009) discusses motivation for holding inventory, which consists of seven factors. The factor *economies of scale* refers to producing products in batches instead of one by one, in order to decrease the fixed setup cost. *Uncertainties* motivates inventory by countering for example uncertain external demand, uncertain lead time or an uncertainty in supply. *Speculation* is about trying to speculate how the future will turn out, by for example purchasing materials that are expected to increase in price in the future. *Transportation* is in-transit or pipeline inventory. When the transportation times are long the investment in pipeline inventories can be considerable. *Smoothing* aims at leveling, for example, the needed production capacity by storing finished goods, so that it can be used during peak-period when the production capacity is not enough. There are two types of changes in demand: deterministic and random. Seasonality is a type of deterministic change in demand, while random changes cannot be anticipated. *Logistics* is also a motivation for keeping inventory; it refers to certain constraints that can arise in the supply chain that forces the company to keep inventory, like for example an article that has to be purchased in minimum quantities. The last factor Nahmias (2009) discusses is *control costs,* which is the cost of maintaining the inventory control system – a system where more inventory is carried generally requires less effort to control than a system where the inventory levels are kept to a bare minimum. Therefore it can sometimes be more cost-effective to keep large inventories of inexpensive items than to use the workers' time to manage these items in detail.

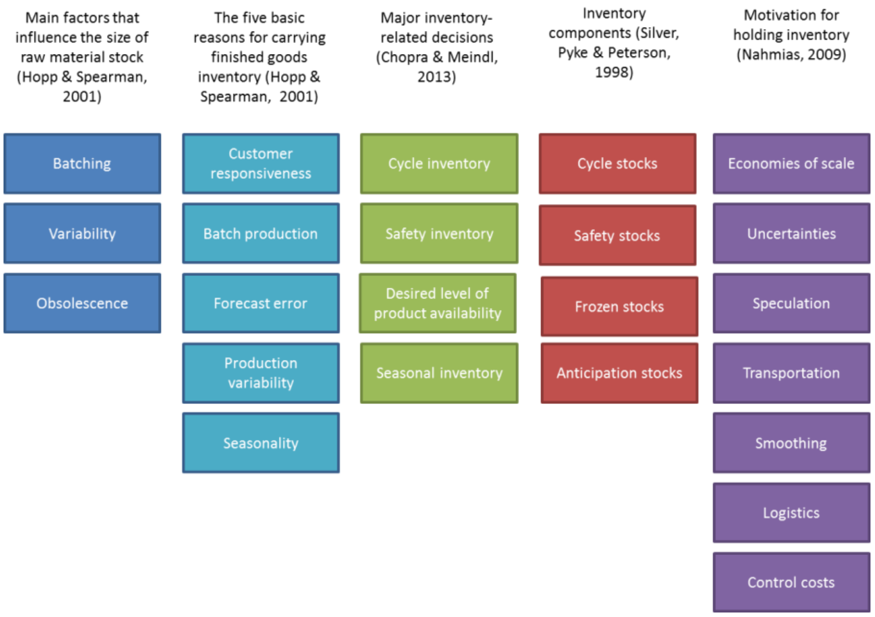


Figure 8. Overview of the main factors affecting the size of inventory.

In Figure 8 an overview of the factors discussed above can be viewed. It is noticeable that the five groups of factors overlap each other, for example cycle inventory and cycle stocks almost share the exact same formulation. In order to create a framework with factors to use when analyzing TAC's inventory of caps, the four groups of factors presented above have to be merged where the factors overlap. The new groups can be seen in Figure 9 and the motivations for the mergers of factors can be viewed in Appendix A: Mergers of Factors. From the merger five factors emerge, or more correctly five groups of factors are defined. For example, there are several factors affecting the safety inventory. The new groups are: cycle inventory, safety inventory, seasonal inventory, desired level of product availability and obsolescence. When merging the factors new names had to be chosen; for simplicity the names by Chopra & Meindl (2013) were chosen, with the addition of obsolescence that was not mentioned by the previously mentioned authors. The new groups will include all the factors mentioned earlier, but merging them into groups was considered necessary to get a better structure. As mentioned, the new groups are broad, so before they can be used to analyze TAC's business they have to be understood better and the factors included in the groups have to be identified. Therefore, the groups are discussed in greater detail below.

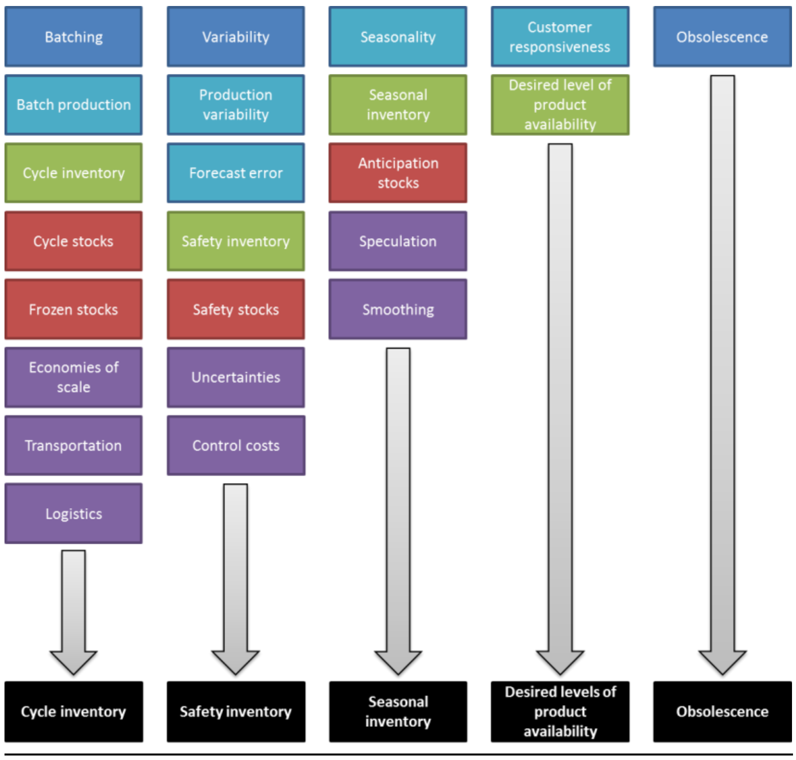


Figure 9. Illustration of which factors were merged.

3.2.1 Cycle Inventory

There are also other definition of cycle inventory (CI), apart from the definition from Chopra and Meindl. Stock & Lambert define CI as "inventory that results from the replenishment process and is required in order to meet demand under conditions of certainty" (1987, p. 399).

Other definitions of CI are “working stock”, “base stock” and “lot-size stock” (Larson & DeMarais, 1990). The CI can vary between zero and *Q* (lot-size/batch quantity) units, with the average value of *Q/2,* when assuming constant sales and inventory depletion (ibid).

Batching

A lot or a batch size is defined as “the quantity that a stage of a supply chain either produces or purchases at a time” (Chopra & Meindl, 2013, p. 283). Batching is the reason why CI is needed in a supply chain (ibid.). It is common that the supplier gives discount on the price per product for larger orders compared to smaller orders, since smaller order often require the same amount of work, in terms of production, administrative processing and physical processing (Weele, 2010). Sometimes the supplier sets a constraint in the form of a minimum purchase quantity, which may force the purchasing company to order more than needed. This type of constraint that motivates holding inventory Nahmias (2009) is included in the logistics factor. Another example of the logistics factor is the logistics of manufacture, which refers to the fact that it is practically impossible to reduce the inventories to zero and still have continuity in the manufacturing process.

Figure 10 illustrates how batching affects the inventory levels. However, it should be mentioned that the figure differs from the reality in the way that the lead time (*L*) is assumed to be zero and the demand constant.

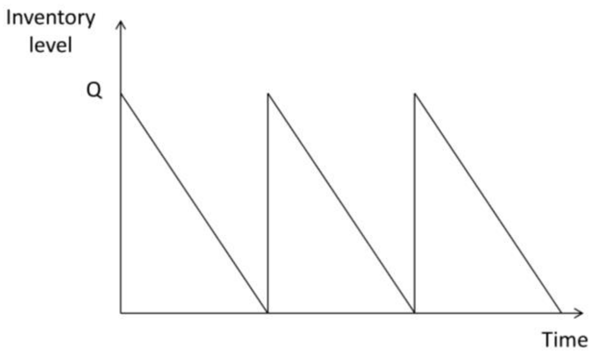


Figure 10. How the inventory level develops over time.

There are many ways to calculate the order quantity. Mattson & Jonsson (2003) discuss the following methods: (i) according to need, (ii) approximated order quantity, (iii) economic order quantity (EOQ), (iv) variations of the EOQ, (v) approximated coverage time, (vi) economic coverage time, (vii) Silver-Meal and (viii) lowest total cost. The EOQ model is one of the most recognized models in the inventory control area used to calculate the optimal order quantity. The definition according to Axsäter (2006) is shown below. Let *h* be the holding cost per unit and time, *A* ordering or setup cost, *d* demand per time unit and *Q* batch quantity. Then the EOQ is defined as

$$EOQ = \sqrt{\frac{2Ad}{h}} \quad (3.1)$$

The model 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.

The EOQ model should in theory eliminate stock outs and calculate the batch quantity that gives the lowest cost. However, in reality the demand is seldom constant and continuous, which is one of the assumptions in the model; therefore it is hard to use the model in practice.

Supplier Lead Time

Lead time, denoted as L, is defined as the gap between when the order is placed and when it arrives (Chopra & Meindl, 2013). The lead time forces companies to order in batches, which adds to the cycle inventory. Companies also have to counter for variability in demand during the lead time, meaning that longer lead time will increase the need for safety inventory (ibid). Furthermore, Howard says that “The length of lead time directly affects the size of the capital investment in inventories.” (1984, p. 5). By decreasing the lead time the company can decrease the uncertainty of demand during the lead time. It is especially beneficial to reduce the lead time for seasonal items since multiple orders can be placed with a substantial increase in the accuracy of the forecast (Chopra & Meindl, 2013). However, a reduction in lead time requires a significant effort from the supplier, while the reduction in safety inventory occurs at the purchasing company. Therefore it is important to share the benefits resulting from such an agreement (ibid). Transportation is included in the lead time, and as mentioned earlier a long transportation time can affect the stocks considerably. This factor has motivated many companies to establish production domestically (Nahmias, 2009). Figure 11 shows the different components included in the replenishment lead time, which is adapted from Mattsson & Jonsson (2003). Howard (1984) also makes a similar division of the lead time, but he uses different names for the components. In this thesis the main focus will be on the delivery time, which includes the supplier’s delivery time and the transportation time.

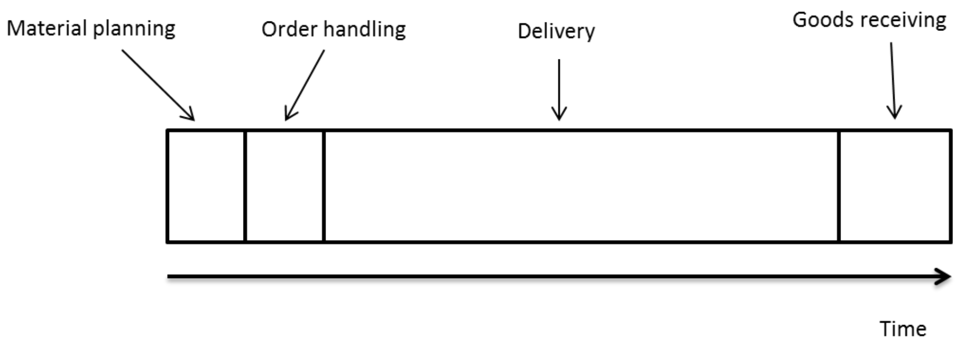


Figure 11. Replenishment lead time, adapted from Mattsson & Jonsson (2003)

3.2.2 Safety Inventory

As mentioned earlier safety inventory (or "safety stocks", or "buffer stocks") serves as a buffer to counter for variations in for example demand or lead time. In all types of material planning there are uncertainties, for example regarding how much will be produced and sold in the future and how well the supplier will meet delivery agreements regarding quantity and time. In order to safeguard against these types of uncertainties there are two methods that are commonly used: safety stock and safety time (Mattsson & Jonsson, 2003). Safety time is when the goods are ordered to arrive before they are needed, and safety stock is when the goods are ordered to always remain above the safety level (Hopp & Spearman, 2001). When using safety time an order should be delivered at least one safety period before it is needed (Axsäter, 2006). The safety stock is defined according to Axsäter (2006) as

$$SS = R - \mu' \tag{3.2}$$

R is the reorder point

μ' is the expected demand during the lead time

There are two ways to calculate the safety stock/safety time. The first method is to do it manually or with simple calculations. Normally, when using this method, the dimensions of the safety stock/safety time are not connected to a goal you want to achieve, such as a pre-defined service level (see section 3.2.4). The second method is to do advanced calculations with a set goal, for example optimizing the safety stocks with respect to the desired service levels (Mattsson & Jonsson, 2003). An example of how to calculate the SS is to assume that S is the maximum daily sales, s is the expected daily sales and the lead time L is certain. Then a 100 percent service level can be achieved with the following equation (Larson & DeMarais, 1990).

$$SS_{100\%} = t(S - s) \tag{3.3}$$

However, in order to determine the exact level of safety stock three factors must be considered: (i) the possible variation in replenishment lead times, (ii) variation in demand over the lead time and (iii) the service level policy of the company (Gattorna et al., 1991). The same authors say that it is not easy to determine an exact safety stock level due to the probabilistic nature of the fluctuations in demand and lead time, which usually makes it necessary to employ simulation to come up with a satisfactory answer to safety stock problems.

Forecast and Forecast Error

There are many reasons why a company needs forecasting. The lead time from the suppliers creates incentive to forecast the production demand to know how much to purchase out of each article (Mattsson & Jonsson, 2003). There are also economic benefits in ordering batches corresponding to full trucks. However, the forecasts are not always accurate, which results in the need of a safety stock to safeguard against a greater customer demand than expected. In order to know how much extra stock is needed the forecast uncertainty, or the forecast error, must be estimated.

The accuracy of the forecast affects the size of the safety stock, because with an uncertain forecast, a larger safety stock is required (Axsäter, 2006). Improved forecasting can help improve the company's profitability considerably by decreasing excess inventory and minimizing lost sales due to understocking (Chopra & Meindl, 2013). Improved forecasting can be achieved by understanding the customers better and by coordination actions within the supply chain (ibid.). A company must also consider their sourcing strategy when deciding how accurate a forecast is desired. If several sourcing options with short lead times are available, the forecast is not as important as it would be with only one supplier and a long lead time (ibid.).

Regarding forecast error, the most common way to describe variations around the mean is to use the standard deviation (Axsäter, 2006). Let X be a stochastic variable with mean $m = E(X)$. The standard deviation is defined as

$$\sigma = \sqrt{E(X-m)^2} \tag{3.4}$$

Due to tradition, it is not common to use the standard deviation when calculating the forecast error; instead the Mean Absolute Deviation (MAD) is used (Axsäter, 2006). This is defined as

$$MAD = E|X-m| \tag{3.5}$$

If the forecasting system works as it should, then the calculated standard deviation or MAD can show how much the demand is expected to deviate from the forecast (Axsäter, 2006).

There are also other methods for evaluating the forecast's performance. The most popular measure used in practice is the Mean Absolute Percentage Error (MAPE), but this has long been criticized for not taking into account the demand volume, which can cause extremely high percentage errors arising from relatively low actual demand values (Davydenko &

Fildes, 2013). Therefore, Mean Absolute Scaled Error (MASE) was developed to overcome the disadvantages with MAPE (Ibid). Below the two methods are defined.

$D_1, D_2, \dots, D_t$ is actual demand for that period

F_t is the forcast made for period t in period t-1

$e_t = F_{t-\tau} - D_t$ is the forecast error for multiple-step-ahead forecasts

$e_t = F_t - D_t$ is the forecast error for one-step-ahead forecasts

n is the number of periods

$$MAPE = \left(\frac{1}{n}\sum_{i=1}^{n}\left|\frac{e_i}{D_i}\right|\right) \cdot 100 \tag{3.6}$$

$$MASE = \frac{1}{n}\sum_{t=1}^{n}\left(\frac{|e_t|}{\frac{1}{n-1} \cdot \sum_{i=2}^{n}|D_i - D_{i-1}|}\right) \tag{3.7}$$

Quality Defects

Another factor that is causing variability and hence increased stock is the factor quality defects. Quality defects increase the need for larger inventory levels since the company needs to ensure availability of material for production even when quality issues occur (Mattsson & Jonsson, 2003). The quality defects can be measured as the fraction of inventory lost due to defects. Quality losses, which is the term used as a measurement for the amount of quality defects, hurt both the financial performance and the responsiveness of the company (Chopra & Meindl, 2013). To calculate the quality losses, the definition of quality must be determined. There are numerous definitions of what quality is and Hopp & Spearman (2001) give five examples. The first view is the transcendent view, stating that quality refers to an "innate excellence", which means that quality is not a specific attribute but is recognized when seen. The second view is the product-based view, which states that quality is a function of the attributes of the product. This view is a "more is better" approach where for example the quality of an automobile bumper is determined by the dollars of damage caused by a five-mile-per-hour crash. The third view is the user-based view, where the quality is determined by how well the customer preferences are satisfied. In practice high quality means that the customer values, in terms of features, durability, aesthetics, etcetera, are met. The fourth view of quality is the manufacturing-based view. According to this view quality is determined based on how well the produced goods comply with the specifications. This definition of quality directly refers to the process of manufacturing the products. The last view is the value-based view. From this view the quality is determined jointly by the performance and the price of the product. The price determines the quality of the product, i.e. a product with a high price could perform well but if a low cost product can perform equally well, the cheaper product is considered to have a better quality.

Delivery Reliability and Dependability

According to Mattsson & Jonsson (2003) delivery reliability refers to the extent to which the deliveries are made at the agreed date. A measure for calculating the delivery reliability is the number of deliveries delivered at the agreed date in relation to the total amount of deliveries (Mattsson & Jonsson, 2003). This measure tells the delivery reliability in percentage, and the definition of deliveries made at the right date can be customized to suit each company. For example, a company can allow the delivery to be delivered a number of days ahead of schedule and still consider it to be on time. The same goes for the deliveries made after the agreed date, but it is important that the time window is well-defined to avoid unclearness.

Delivery dependability is defined by Mattsson & Jonsson (2003) as to which extent the supplied products correspond to the ordered products, in terms of quantity and that the right article is delivered. The delivery dependability can be calculated in percentage by dividing the number of accurate deliveries with the total number of deliveries (Mattsson & Jonsson, 2003). Both delivery reliability and delivery dependability affects the inventory levels. Early deliveries require warehouse space before the ordering department scheduled it which can lead to an increase in the warehouse utilization (Bartholdi & Hackman, 2010; Mattsson & Jonsson, 2003). The increased utilization in the warehouse can affect the warehouse operations in terms of lowering the efficiency, for example by increased double handling (Bartholdi & Hackman, 2010). Late deliveries and inaccurate deliveries, in terms of quantity and article type, lead to the company purchasing the components being forced to carry more inventories to ensure the availability of components (Mattsson & Jonsson, 2003).

Component Commonality

For many companies it is crucial to use one component for several products in order to decrease the variability and to keep the raw material stocks at a reasonable level. An example of this is a PC manufacturer who needs hundreds of components for a single computer; if every component would be unique for each computer and the manufacturer would produce a large variety of products, the stock would grow very large (Chopra & Meindl, 2013). Without common components, the uncertainty of the component is as high as the uncertainty for the finished product, but when designing common components the demand for several products can be aggregated and thereby the uncertainty for the component is lowered. Hence, the required safety inventory is decreased (Chopra & Meindl, 2013). Furthermore, when taking advantage of component commonality one can also order in bigger batches and thereby benefit from economies of scale.

Control Cost

Control cost refers to the cost of operating the inventory control system, which includes costs for data collection and computation and costs for training the involved personnel (Axsäter, 2006). Nahmias (2009) states that the control cost is often overlooked, and even though control cost is an important factor when determining a suitable inventory control technique or system it is rarely included in the analysis (ibid). Jonsson & Mattson (2005) stresses the fact that when making decisions regarding changes in the logistics system it is important to consider the total cost to get a holistic view. A new advanced inventory control system might improve the inventory levels drastically, but the cost of operating it might be higher than the gains received by the lowered inventory holding cost. As mentioned before, it might be cost efficient to have high stock levels on inexpensive items, and therefore the safety inventory level will be affected by this factor.

3.2.3 Seasonal Inventory

Chopra and Meindl considered the seasonal inventory only as a counter for seasonal demand variations, but in this thesis it will also include speculation stock. Larson & DeMarais (1990) includes the following in speculation stock: inventory held in advance of seasonal demand, inventory procured due to expected increase in price, inventory held due to anticipated changes in demand or supply. Speculation is a result of market fluctuations, where companies purchase larger quantities due to expected price increases (Nahmias, 2009).

Many products experience seasonal variation, for example ice cream and lawn mowers have an increased demand during the summer, which will affect the accuracy of the forecasts (Hopp & Spearman, 2001). In the occurrence of seasonal demand it is not appropriate to use the average demand and standard deviation calculated over the year when determining reorder-points and stock levels. The values for average demand and standard deviation must be adjusted over the year to match the difference in demand. Furthermore, corresponding changes need to be made for the reorder points, order-up-to-levels and safety inventory levels (Chopra & Meindl, 2013). Winters (1960) presented a way to include the seasonality in the forecast by dividing the season into N periods. Each period’s demand is divided with the average demand for the whole season in order to get a ratio for each period. This means that the sum of the periods’ ratios always will be equal to N. With the use of historical data the forecasts can be smoothed, by comparing the outcome of previous years with the outcome of the current period (Winters, 1960).

3.2.4 Desired Level of Product Availability

The safety inventory is also linked to the desired level of product availability, which can be expressed in a service level. The size of the safety inventory is affected by the uncertainty of supply and demand and the desired level of product availability (Chopra & Meindl, 2013). Axsäter (2006) describes three common definitions of service levels:

- S_1 – Probability of no stock out during an order cycle.
- S_2 – Fraction of demand that can be satisfied immediately from stock on hand. Also called fill rate.
- S_3 – Fraction of time with positive stock on hand. Also called ready rate.

An advantage with S_1 is that it is easy to calculate. However, there are also some major disadvantages. For example, it does not take the batch quantity into account, which means that if the batch quantity is very big and meets the demand over a long time the real service can be good, with the S_1 being poor at the same time (Axsäter, 2006). S_2 and S_3 are harder to calculate but they represent the true service level better, since they also consider the batch quantity. In the case of continuous demand or Poisson demand S_2 and S_3 are equivalent (Ibid). Furthermore, the service level can vary greatly when comparing the service levels for complete orders, delivered order lines and number of delivered articles (Mattsson & Jonsson, 2003). To exemplify how the measurements can give different service levels an example from Mattsson & Jonsson (2003) will be illustrated below.

$$\text{Fraction of complete } \textit{orders} \text{ immediately satisfied} = \frac{0}{3} = 0\%$$

$$\text{Fraction of complete } \textit{orders lines} \text{ immediately satisfied} = \frac{6}{11} = 45\%$$

$$\text{Fraction of } \textit{units} \text{ immediately satisfied} = \frac{1078}{1245} = 87\%$$

Hence, it is important that the goals are defined with appropriate measurements and that the availability is measured as it is defined. Moreover, Chopra & Meindl (2013) stress the fact that the overall trade-off is between responsiveness and efficiency. They say that higher inventory levels generally makes the supply chain more responsive, while it also facilitates a reduction in transportation and production costs, because of the improved economies of scale. However, increased inventory also increases the inventory holding cost. Fisher (1997) discusses the difference in an efficient and responsive supply chain and states the importance of matching the supply chain to the product. The supply chain can be identified either as efficient or responsive. The efficient supply chain is characterized as predictable, with a high utilization rate in the production, high turnover in inventory and the suppliers are primarily chosen based cost and quality. The responsive supply chain is characterized by a volatile demand, with excess buffer capacity and suppliers are primarily selected based on speed, flexibility and quality (ibid). Regarding the product, it can be identified either as a functional or an innovative product. The functional product is characterized by a long life cycle, a low product variety, an accurate forecast, a low stockout rate and no markdown of the price in the end of the season, while the innovative product is characterized by a short life cycle, a high level of product variety, large forecast errors, large stockout rate and a high end of season markdown (ibid). A mismatch of the supply chain and the product hampers the ability to meet customer demands by having inaccurate levels of product availability, increased costs and excess inventory (ibid).

Howard has identified three costs related to inventory, “which may be involved in balancing the conflicting objectives for inventory” (1984, p. 5). The first cost is ordering or set-up cost, and for bought-in items it includes all costs related to the actual ordering process. The second cost is the inventory carrying cost (also discussed in 3.3.1), which includes all expenses needed to maintain inventory. It includes (i) obsolescence, (ii) deterioration (damaged or spoiled material that no longer can be used), (iii) taxes (on holding inventory), (iv) insurance, (v) storage, (vi) cost of capital. The third cost is the stockout cost, which includes all costs related to a shortage. It includes costs such as backorder cost and losses in profits due to lost sales. Backorder costs consist of extra paper work needed, loss of return of capital and loss of customer goodwill due to failure in delivering the order in time. Howard (1985) continues to say that the stockout cost is hard to estimate, and is normally controlled with the adoption of service levels, which involves an implicit estimation of the cost of a stockout.

3.2.5 Obsolescence

Perishable products have a fixed lifetime known in advance, like food, pharmaceuticals and photographic film. Obsolescence differs from perishability in that the lifetime subject to obsolescence cannot be predicted in advance (Nahmias, 2009). Obsolete inventory is measured as the fraction of the inventory older than a specific date (Chopra & Meindl, 2013). The cost, financially and in lost inventory, for the obsolete articles is estimated with the rate of which the article's value drops, which is based on the falling market value and quality of the article. This cost can vary dramatically between articles, as much as many thousand percent depending of the article type (ibid). Perishable products have a high obsolescence rate and even non-perishable products can have a high obsolescence rate if they have a short product life cycle. Therefore both the factor of perishability and the factor of obsolescence affect the inventory level and they should be investigated separately.

The product life cycle is the time when it is financially justifiable to sell a product. The product life cycle is determined by either the technical or the economical product life (Jonsson & Mattsson, 2005). The technical product life is the time period before the article's technology is out of date, while the economical product life is the time period before it becomes financially unjustifiable to sell. During a product life cycle different maturity phases occur. There is an introduction phase, a growth phase, a maturity phase and a decline phase, which can be viewed in Figure 12 (ibid). These phases affect the accuracy of the forecasts. During the maturity phase the demand is reasonably stable and the volumes are large, making it the easiest phase to forecast. In the other three phases the demand is harder to predict, making the forecast less accurate (ibid).

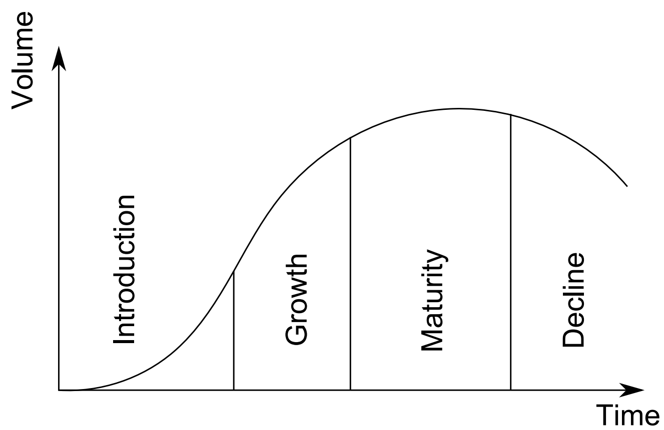


Figure 12. The product life cycle and the maturity phases.

3.2.6 Summary of Factors

From the five main factors several "sub-factors" have been derived that can be viewed in Figure 13. This list of factors will later be used when analyzing TAC's material and information flow of caps. The "long list" of factors are: purchase batching, production batching, supplier lead time, forecast accuracy, quality defects, delivery reliability, delivery dependability, component commonality, seasonality, anticipation stock, desired level of product availability, obsolescence and perishability.

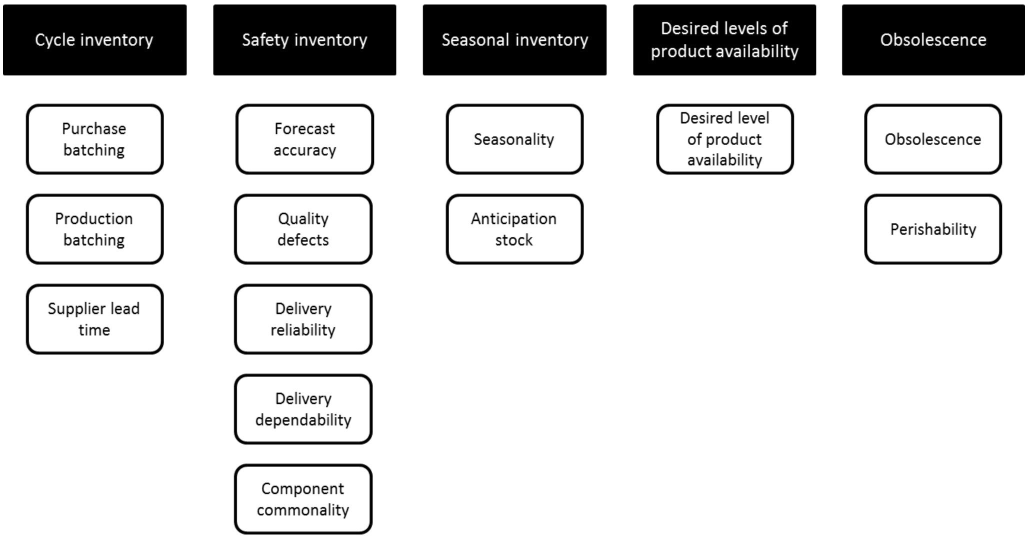


Figure 13. List of factors that will be used for analyzing the material and information flow of caps at TAC.

In addition to the factors that are easily identified, there are also problems hidden due to excess inventory, which is discussed in the Lean manufacturing philosophy. Lean manufacturing is a well-known concept in the manufacturing industry. It focuses on identifying what are value-adding and non-value-adding activities and to eliminate waste within the system. One of the seven identified wastes is unnecessary inventory (Pepper & Spedding, 2010). Apart from the increased inventory holding cost that comes with excess inventory, there are other reasons for lowering the inventory levels – the inventory can hide problems that are not obvious. Unnecessary inventory can increase the lead time, cause shortage of space, prevent rapid identification of problems and thereby impede communication (Hines & Rich, 1997). One manufacturing philosophy to identify the hidden problems is the Japanese sea (Ståhl, 2012). The Japanese sea was developed from the concept of removing all inventories in order to identify problems in the company's logistics processes. In other words, lowering the inventory levels discloses problems that were previously hidden (ibid). In practice the process of the philosophy is a cautious step-by-step lowering of the inventory levels to identify the first hidden problem. After the problem is identified the inventory levels should be raised until the issue is handled. Then the process of identifying the next hidden problem starts over again with a step-by-step lowering of the inventory levels (ibid). The Japanese sea is illustrated in Figure 14. The inventory lines A and B represent different inventory levels.

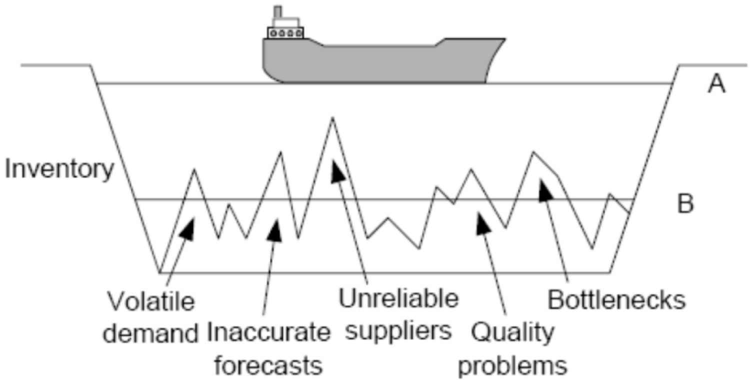


Figure 14. The Japanese sea where the inventory hides the problems (Karwowski & Orlowski, 2010).

3.3 Inventory Control

For more or less all organizations in any sector of the economy Supply Chain Management is crucial to manage (Axsäter, 2006). Inventory control is the supervision and coordination of supply, storage and accessibility of items in order to ensure an adequate supply without excessive oversupply. There is a wide range of different inventory models that can be used to develop an inventory control system. By investigating the inventory control system at TAC together with the factors found in the pre-study and the theory regarding inventory control, a foundation for a supporting tool for TAC's inventory control will be established.

3.3.1 Holding Cost

The holding cost, which is the cost of holding inventory, can be calculated in different ways, and in the following text three methods will be presented and compared. Axsäter (2006) argues that the capital cost is usually regarded as the dominating part of the holding cost. According to the same author, the cost of tied capital should be closely related to the return of an alternative investment. Other parts of the holding cost can be material handling, storage, damage and obsolescence, insurance and taxes (ibid). All costs that are variable with the inventory levels should be included when the holding cost is calculated.

Jonsson & Matsson (2005) the use incremental cost (IC) of holding one additional unit to calculate the cost of holding inventory, which is derived from the average inventory and the IC of capital, storage and uncertainty (ibid); presented in Equation (3.8). Out of these IC costs Jonsson & Matsson (2005) state that since the IC of storing is derived from the alternative of having more or less inventory, and not from having or not having inventory, the impact from the storing cost is relatively low, particularly in the cases were the business owns the storing location. Jonsson & Mattson (2005) agrees with Axsäter that the IC of capital, or the capital cost as Axsäter terms it, is the dominating factor when calculating the cost for carrying inventory. However, Jonsson & Mattsson (2005) develop the uncertainty term and argue that this factor is highly dependent of the characteristic of the articles. For articles with a high uncertainty the impact of the IC for the uncertainty can become as significant as the IC for the capital.

$$Holding\ cost\ (\%) = \frac{IC\ of\ capital + IC\ of\ storing + IC\ uncertainty}{average\ inventory} \quad (3.8)$$

Chopra and Meindl (2013) derive the holding costs from the cost of capital, obsolescence cost, handling cost, occupancy cost and miscellaneous costs. The components can be compared to Jonsson & Mattssons (2005) components where IC of capital equals the cost of capital, the obsolescence is part of the IC uncertainty and the cost for handling, occupancy and miscellaneous combined equals the IC of storing. Chopra & Meindl (2013) also claim that the cost of capital is the dominant component of the holding costs for products that do not become obsolete quickly. To calculate the cost of capital, the equation of weighted-average cost of capital (WACC) is appropriate to use (Chopra & Meindl, 2013; Myers, 2001). The WACC takes the required return of the firm's equity and the cost of debt into account and is presented in (3.9).

$$WACC = \frac{E}{D+E}\left(R_f + \beta \cdot MRP\right) + \frac{D}{D+E} R_b (1-t) \quad (3.9)$$

E = amount of equity
D = amount of debt
R_f= risk-free rate of return
β =the firm's beta
MRP = market risk premium
R_b = rate at which the firm borrow money
t = tax rate

From comparing the methods of calculating the holding cost it can be concluded that the authors agree on that the holding cost should be derived from three components: cost of capital, cost of storing and the cost of uncertainty. Out of these components the authors state that the cost of capital is the dominant component when determining the holding cost. Although the authors have different methods of calculating the cost of capital, but all of the methods can be derived from the opportunity cost. Axsäter (2006) suggests that the majority of the cost of capital can be calculated with the use of the company's alternative return of investment. Jonsson & Mattsson (2005) derive the cost of capital from the IC of the capital whereas Chopra & Meindl (2013) derives the capital cost from the more information demanding WACC.

3.3.2 Inventory Turnover

A drawback when using holding cost as an absolute number to measure the efficiency of the operations is the limited possibility for comparison with other businesses, due to that the holding cost is highly company specific (Mattsson & Jonsson, 2003). To obtain a comparable number for the tied up capital one can use the inventory turnover. Inventory turnover measures the efficiency with which inventory is used in inventory turns, or the turnover ratios, which is defined as the ratio of throughput to average inventory. The inventory turnover is defined according to Mattsson & Jonsson (2003) as:

$$Inventory\ turnover = \frac{Delivered\ value}{Average\ tied\ up\ capital} \qquad (4.1)$$

The inventory turnover expresses the relation between the value of the material flow during a time period and the capital that is tied up during the same time period. To achieve an accurate inventory turnover the delivery value and the average tied up capital must be measured in the same unit, e.g. SEK.

3.3.3 Ordering Systems

The theory regarding ordering systems contains different concepts and methods that must be known in order to understand a company's ordering system.

3.3.3.1 Inventory Position and Inventory Level

Inventory control is about determining how much to order and when to order. To do that, it is important to know the meaning of two basic concepts: inventory position (IP) and inventory level (IL). Axsäter (2006) defines them as follows:

$$inventory\ position = stock\ on\ hand + outstanding\ orders - backorders$$

$$inventory\ level = stock\ on\ hand - backorders$$

3.3.3.2 Continuous and Periodic Review

Axsäter (2006) describes two different inventory control systems. The first one is to monitor the inventory position continuously, which is denoted as continuous review. When using continuous review an order is triggered directly when the inventory position reaches the reorder point. The order will then arrive after the lead time L. The second one is periodic review, which means that the inventory position is reviewed only at certain given points in time. The interval, denoted T, between these points is often constant.

The same author also describes that there are both advantages and disadvantages with these methods. Continuous review will reduce the need for safety stock (SS). The reason for this is that an order is triggered directly when the reorder point is reached, which implies that the SS only needs to safeguard for the period L. On the other hand, when using periodic review and no order is triggered during the review of the inventory position, the SS needs to act as a buffer for the time period $T + L$. However, periodic review is favorable when there is a need to coordinate orders for several types of items.

3.3.3.3 Ordering Policies

When talking about inventory control there are two methods that are the most common: *(R, Q)* policy and *(s, S)* policy (Axsäter, 2006).

(R, Q) Policy

When customers order goods from the warehouse the inventory position declines. When the inventory position reaches the level *R* or under, a batch quantity of *Q* units is ordered. Sometimes it is not enough to order just one batch, then multiples of *Q* can be ordered – therefore the policy is sometimes referred to as a *(R, nQ)* policy (Axsäter, 2006). Figure 15 illustrates how the *(R, Q)* policy works when using periodic review, under the condition that the demand is continuous.

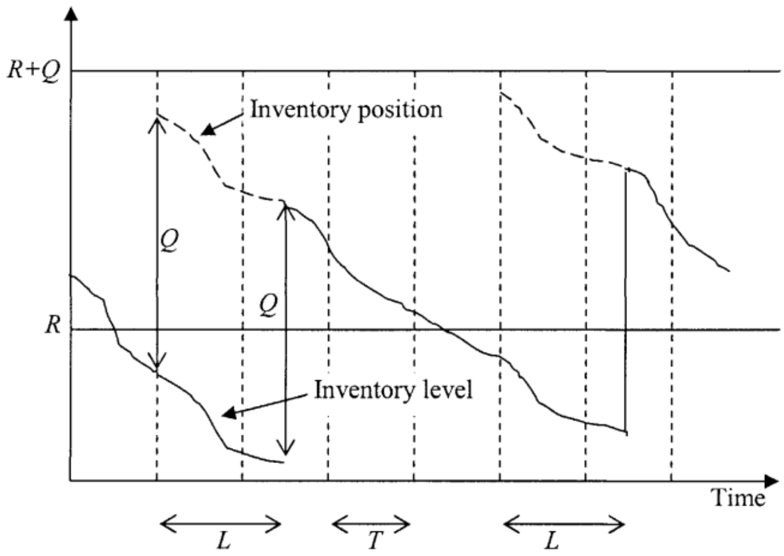


Figure 15. (*R, Q*) policy with periodic review and continuous demand (Axsäter, 2006).

(s, S) Policy

The *(s, S)* policy is similar to the *(R, Q)* policy, but the reorder point is instead denoted by *s*. When the inventory position declines to or under *s* a batch is ordered up to the level *S*. The difference between the two policies is that multiples of a given batch quantity is not ordered with a *(s, S)* policy. Figure 16 illustrates how the *(s, S)* policy works when using periodic review under the condition that the demand is continuous.

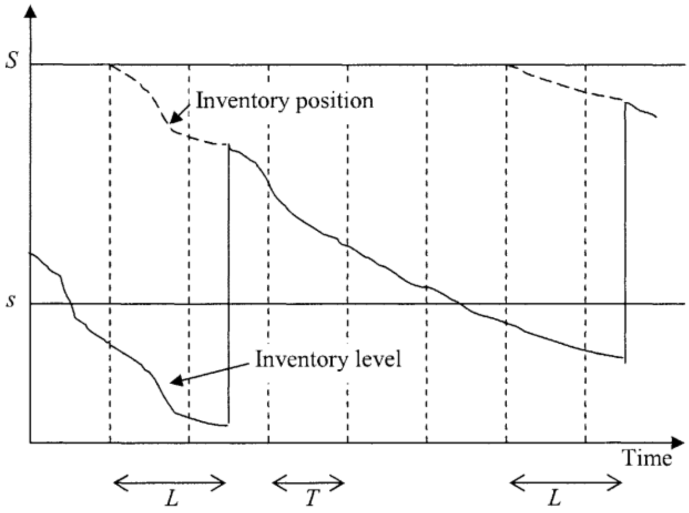


Figure 16. ***(s, S)*** **policy with periodic review and continuous demand (Axsäter, 2006).**

3.4 Summary of the Conducted Literature Review

The literature review is summarized in Figure 17. The figure shows which factors will be analyzed to answer RQ 1 and which concepts from inventory control will be used to create the tool for RQ 3. Regarding RQ 2, how the factors affect the inventory levels of caps, the analysis for RQ 1 has to be made before knowing which factors will be used to calculate how the factors contribute the inventory.

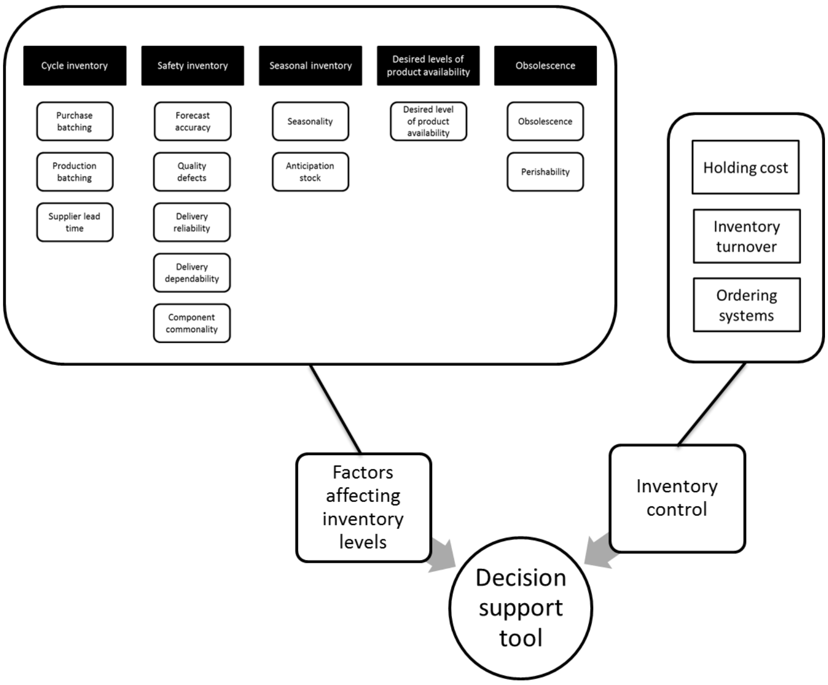


Figure 17. Summary of the literature review.

4 Empirical Data

This chapter contains all the empirical data collected for this thesis, which later is analyzed with the help of the frame of reference. The chapter starts with an introduction to TAC, followed by a description of the production planning and forecasts, suppliers, and inventory and safety stock.

4.1 Introduction to The Absolut Company

The master thesis company is introduced in the text below. First the owner structure is presented with further information about TAC. Then a current state map of the processes and functions investigated in this thesis is given.

4.1.1 The Absolut Company and Pernod Ricard

Vin & Sprit AB (The Swedish Wine and Spirits Company) was established in 1917 as a state-owned monopoly for import, export and production of all wine and spirits in Sweden. The company's original mandate was to limit the consumption of alcoholic beverages, but grew over the year to encourage responsible consumption and produce premium products (The Absolut Company, 2012). The portfolio of Vin & Sprit consisted of brands such as Aalborg Akvavit, Blossa, Explorer Vodka, Gammel Dansk and the flagship Absolut Vodka. Absolut Vodka was first exported in the year 1979 through an innovative combination of advertising and art which founded the concept of premium vodka. As Absolut Vodka started to make a name for itself, Vin & Sprit created a subsidiary for Absolut Vodka called The Absolut Company (TAC). In 2008 TAC joined the Pernod Ricard group and received the global responsibility for the production and marketing strategy of the following brands, in addition to Absolut Vodka: Malibu, Kahlúa, Frïs, Wyborowa and Luksusowa (Pernod Ricard, 2012). The product portfolio of TAC can be seen in Figure 18.

Figure 18. The product portfolio of TAC (The Absolut Company, 2012).

Today, Pernod Ricard is co-leader of wine and spirits worldwide (Pernod Ricard, 2012). They have organized their companies into two groups: brand companies and marketing companies (Pernod Ricard, 2012). The brand companies are located in their home countries and are responsible for product development and the global marketing strategy for the products included in their portfolio; while the marketing companies adopt Pernod Ricard's strategy to suit the local markets. TAC's products are distributed in Sweden through Pernod Ricard Sweden, which is included in Pernod Ricard Europe. The dialog between the brand companies and the marketing companies is coordinated by the holding company, Pernod Ricard, and the holding company defines the major strategic guidelines (Pernod Ricard, 2012). The organization of Pernod Ricard can be seen in Figure 19.

Figure 19. Pernod Ricard's organization (The Absolut Company, 2012)

In total, there are 680 people working at TAC. Out of these, 170 people are located in TAC's headquarter in Stockholm and 300 are located in Åhus, in southern Sweden. The office in Stockholm is the base for human resources, marketing, innovation, legal and the board of directors, while the functions procurement, production and logistics are situated in Åhus. All of the production of Absolut Vodka is done in Åhus, divided between two production sites. The main plant is located in the town of Åhus and the other plant (Satelliten) is located in the outskirts of Åhus. The main plant bottles all of the different vodka types and tastes and Satelliten bottles only the original Absolut Vodka and Absolut Vodka Citron. In the main plant there are four lines and in Satelliten there is one line, which is the most efficient, since it only bottles two different tastes and therefore has few changeovers. The vodka is distilled in

Tings Nöbbelöv located in the outskirts of Åhus, and all of the wheat used for the distillation of the vodka is grown in the surrounding area (The Absolut Company, 2012). Absolut Vodka is the second most sold vodka in the world (Pernod Ricard, 2012). The volumes produced are high, with yearly sales around 100,000,000 liters (The Absolut Company, 2012). It comes in many different tastes and in many different bottle designs and sizes. The original Absolut Vodka stands for the major part of the sales (~80%) followed by Absolut Vodka Citron. Other vodka types are Peppar, Kurant, Mandarin, Vanilia, Raspberry, Apeach, Ruby Red, Pears, 100, Mango, Berri Acai, Orient Apple, Gräpevine, Cherry Kran and Elyx (Pernod Ricard, 2012).

4.1.2 Current State Map of the Caps' Material and Information Flow

A current state map was created, from interviews with the employees and from observations at TAC, to get a better view of the material and information flow of the bottle caps, which can be seen in Figure 20. The numbers for each process follow the material and information flow of the bottle caps, starting with the production planning process. All symbols used in the map come from Microsoft Visio's set of icons for value stream mapping, but the icons have also been validated by comparing the icons with the ones used in Braglia et al. (2006).

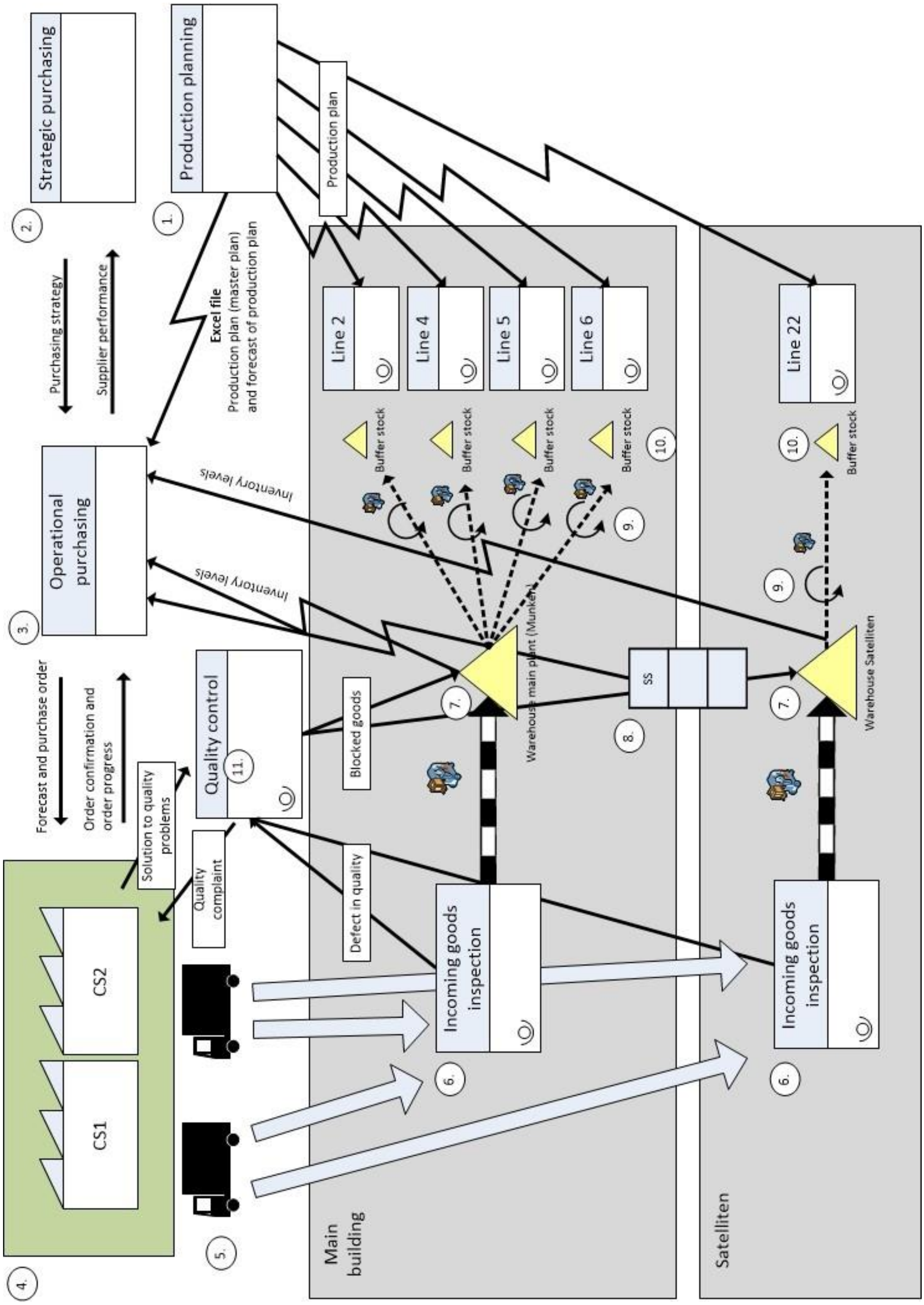


Figure 20. Current state map of the caps' material and information flow.

In Table 4 the processes identified in the value stream map are described, including a brief explanation of the task and which company that owns the process.

Table 4. Description of the processes/organizational units linked to the caps at TAC.

Number	Process/organizational unit	Task	Process owner
1.	Production planning	Schedules production, sends production orders and generates material need.	TAC
2.	Strategic purchasing	Negotiates contracts with suppliers and performs supplier evaluations.	TAC
3.	Operational purchasing	Places purchase orders and sends forecasts for caps to the suppliers. Also keeps track of the inventory levels and updates strategic purchasing on the suppliers' performance.	TAC
4.	Suppliers	Manufactures and delivers caps to TAC.	Supplier
5.	Transportation	The transport of articles from the suppliers to TAC. This is performed by the suppliers.	Supplier
6.	Incoming goods inspection	Ensures that the quality delivered from the suppliers is acceptable. This is done by inspecting one carton from every purchase order and analyzing the number of quality defects.	TAC
7.	Inventory	Stock to cover the ongoing production need.	TAC
8.	Safety stock	Makes sure that the production can keep on going despite problems with the cap deliveries. It also helps when demand is higher than expected.	TAC
9.	Call from production	When the production is about to run out of caps they make a phone call to a warehouse worker, who refills the buffer stock with a new pallet.	TAC
10.	Buffer stock in production	Stock that covers the imminent need of caps in the bottling lines. The buffer stock consists of one pallet.	TAC
11.	Quality control	Works with quality control and improvements for the entire	TAC

		value chain, for all the materials.

4.2 Production Planning and Forecasts

Production planning is made for the production lines to know how much they are supposed to produce, but also for the material planners to know how much they are supposed to order. There are two types of forecasts for the master planning. The first one covers one year ahead and describes how much should be produced every month. This forecast is an aggregated demand for all the articles. It is updated continuously according to incoming orders and production performance, and made public trough TAC's intranet. The second forecast is more detailed as it is divided based on articles. It covers two months ahead and it is updated once every month. One week before production start the production plan is frozen and no more changes are made to the production schedule after that. The forecast is created based on a combination of the forecast sent from Pernod Ricard's marketing companies and historic data gathered by TAC. When making the forecasts there is little support from computer systems, instead they are mainly based on the production planner's experience.

4.2.1 Ordering System

TAC is using an (*R*, *Q)* policy with a periodic review system (discussed in section 3.3.3.2). The decision to order caps or not is made roughly once a week, which means that the inventory levels are reviewed once every week to ensure the availability of components. A calculation of how many times per month a specific cap is ordered can be viewed in Table 5. These figures are calculated based on the purchase orders during 2013.

Table 5. Order frequency for the different caps.

Cap type	Order frequency (times per month)
28 mm	2.7
33 mm	4.3
35 mm	1.3
NRC	3.8

How much to order is based on the forecasts made by the production planner, but also on how much is currently being held in stock and on the directives given from the strategic purchasing function. Strategic purchasing decides how much should be bought from each of the two cap suppliers by giving the material planner a quota. Since TAC has two warehouse locations the material planner has to keep track the of inventory levels at two places. The decision whether the order should go to the main building or to Satelliten is made just days before the delivery arrives, so the material planner is basing all the decisions concerning how much to order on the aggregated demand of the two production sites. When it has been decided how much should be ordered, a purchase order is sent manually by e-mail to the supplier.

4.2.2 Demand

The yearly demand from 2008 to 2013 can be viewed in Figure 21 where the historical production volumes for each article are presented. In Figure 22 the monthly demand is presented for the same time period. It can be concluded when looking at the two mentioned figures that there are only small variations in the yearly demand, while there are fairly big variations in the monthly demand. However, the graphs are not based on the actual demand but on what has been produced, as it is assumed that these two data sets correspond well with each other. This is seen as a good approximation since the risk of obsolescence is low and the product life cycles are long. The dates of actual sales do not match the dates when production is made, but this is estimated to have little effect of the results in this thesis.

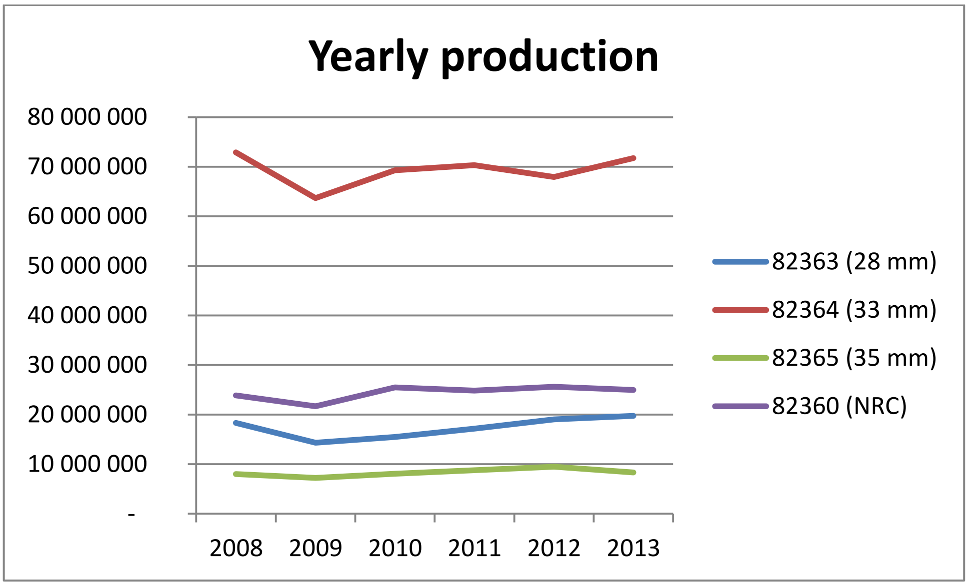


Figure 21. Shows how the production volume has developed during the recent years.

In Figure 22 it can also been seen that the demand pattern is repeated from year to year, which is due to seasonality. During July to December it is high season and TAC produces more than during the rest of the year. Also, during the high season the production workers are contracted to work longer hours than during the low season (Interview 12, 2014).

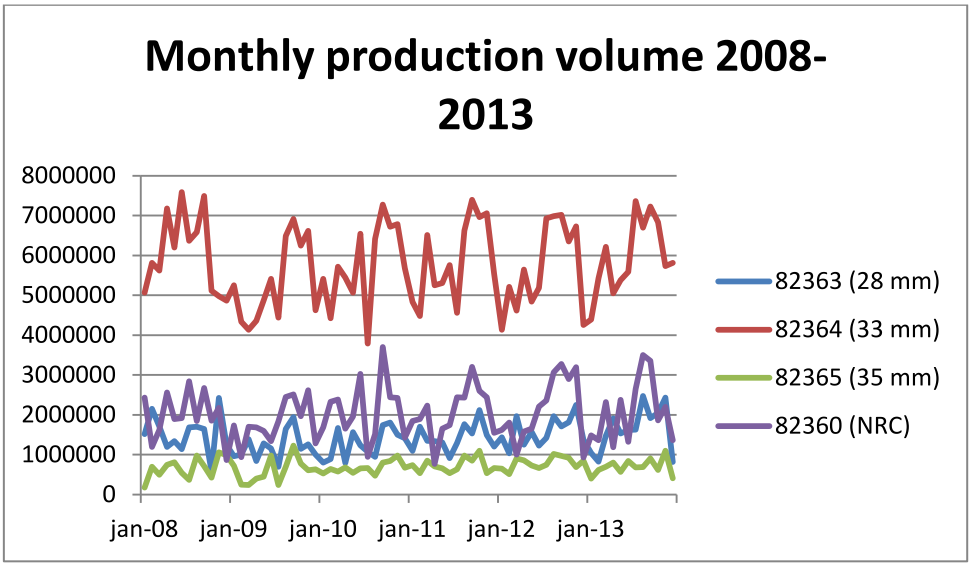


Figure 22. The production volume every month during the recent years.

In Table 6 the mean, standard deviation and relative standard deviation for the demand during 2008-2013 is presented. The 33 mm cap stands out as having the largest average demand per year, but also the lowest relative standard deviation (RSTD).

Table 6. The mean, standard deviation and relative standard deviation for the caps in focus.

Article	Mean	STD	RSTD
82363 (28 mm)	1 445 234	428 601	30%
82364 (33 mm)	5 774 860	999 141	17%
82365 (35 mm)	694 336	216 565	31%
82360 (NRC)	2 034 696	674 634	33%

4.2.3 Forecasts

Today, TAC does not measure the forecast errors regarding the master planning and neither do they measure the forecast error for the forecasts sent to the cap suppliers. As mentioned earlier, TAC uses two types of forecasts: one aggregated covering the coming year and one on article level covering two months ahead. The material planners use the aggregated forecast when ordering bottle caps, which tells them how many vodka bottles will be produced every month. In order for them to use the aggregated forecast it must be converted into amount of caps needed out of each sort. To do this they use the sales data for the last year and simply calculate how many percent each cap constituted of the total demand. The numbers are modified when needed, but at least once every year. The percentages are then multiplied with the aggregated demand, which gives the number of caps that will be needed in the coming year. This means that it is assumed that the same percentage of that specific bottle caps will be used for the coming year. However, it should be kept in mind that the numbers are modified if needed. The aggregated forecasts are sent to the supplier in order for them to plan the production for the coming year, but purchase orders are also sent to the suppliers later in time, as mentioned above. The forecast process can be viewed in summation in Figure 23.

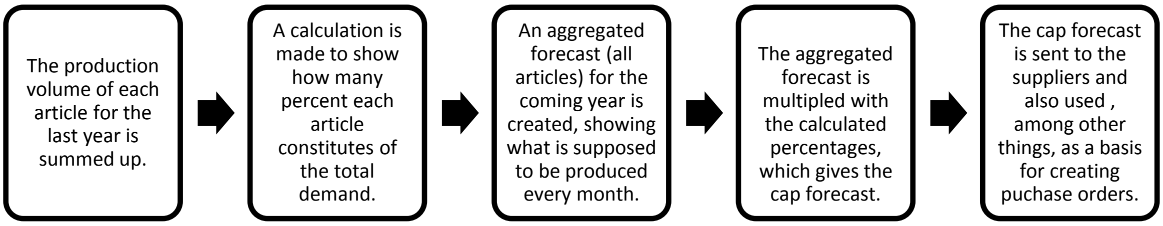


Figure 23. How the forecasts are made for bottle caps.

4.2.4 Forecast Error

The forecast error for each article has been calculated by comparing the forecasted demand for the articles with the actual demand. Also the MAPE for each article are presented in Table 7.

Table 7. MAPE for each article

	28 mm	33 mm	35 mm	NRC
MAPE	32%	15%	36%	35%

The forecast error for each article during 18 months is presented below in Figure 24-Figure 27. The graphs in the figures illustrate the error in percent, where a positive error means that the forecasted demand was larger than the actual demand, and a negative error means that forecasted demand was smaller than the actual demand.

The largest forecast error for the 28 mm caps is in February 2013 where the forecasted demand was 109 % larger than the actual demand, corresponding to 900 000 units. During the time period in focus, three months had an actual demand larger than the forecasted demand and during six months the forecasted demand had an error of less than 10 %.

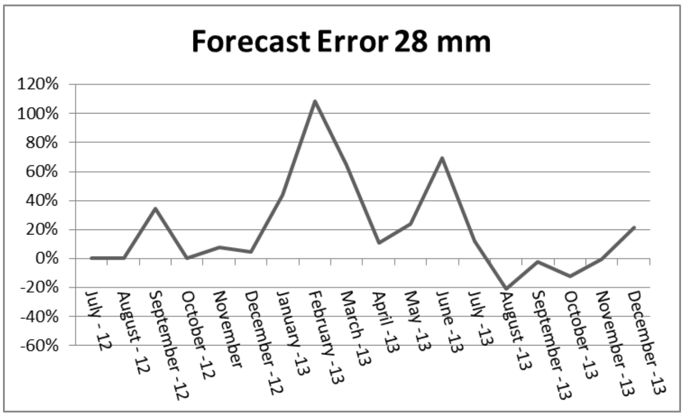


Figure 24. Forecast error of 28 mm in percent.

Regarding the forecast for the 33 mm caps there where two occasions when the actual demand was larger than the forecasted demand. During seven of the forecasted months, the actual demand was within 10 % of the forecasted demand. The largest forecast error was in January 2013 with an error of 37 % or 1 600 000 units.

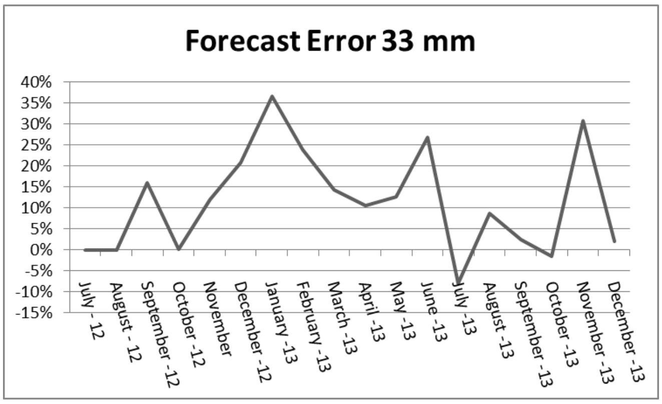


Figure 25. Forecast error of 33 mm in percent.

The actual demand for the 35 mm caps was larger than the forecasted demand in one of the 18 months. The largest forecast error was in May 2013 with an error of 137 % or 780 000 units. Five of the forecasted months were within 10 % of the actual demand.

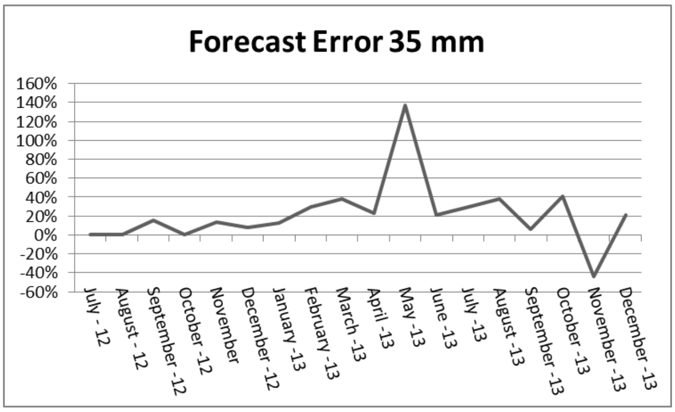


Figure 26. Forecast error of 35 mm in percent.

Regarding the forecasts for the NRC cap the actual demand exceeded the forecasts in six of the 18 months. Out of all the forecasted months, seven were within 10 % of the actual demand. The largest forecast error occurred in December 2013 with an error of 97 % or 1 280 000 units.

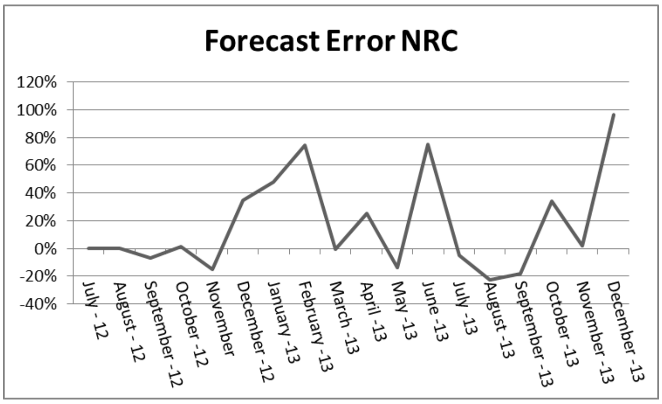


Figure 27. Forecast error of NRC in percent.

4.3 Suppliers

TAC has two suppliers of bottle caps, which will be referred to as CS 1 and CS 2 in the rest of the thesis. Currently CS 1 is supplying TAC with 28 mm, 33 mm and 35 mm caps. CS 2 is supplying TAC with NRC and 33 mm caps. TAC has worked a long time with both suppliers. There are some differences between the two suppliers, which will be described below.

4.3.1 Lead time

The lead time from CS 1 is one month while the lead time from CS 2 is two months. The difference is mainly due to the suppliers' production flexibility and their geographical locations. However, as mentioned earlier, TAC delivers forecasts to their suppliers, which means that the suppliers know a long time in advance approximately how much they are supposed to produce.

4.3.2 Lot Size

TAC strives to always buy full truckloads (FTL). There are differences in lot sizes between the two suppliers, which can be viewed in Table 8.

Table 8. Lot sizes for the different caps and suppliers.

Cap type	Supplier 1 (million units)	Supplier 2 (million units)
28 mm	0.50	N/A
33 mm	1.44	1.82
35 mm	0.56	N/A
NRC	N/A	0.49

4.3.3 Delivery Reliability and Dependability

TAC has recently started measuring the delivery reliability (end of 2013), which will be used in this thesis. Regarding the delivery dependability there are data available further back and therefore data from the beginning of 2013 will be used. A delivery was considered on time if the delivery was performed on the day that had been agreed on and a delivery was considered to have the right quantity if the number of delivered articles corresponded exactly to the ordered quantity.

Delivery Reliability

There are some differences between the delivery reliability for the two suppliers. CS 1's delivery reliability during 2013 is presented in Figure 28. The figure shows that 21 percent of the deliveries were early, 45 percent were on time and 34 percent were late. Out of all late deliveries two were more than ten days late, six were between three and nine days late, and five were between one and two days late.

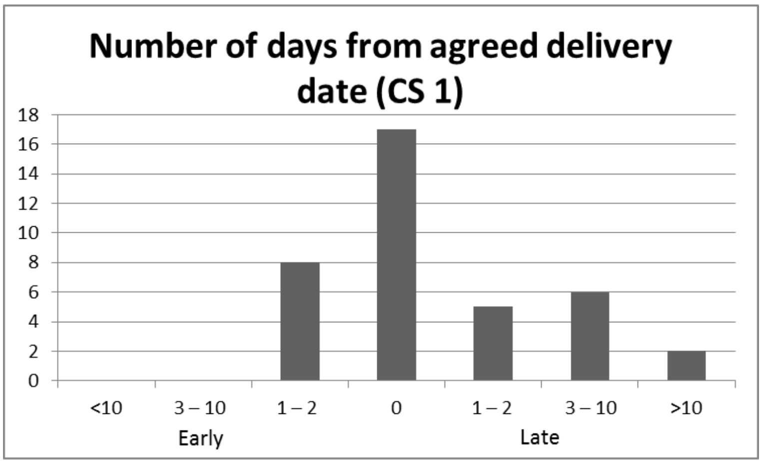


Figure 28. The delivery reliability for CS 1.

The delivery reliability of CS 2 is presented in Figure 29 It shows that 29 percent of CS 2's deliveries came too early, 54 percent on time and 18 percent too late. Out of all the late deliveries three were between three and ten days late and two deliveries were more than ten days late.

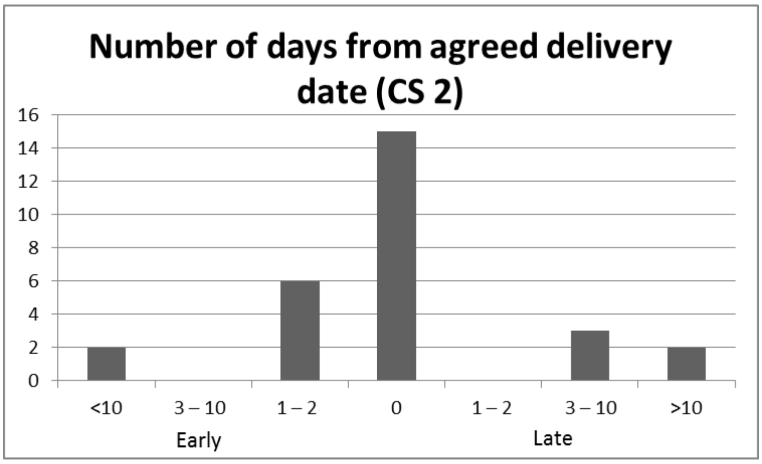


Figure 29. The delivery reliability for CS 2.

Delivery Dependability

There are differences between the suppliers regarding the delivery dependability as well. Three percent of the deliveries made by CS 1 contained less than ordered, 95 percent contained the ordered quantity and two percentages contained more than ordered. The historic delivery dependability of CS 1 is presented in Figure 30. Two deliveries were above the ordered quantity and one delivery was below.

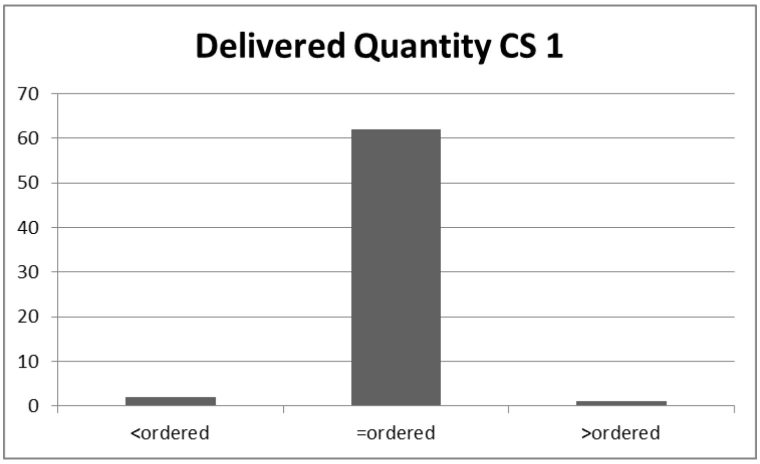


Figure 30. Delivery Dependability of CS 1.

Out of all the deliveries made by CS 2 five percent contained less than ordered, 88 percent had the ordered quantity and seven percent had more than ordered. CS 2's delivery dependability is presented in Figure 31. Five deliveries exceeded the ordered quantity, 80 met the ordered quantity and six contained too few units. Out of these six deliveries four lacked nearly or more than 100 000 units.

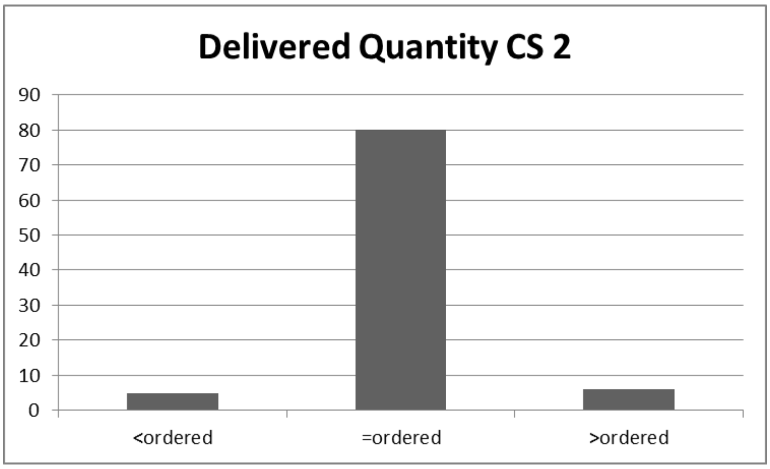


Figure 31. Delivery Dependability of CS 2

4.3.4 Quality Defects

TAC is working hard to improve the quality of their supply chain – both their internal processes and their suppliers' processes. They have a close relationship with their suppliers and they have frequent discussions about how to improve the quality of the products delivered to TAC. This work has led to a decreased amount of quality defects during the recent years. Quality defects are important to minimize since they add to the uncertainty that needs to be considered when ordering raw materials. However, TAC rarely sends material back to the suppliers even though the caps have quality defects, which means that there are no immediate consequences for the suppliers (Interview 9, 2014). Quality deviations also affect the degree of efficiency for the production, which is an important measure for TAC.

Because of the occasional quality defects in the delivered caps TAC has to inspect the quality of the incoming goods. TAC takes one box for every delivery that comes in and inspects the quality of the caps in the box. This is done by "adding" the caps in the production line and then "taking out" bottles (with caps screwed on) according to the number of screw heads in the machine that screws caps on to the bottle, and testing them according to the predefined tolerances. If too many quality defects are detected the rest of the pallets in that delivery will receive tags that indicate that they are defect, and will henceforth not be picked. There are three classifications of quality defects: (i) *critical defect*, which is contamination of some form, (ii) *serious defect*, which is a cosmetic defect or defects with the functionality, and (iii) *other defects*, which are also cosmetic defects or defects with the functionality.

When defects are discovered two things can happen. Either the goods are sent back to the supplier or the fault is noted but not sent back. If the goods are sent back or not depends on the severity of the defect. Either way, the deviation is noted in the system and a report is sent to the supplier, with a demand from TAC that the supplier comes up with a short and long term plan of how to solve the problem (Interview 9, 2014). An example of when the goods are not sent back is when some of the caps in the batch contain scratches. It is not worth sending the caps back, but TAC still wants to inform the supplier in order for them to improve (Interview 9, 2014). Below, in Figure 32 and Figure 33, the amount of cases with quality defects connected to each cap supplier during 2013 is presented. There are clear differences between the suppliers regarding the amount of cases with defects. As can be seen in Figure 32, twelve cases of quality defects were detected for CS 1.

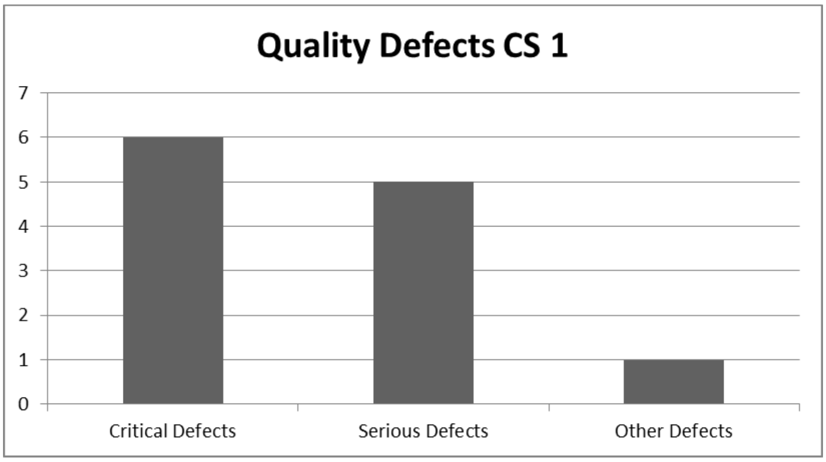


Figure 32. The defects connected to CS 1.

In Figure 33 it can be seen that CS 2 has had many more cases of quality defects during the same period; in total 45 cases of quality defects were reported.

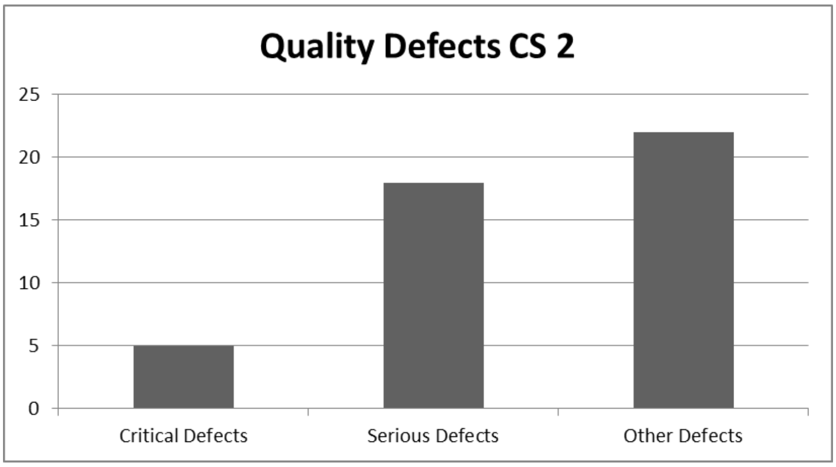


Figure 33. The defects connected to CS 2.

In Table 9 it can be viewed how many caps the above mentioned cases represents. It can be seen that CS 2 delivered many more caps with quality defects.

Table 9. The number of discarded caps due to quality defects derived from each supplier.

Supplier	CS 1	CS 2
Number of Discarded Caps	48000	953000

4.3.5 Environmental Aspects

TAC is continuously working to lower their carbon footprint, both for their own processes and for their suppliers' processes. They also perform audits at their suppliers to test if they fulfill the environmental demands that have been agreed upon. Furthermore, TAC works with environmental certification. All of TAC's facilities have the ISO 14001 certificate and the company is also ISO 9001 and OHSAS 18001 certified. The purchasing department at TAC strives to purchase from suppliers with these certificates. TAC also focuses on trying to improve the fill rate, both for incoming and outgoing goods. They always order full truckloads from the cap supplier, in order to reduce the environmental impact.

4.4 Inventory and Safety Stock

The inventory of caps is needed for several reasons, as has been discussed earlier. TAC's overall strategy is to always have caps in stock. It is considered more important to ensure constant supply than to lower the cost of inventory, resulting in extra stock that is not used. This means that the inventory levels have historically been high. The average inventory levels (IL) are set to set to be 30 days for the caps 28 mm, 33 mm and 35 mm, while the average IL for the NRC caps are set to 35 days. These values are set based on the staff's experience and by looking at what values have been used during the recent years. Also the ERP-system of TAC has a safety stock (SS) measure set to 1.5 million pieces. When the inventory level goes under this limit a purchase order is automatically triggered. However, this figure is not used on a regular basis. It is seen as a safety precaution so that if someone forgets to order, the system will remind you. As mentioned, TAC rather has more in stock than risking a shortage, but they are also trying to reduce the stock levels. This is done by looking at the historic inventory levels and setting the inventory target for next year "a little lower". No calculations are made to support this decision.

TAC experiences that the bookkept stock levels do not always correspond with the actual stock levels, which adds to the uncertainty and consequently increases the inventory levels. This discrepancy is found and corrected during the stocktaking, which is done twice every year. One reason for the stock value discrepancies is that TAC only keeps track of how many caps end up with a finished bottle. It is only when the production batch is ready that the material consumption is entered into the system, which means that scrapped material does not result in lowered stock level in the system. To counter these discrepancies, stocktaking reports have been used for correction when calculating inventory levels, in order to get more accurate results. In Figure 34 the average inventory in days has been calculated based on the average monthly inventory level divided with the average daily production.

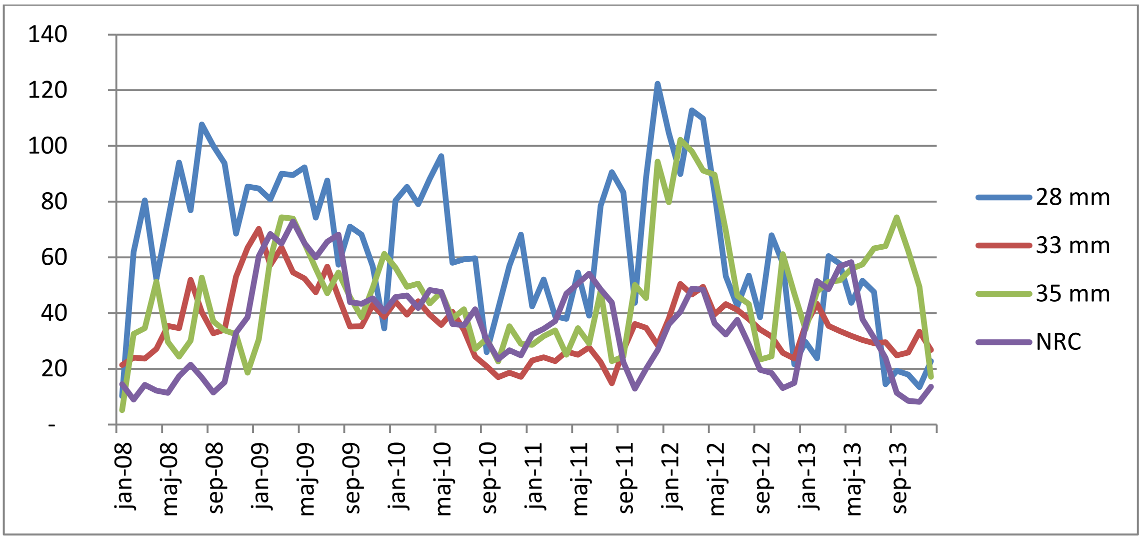


Figure 34. Days of inventory from 2008 to 2013 (72 months).

Figure 35 shows the same calculation as Figure 34, but only for the year 2013 in order to give a more detailed view of the current situation.

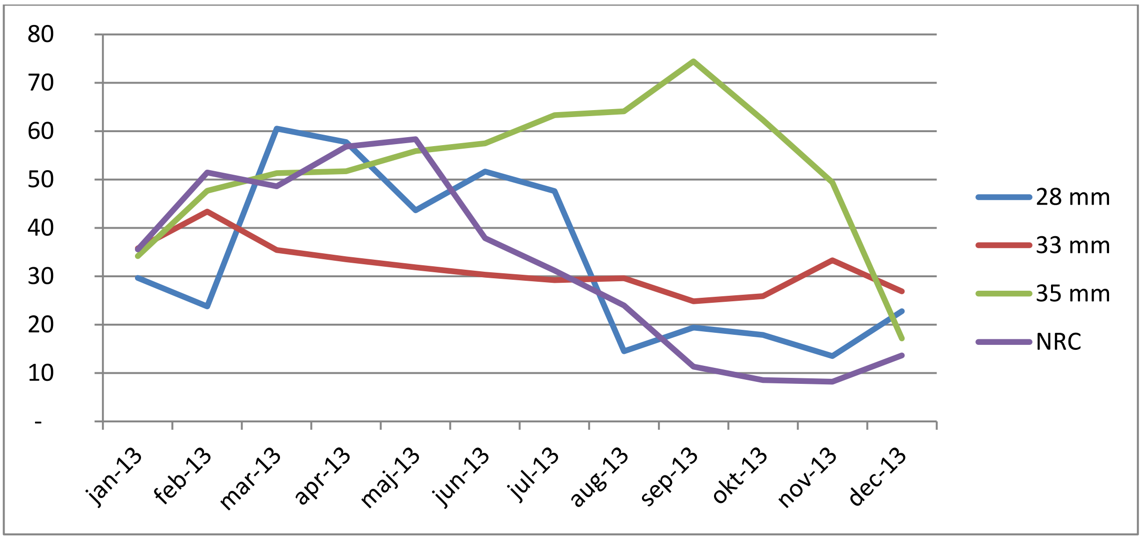


Figure 35. Days of inventory during 2013.

The two graphs above are affected by how much has been produced, so in Figure 36 the absolute inventory levels are shown in terms of units, in order to give a more wide-ranging view of the inventory situation.

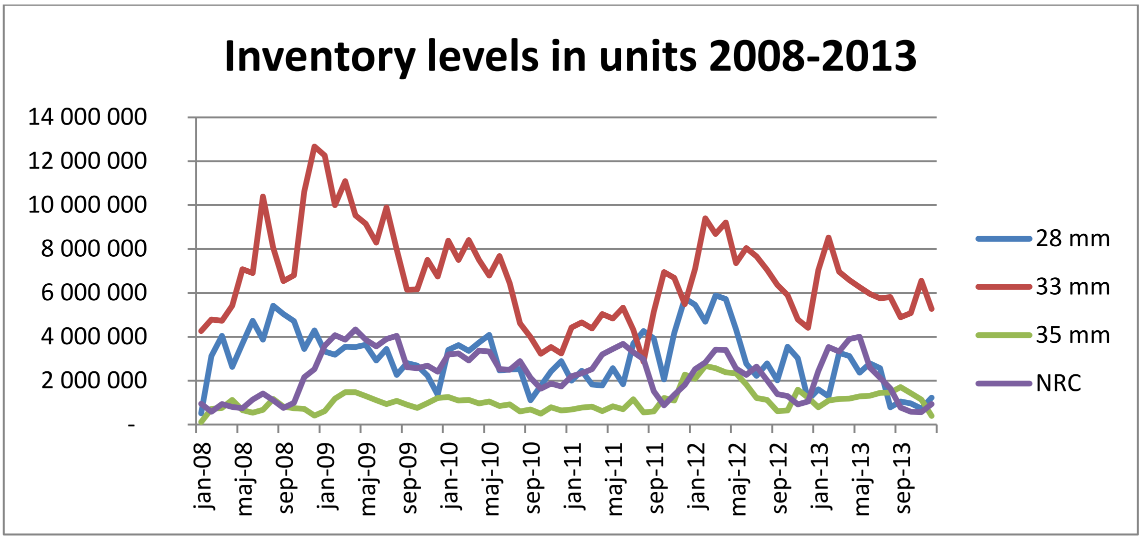


Figure 36. Average monthly inventory levels in units 2008-2013 (72 months).

In order to give a more detailed view of the inventory levels in absolute values, Figure 37 has been created. It shows the same data as the previous figure, but only for the year 2013.

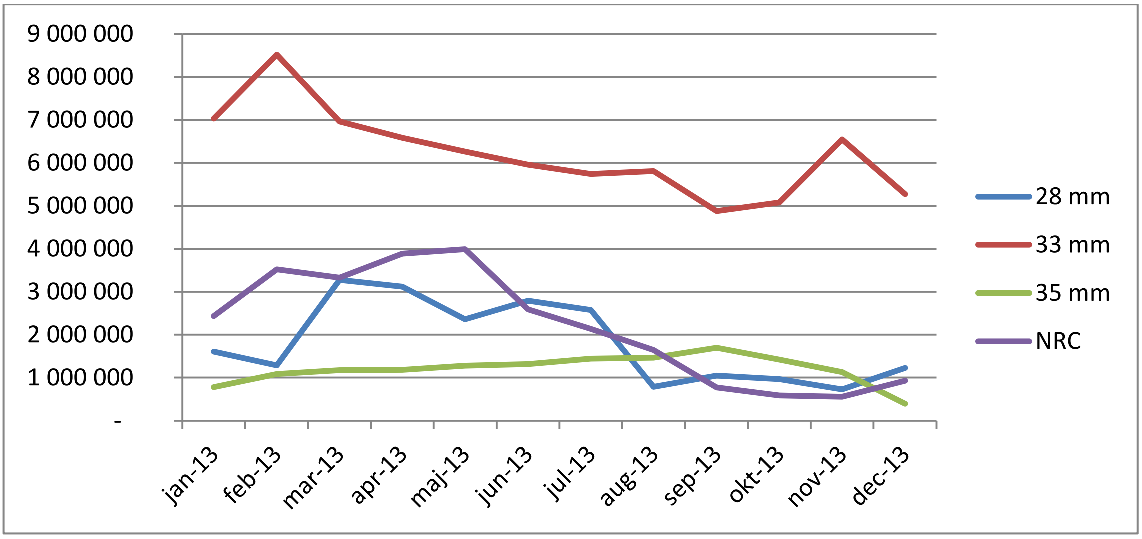


Figure 37. Average monthly inventory levels in during 2013.

5 Analysis

In this chapter the empirical data will be analyzed with the theoretical framework in order to answer research question 1 and 2.

5.1 Introduction

The analysis chapter is structured to answer each research question separately. Firstly, RQ 1 is analyzed in section 5.2 and then RQ 2 is analyzed in section 5.2.6. Therefore the chapter starts by going through the list of factors identified in the literature and analyzing if they have an effect on TAC's inventory levels of caps. In the list, the factors are either rejected because they clearly have none or little effect on the stock levels of the caps, or they evidently affect the inventory levels, or as a third alternative, it is hard to say to what extent they influence the inventory levels. The rejected factors will not be analyzed further, but the other factors, the short list, are analyzed more thoroughly in 5.2.6. RQ 2 is answered in section 5.2.6 by analyzing how the factors from the short list affect the inventory levels of bottle caps. The factors will be discussed one by one, and when possible the factors' contribution to the inventory is presented.

5.2 Factors Affecting the Inventory Levels at TAC

The list of factors will be analyzed one by one in the following section. They are divided in their respective group according to Figure 13, in the chapter Frame of Reference. It should be mentioned that the following analysis is only intended to identify the factors that should be analyzed further; therefore the analysis for each factor is kept brief.

5.2.1 Cycle Inventory

The factors related to the cycle inventory are discussed below, which are purchase batching, production batching and supplier lead time.

Purchase Batching

The purchases at TAC are made in batches today, since it is expensive to buy small quantities frequently. Each cap has a low unit cost and each cap represents only a small percentage of the total cost of producing the finished product. Therefore it is not economically justified to order quantities smaller than a full truck load (FTL). TAC is also concerned with having a high fill rate, to keep emissions as low as possible but also to decrease the shipping cost induced on every cap, which advocates ordering full trucks. This means that TAC has to keep inventory between the deliveries from the suppliers, which contributes to the cycle inventory (Chopra & Meindl, 2013). Therefore this factor is also considered to contribute significantly to the inventory levels and will therefore be investigated more in detail. Concerning the factor logistics that Nahmias (2009) discussed; he pointed out that there are constraints that will affect the inventory levels. There are some constraints in TAC's business, like for example the minimum order quantity. Minimum order quantities have not been investigated in this thesis, but since TAC focuses on purchasing caps at a low cost and since they are concerned with the environmental impact, they always aim to buy full truckloads of caps (Interview 6, 2014). Buying full truckload will lower the transportation cost induced and higher the fill rate, which will lower the environmental impact. Based on the reasoning above, this factor also affects the inventory levels and will be investigated further below in section 5.2.6.

Production Batching

TAC produces products in batches due to the changeover time and changeover cost in the production. The extent to which the produced volume is spread out over time will have an effect on the average inventory levels (Chopra & Meindl). Suppose that a target inventor level is set for a specific month and during that month the company receives four deliveries. If the production scheduling is done so that the whole batch of that product is supposed to be produced during the first week, the inventory levels during the first week might not be sufficient, since the inventory levels are set based on four deliveries. This is why this aspect has to be analyzed further, which is done below.

Supplier Lead Time

The lead time for caps at TAC is rather long; 1-2 months depending on the cap type (Interview 6, 2014), which compels TAC to keep inventories to handle the daily production variations and unforeseen problems. The long lead time is a result of inflexible production processes at the supplier together with the fact that one supplier is located abroad, which prolongs the transit time. Consequently TAC has to make forecasts to predict their production need, to be able to order at least one lead time before they want the products to arrive. This adds to the need for inventory of caps, since batches have to be ordered (Chopra & Meindl, 2003; Mattsson & Jonsson, 2003). Therefore the effects of this factor will be evaluated further in section 5.2.6

5.2.2 Safety Inventory

The factors related to the safety inventory are discussed below, which are forecast accuracy, quality defects, delivery reliability and dependability and component commonality.

Forecast Accuracy

With a long lead time it becomes more important to make accurate forecasts (Axsäter, 2006). The lead time for the bottle caps is long, which makes the forecast accuracy important for TAC. Furthermore, the forecast accuracy affect the decision of how much to keep in safety stock, as seen in Equation (3.2). There can be many reasons behind inaccurate forecasts, but the reasons behind large forecast errors at TAC can be seasonality, tax regulations in the sales markets and campaigns, among others (Interview 1, 2014). With inaccurate forecasts the inventory levels need to be higher than necessary, making it a factor worth taking into consideration and this will therefore be analyzed further below.

Quality Defects

Quality defects originate from the supplier’s production process or from damages during the transportation. It is hard to determine more exactly what is causing the problems, since the suppliers have not been interviewed in this thesis. As discussed in the frame of reference chapter there are many definition of what quality is, but since the thesis focuses on the inventory levels of the caps the quality defects will be defined in terms of manufacturing-based quality. This means that the quality of the articles will be measured based on either whether they are within the dimensional tolerance or whether they achieve the stated performance standards (Hopp & Spearman, 2001). This definition of quality directly refers to the process of making products, and according to Hopp & Spearman this definition is closely related to the "do it right the first time" view of quality. The definition is suitable for the thesis due to the fact that the caps have a clear specification on tolerances, dimensions and performance standards, as well as the fact that each article has such a low cost that no reworks on defects are performed.

Quality defects will cause breakdowns in production if the defects are not found before. The production can continue if only a small part of the caps are defect, but only up to a certain level. If the amount exceeds this limit the goods have to be sent back to the supplier and can therefore not be used in the production (Interview 8, 2014; Interview 9, 2014). Quality defects can also be discovered during the quality control, which will have the same effects as the scenario above, but without breakdowns in the production. The safety inventory has to counter for the quality defects and therefore this is a factor worth considering.

Delivery Reliability and Dependability

The problems with delivery reliability (correct time) and dependability (correct quantity) also stems from the supplier, which makes it hard to know exactly what is causing it. However, the delivery reliability is affected by delays during transportation from the supplier to TAC, variability in the supplier's production process, and differences in corporate culture between the supplier and TAC regarding the importance to deliver orders in time. Communication problems have also occurred between TAC and the supplier, leading to misunderstandings. As with the delivery reliability it is difficult to determine the cause of the problem. However, the problems can be because the production of the supplier is behind and the order is not ready or, as mentioned earlier, differences between TAC's and the supplier's culture. The problems can also be caused by a calculation mistake from TAC or the supplier, or that some caps disappear during the transportation. In section 0, in the empirical data chapter, it was presented that TAC is experiencing problems with deliveries being delivered outside of the delivery window and sometimes with the wrong quantity. These problems force the company to keep higher inventory levels (Mattsson & Jonsson, 2003), since deliveries arriving late or containing fewer units than ordered can cause shortages in the raw materials warehouse. Therefore these factors are considered in the analysis performed in 5.2.6.

Component Commonality

Component commonality was defined by Chopra & Meindl (2013), concerning to which extent the same components can be used in several product, as discussed in the chapter frame of reference. TAC has standardized the caps based on the size of the bottles, with a few exceptions where a unique cap is required (Interview 1, 2014; Interview 3, 2014). Therefore

TAC can use the same cap type for many types of articles, which makes the component commonality rather high for the bottle caps. Moreover, the caps' forecasts are based on an aggregated demand (finished products), which makes component commonality a less important factor in this case, since more accurate forecasts can be achieved with an aggregated demand; this will therefore not be analyzed further in this thesis.

5.2.3 Seasonal Inventory

The factors related to the seasonal inventory are discussed below, which are seasonality and anticipation stock.

Seasonality

From Interview 1, 2 and 4 (2014) it was found that TAC experiences seasonality. That is also the reason for having contracted the production workers to work longer days during peak season. However, it has not been investigated if the seasonality exists on a product level, but the graph (Figure 22) illustrating the demand for the four caps in focus from 2008 to 2013 implies that there are re-occurring demand variations. Because of the seasonality, the production demands different quantities depending on the season of the year and the inventory levels must therefore be adjusted accordingly. However as TAC derives their forecast from the historical data the seasonality is considered to be included in TAC's forecast, which is why this factor is not analyzed further.

Anticipation Stock

Anticipation stock is, as mentioned before, a technique to counter for changes in demand and to speculate in market fluctuations. Except for countering the seasonality, TAC does not use any anticipation techniques regarding the caps (Interview 2, 2014); therefore this factor will not be considered further.

5.2.4 Desired Level of Product Availability

The factor related to the desired level of product availability is discussed below.

Desired level of product availability

The desired level of product availability is affected by the cost of stockout, which is affected by the backorder cost of the cost of lost sales, and the inventory holding cost (Howard, 1984). For TAC it is very important that the production lines do not stop, for example due to shortages in the raw materials warehouse (Interview 1, 2014; Interview 3, 2014; Interview 6, 2014). Moreover, the caps are cheap to purchase, which has resulted in a high level of desired product availability at TAC due to the low inventory holding cost. Because of the high demands on the level of product availability, this factor is considered to contribute to the inventory level of caps, but as probability would be needed to calculate the impact of the product availability it will not be further investigated due to the time constraint of the thesis. Furthermore, the required volumes to achieve the high level of product availability are highly connected to the planned production and therefore the issue to achieve required product availability is seen as a material planning issue.

5.2.5 Obsolescence

The factor related to obsolescence is discussed below.

Obsolescence, perishability and product life cycle

The bottle caps are not perishable and the product life cycle is long, especially for the caps due to the high level of component commonality, which makes the caps usable in many different products (Interview 1, 2014; Interview 10, 2014; Interview 3, 2014). Hence, the risk of obsolescence for the bottle caps is low. The product life cycle for the finished products is also long and when the cap design is updated, the old stock of caps is used before the new design is introduced to the production, preventing the cassation of the old stock. Based on the reasoning above, this factor will not be analyzed further.

5.2.6 Summary of Factors

Figure 38 presents the factors that were chosen to be studied further (the ones not crossed over). This list of factors is the answer to RQ 1 – what factors affect the inventory levels of bottle caps at TAC? The factors are: purchase batching, production batching, supplier lead time, forecast accuracy, quality defects, delivery reliability and delivery dependability. Regarding the factors that have been crossed over in the figure, they will not be analyzed further as they are considered to have none or little effect on TAC's inventory levels.

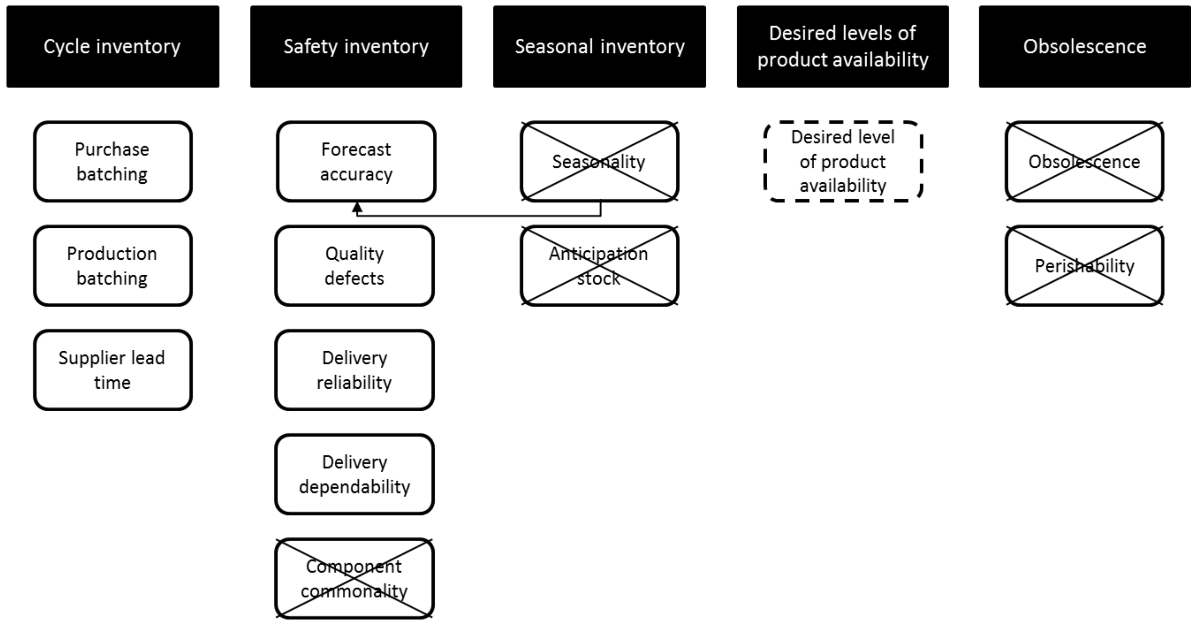


Figure 38. The theoretical factors affecting the inventory levels at TAC

5.3 How the Identified Factors Affect the Inventory Levels

Below the factors chosen for further analysis are investigated (taken from Figure 38) and as can be seen in the figure, only factors from the groups cycle inventory and safety inventory remain. In the following text the factors' impact on the caps' inventory levels is calculated. The impact presented below represents the inventory required to cover the average error during the forecasted period for each factor. However, some factors do not add to the inventory levels but add a condition connected to the inventory levels that has to be fulfilled; for example the inventory level cannot exceed the available warehouse space. Furthermore, the calculations performed below serve as a basis for the calculations performed in the decision support tool. Decisions made below are thus taken into consideration of the tool's design; for example assumptions are made to suit the functionality of the tool to TAC.

5.3.1 Cycle Inventory

In the text below the factors purchase batching, production batching and supplier lead time will be analyzed further.

Purchase Batching

The cycle inventory, which is a direct consequence of batching, was calculated to know how much inventory is needed during one delivery interval. Larson & DeMarais (1990) said that the cycle inventory can vary between zero and *Q* units, with an average of (*Q/2*) units when assuming constant sales and inventory depletion. However, a different approach will be used in this thesis for calculating the average cycle inventory; instead of using the lot size, the forecasted production and the amount of times ordered during one delivery interval will be used, as can be viewed in Equation (5.1). Consequently, the cycle inventory changes according to the forecasted production volume. If the average cycle inventory would have been calculated as (*Q/2*) instead, the cycle inventory would not have changed, because of the fixed *Q* at TAC.

It should be mentioned that the calculation made in Equation (5.1) is not completely accurate since the inventory for bottle caps at TAC is not depleted at a constant rate – TAC produces several types of products in all of their lines and they produce in batches. Nevertheless, it is assumed that the depletion rate is constant, because the data provided from TAC only included the date and time when *batches of units* were taken out from the warehouse. Hence, the data did not make it possible to calculate the actual depletion rate. This assumption is not considered to have a big impact on the results however, as the inventory levels suggested by the decision support tool are for two months, and a more accurate average can thus be calculated. In Table 10 the inventory added due to purchase batching can be viewed, divided between the four caps in focus. The data used for the calculations is taken from January and February 2014.

$$Average\ CI = \frac{Forecast\ for\ two\ months}{2 \cdot Amount\ of\ times\ ordered\ during\ two\ months} \qquad (5.1)$$

Table 10 shows that the amount of days added to the inventory is largest for the 35 mm cap, due to the low order frequency for that cap; it was only ordered 2.6 times during a two month period while the 33 mm cap is ordered 8.6 times per month. However, the 35 mm cap is the cap of which the least volume is produced, and therefore the least amount of units are added to the inventory for the 35 mm cap.

Table 10. Cycle inventory in days for each article

Article	Average cycle inventory (days)
28 mm	5.3
33 mm	3.4
35 mm	12.0
NRC	4.0

Production Batching

Production batching will not affect the inventory levels directly but will add a constraint, which will be explained in the following text. The inventory has to cover the demand from the production even when big batches are produced during a short period of time. TAC produces articles in batches and there can be large differences in the produced quantity between the weeks in the forecasted period. For example, if 70% of the production of an article takes place during the first half of the forecasted period the cycle inventory will not be enough to cover the requested demand. This issue can be solved with increased inventory or by adjusting the production planning for a smoother production. Furthermore, good communication between the production planner and the material planner is encouraged, so that more inventory could be purchased if many caps are planned to be used during a short period of time. Consequently, it was decided, together with TAC, that the variations resulting from the production batches are seen as a planning issue, and should not be considered in the decision support tool, discussed in 5.3. The production batches will therefore not be further investigated; instead the material planner has to consider this manually when placing purchase orders.

Supplier Lead Time

As stated earlier the lead time is the time from when the order is placed to the time when the order arrives, but since TAC shares their forecast with their suppliers for the coming three months the suppliers know approximately how much they should produce in the coming months. Therefore the suppliers should be prepared when the purchase order from TAC is received. Due to the suppliers good knowledge of how many bottle caps they should produce for TAC during the coming months the lead time is of less importance. However, the lead time is of greater importance if TAC experiences a surge in demand and needs to produce more than forecasted, or if the delivered caps are of inadequate quality and have to be sent back. Then TAC has to get hold of caps quickly, in the form of a replenishment order, which is facilitated by short lead times from the suppliers. Today, TAC is working with prioritization of orders to counter for potential shortages of caps – they tell the cap supplier to prioritize orders containing the caps they need for the moment. It is difficult to estimate how much extra inventory is needed due to the lead time. The lead time would add to the batch inventory if TAC had not sent forecasts to their suppliers, but in this thesis the order frequency, which is seen as fixed, is used instead of the lead time when calculating the cycle inventory. However, the supplier lead time will add a constraint that purchases has to be made in batches, which consequently adds to the cycle inventory.

5.3.2 Safety Inventory

In the text below the factors forecast accuracy, quality defects, delivery reliability, delivery dependability and desired level of product availability will be analyzed further.

Forecast Accuracy

As mentioned earlier in the chapter Empirical Data, TAC makes two forecasts – one for the aggregated demand of all article numbers covering one year ahead, and one forecast for every article number covering two months ahead. In this thesis the former forecast will be used for calculating the forecast accuracy. This forecast is shared with the suppliers and, together with the purchase orders, it is this forecast the suppliers base their production on. To estimate how the forecast errors impact the inventory levels the Mean Absolute Percentage Error (MAPE) is calculated based on data for twelve months back. The formula can be viewed in Equation (3.7) in the chapter Frame of Reference. To calculate how much the forecast error will contribute to the stock levels the MAPE is multiplied with the cycle inventory to give the impact of the forecast errors in units; that is the safety stock needed to cover the forecast error (SS_{FE}).

The MAPE of the forecast represents the average forecasts error. By multiplying it with the cycle inventory, which is derived from the forecast and the order frequency, the inventory needed to cover an average forecast error is calculated. By dividing the SS_{FE} (units) with the forecasted average daily production (FADP) the SS_{FE} (days) is calculated. The formulas for calculating the SS_{FE} is presented below and the results for each article are presented in Table 11.

$$SS_{FE}(units) = MAPE_{12} \cdot CI \qquad (5.2)$$

$$SS_{FE}(days) = \frac{SS_{FE}\ (units)}{FADP\ (units/day)} \qquad (5.3)$$

The data used when calculating the safety inventory needed due to forecast errors comes from the year 2013. In the table below it can be viewed that the 35 mm cap adds the most to the inventory, 4.4 days. This means that this cap has been the most under-stocked in average during the last twelve months. The 35 mm cap is also the smallest in volume, which makes it even more volatile. The 33 mm cap on the other hand is the biggest cap based on volume and has also been under-stocked the least during the last twelve months, adding just 0.5 extra days due to forecast errors.

Table 11. Safety stock covering the average forecast error for each article.

Article	SS_{FE} (days)
28 mm	1.7
33 mm	0.5
35 mm	4.4
NRC	1.4

Quality Defects

In the chapter Empirical Data it was discussed that TAC has problems with quality defects. Quality defects affect the inventory levels directly since the defect units cannot be used in the production and will therefore have to be removed from the inventory. By looking at the historical data of quality errors it can be seen that the quality can vary greatly depending on the cap type (see section 4.3.4). Therefore the impact of quality defects was calculated based on cap type instead of supplier. Below the calculations for the impact of the quality defects are presented in Equation (5.4) and (5.5). The contribution to the safety stock for each article is presented in Table 12.

$$\text{Safety stock covering the quality defects} = SS_{QD}$$

$$SS_{QD}\ (units) = CI \cdot \sum_{i=1}^{12} \left(\frac{monthly\ quality\ defects_i}{monthly\ production\ _i} \right) \tag{5.4}$$

$$SS_{QD}\ (days) = \frac{Quality\ defects\ (units)}{FADP\ (units/day)} \tag{5.5}$$

It can be seen in the table that the quality defects have very little or no effect on the inventory level, at least when calculated to cover for the average amount of quality defects. Since the calculations are based on the average amount of quality defects per month, the added inventory will not solely cover for the worst case scenario, with many caps of inadequate quality. The worst case scenario is further investigated in chapter 6 - Designing the Support Tool, where the max scenario is calculated to cover for the month with the largest error during the last twelve months. Furthermore, TAC has chosen to have two suppliers for the main share of the purchased volume of caps to mitigate the risk; therefore one supplier can cover for the other in problematic situations.

Table 12. Safety stock covering the quality defects for each article.

Article	SS_{QD} (days)
28 mm	0.1
33 mm	0.0
35 mm	0.1
NRC	0.0

Delivery Reliability

As mentioned in the empirical data chapter, there are differences in delivery reliability between the two suppliers. When calculating the impact of late deliveries one must take into consideration that some products have one supplier and some have two. The added safety inventory due to late deliveries has to be based on how much is bought from each supplier. The equation behind the calculation of the added safety stock due to late deliveries (SS_{DR}) is shown in (5.6), where the delivery percentage (DP) is the part of the total purchased volume which is bought from each supplier. SS_{DR} is meant to cover the average late delivery. In Table 13 the amount of extra safety inventory induced due to late deliveries is shown. The safety stock for the delivery reliability is calculated from historic data from January 2014 to May 2014.

$$SS_{DR}\ (days) = DP_{CS\,1} \cdot Average\ days\ late_{CS1} + DP_{CS\,2} \cdot Average\ days\ late_{CS\,2} \qquad (5.6)$$

$$SS_{DR}\ (units) = SS_{DR}(days) \cdot FADP(units/day) \qquad (5.7)$$

Table 13. Safety stock for delivery reliability for each article

Article	SS_{DR} (days)
28 mm	5.7
33 mm	4.3
35 mm	5.7
NRC	2.8

From the calculated result it can be seen that the caps delivered from CS 1 (28mm, 33 mm and 35 mm) need a higher safety stock to cover for the delivery reliability factor. NRC is only supplied by CS 2, which has had higher delivery reliability and therefore the safety stock for the NRC is smallest.

Delivery Dependability

As for the delivery reliability there are some differences between the suppliers regarding delivery dependability. The impact of the delivery dependability was calculated based on Equation (5.8), which is based on how much each supplier has delivered. It is assumed that the added safety stock due to delivery reliability should cover the average error. The calculations of the safety stock for delivery dependability (SS_{DD}) are presented below and the results for each article are presented in Table 14. The safety stock for the delivery dependability is calculated based on data from 2013.

$$SS_{DD}(units) = DP_{CS\,1} \cdot Average\ shortage\ quantity_{\ CS\,1} + DP_{CS\,2} \cdot Average\ shortage\ quantity_{\ CS\,2} \quad (5.8)$$

$$Delivery\ dependablity\ (days) = \frac{SS_{DD}(units)}{FADP\ (units)} \quad (5.9)$$

Table 14. Safety stock for the delivery dependability for each article.

Article	SS_{DD} (days)
28 mm	0.2
33 mm	0
35 mm	0.2
NRC	0

The safety stock required to cover the delivery dependability is small for the 28 and 35 mm caps and close to zero for the 33 and 35 mm caps. This is reasonable as the deliveries from the cap suppliers historically only have differed in small quantities. The impact on the inventory levels for the 33 mm and the NRC cap becomes close to nil as these are produced in large quantities making the ratio of produced articles and the delivery difference close to zero. As the 28 and 35 mm caps are produced in smaller quantities than the 33 mm and the NRC caps the difference in delivered quantity is noticeable but the safety stock needed is still close to zero.

Desired Level of Product Availability

Desired level of product availability is the availability of caps in the raw materials warehouse, which can be seen as the service level to the production. As mentioned earlier in the chapter Empirical Data, TAC strives to have a product availability of 100 percent for all of their caps, which is motivated by the low price of the caps and the large costs connected to interruptions in the production. No analysis of how much a production stop would cost TAC has been made, neither has the set target for product availability been investigated, due to the complexity of the calculations and the time constraint in this thesis. However, if the target level had been set lower the safety stock could be decreased. Each of the five production lines can function with several types of vodka flavors and bottle design, which means that if one product experiences a shortage in any of its raw materials, another product can be produced instead. The most sold product can be run in every line, but other products can only be produced in a limited amount of lines. Therefore it is difficult to calculate how this aspect affects the inventory levels, and this is why this task is left to the material planners.

5.3.3 Hidden problems and soft factors

As mentioned in the chapter Frame of Reference, excess inventory does not only lead to an increased inventory holding cost but can also have other negative impacts on the company's performance. An example of this at TAC is that the high inventory levels make people at TAC less prone to carry out improvements. Petter Andersson, who is Supplier Quality Engineer at TAC, said that: "There are no consequences of quality defects when you have a warehouse that never runs out of stock." and "If we were to stop ten pallets in the warehouse from going into production, we would still not need to interrupt the production. We could continue like nothing happened." If the inadequate quality would have caused a more serious problem for TAC it would have been easier to motivate an improvement project to top management, in order to mend the cause of the problem. At TAC it is very important that the production runs with as few interruptions as possible, so if quality defects were to cause a shortage of caps and thus an interruption in the production it might be motivated to investigate the quality defects more thoroughly. With high stock levels it could also take a long time from when the goods are delivered to when they are used in the production, which delays feedback to the supplier if quality defects are identified. Furthermore, the demands on the suppliers, to improve their quality control, might be higher if the quality defects were to have bigger consequences. It is difficult to quantify the cost for TAC, but if TAC could be sure that their suppliers always supplied them with caps of appropriate quality there would be less uncertainty and the safety stock could be lowered. Similar cases exist with the delivery reliability and dependability; today it does not matter if the delivery is a few days late or if the delivered quantity is half of what was ordered, as the production can still continue due to the excess inventory. But with more accurate deliveries the uncertainty would decrease and so also the need for safety inventory. Another effect of excess inventory is a potential shortage in storage space. TAC stores caps in two places today, at the main plant and at Satelliten. Both of the storage locations have high utilization and improvement projects have been carried out to lower the utilization. The induced costs caused by this are hard to determine, but if the warehouses would fill up completely a new one would perhaps have to be built, which would be expensive.

5.3.4 Summary of the Factors' Impact

The impact of the factors was investigated to answer RQ 2. In Table 15 it can be seen that the factor purchase batching contributes to a large part of the cycle inventory. Regarding the safety inventory, as mentioned earlier, the impact for each factor was derived from the average error for each factor. In Table 15 the impact of each factors addition to the safety inventory, that was possible to quantify, is presented in days of stock. The largest impact comes from the delivery reliability factor. This is due to the fact that the average late delivery from the suppliers is large; leading to that a large quantity of caps needs to be held in stock. The second largest impact comes from the forecast error factor. It can be seen in the table that the 33 mm cap, which is the most produced cap, is forecasted more accurately and therefore needs the smallest safety stock to cover the forecast errors. The 35 mm cap, with the smallest quantity used in the production, has the most inaccurate forecasts of the caps due to a volatile demand and requires the largest safety stock to cover the forecast errors. Regarding the factors quality defect and delivery dependability, it can be viewed in the table that the contribution of these factors is small.

Table 15. Overview of how each factor contributes to the inventory levels.

Article	Purchase batching	Forecast accuracy	Quality defects	Delivery reliability	Delivery dependability
28 mm	5.3	1.7	0.1	5.7	0.2
33 mm	3.4	0.5	0.0	4.3	0
35 mm	12.0	4.4	0.1	5.7	0.2
NRC	4.0	1.4	0.0	2.8	0

6 Designing the Decision Support Tool

In this chapter the design of the decision support tool will be presented. Also presented in this chapter are the results, benefits and limitations of the decision support tool.

6.1 The Design of the Decision Support Tool

The last research question in this master thesis will be answered by determining an appropriate design of the decision support tool. In Figure 39 the framework used to develop the design is shown. As can be seen in the figure, the decision support tool is constructed as a spread sheet model, according to the specifications by Smith (2003), containing two ways to calculate the inventory levels: a mean and a max scenario. The mean scenario suggests an inventory level based on the average error, and the max scenario suggests an inventory level based on the maximum error. Input to the framework is the factors identified to affect the inventory levels and their impact, the requirement set by TAC, and theory regarding inventory control. Simulation is also included in the tool as an extra functionality that can be used to evaluate what happens when the impact of a factor changes. In the following text, the areas presented in Figure 39 will be explained more in detail.

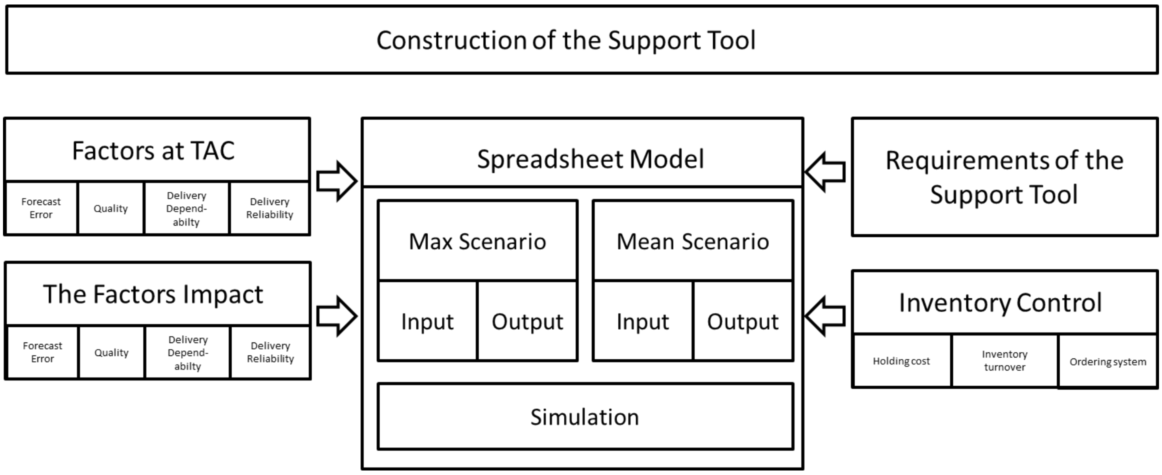


Figure 39. Framework for designing the decision support tool.

6.1.1 Requirements

The decision support tool was intended for TAC and therefore their requirements and wishes served as a basis when developing the structure of the tool. As the project progressed the authors also started to formulate additional requirements, together with TAC, of the tool's functionality. Consequently it was natural to start by listing the demands put on the decision support tool, which are presented below.

The first requirement was determined to show the user the how the factors identified in 5.2 affect the inventory levels of caps.

Requirement 1: Show how the factors identified in 5.2 affect the inventory levels of caps.

The tool should aid the user in the process of determining appropriate inventory levels. This should be done by creating a baseline model reflecting the current situation and developing scenarios from the baseline model to further create understanding of the factors' impact; therefore the following requirement was determined.

Requirement 2: Support the user when deciding appropriate inventory levels for a given time period by presenting the current inventory levels as a baseline model and by creating alternative scenarios for comparison.

In order to enhance the possibility to compare scenarios and to evaluate a suggested inventory, the inventory holding cost will be shown by the decision support too. Also the inventory turnover will be displayed to give the user the opportunity to compare the performance of the warehouse with other companies. Therefore the third requirement was determined.

Requirement 3: Show the inventory holding cost and the inventory turnover for the suggested inventory levels.

TAC stressed the fact that the tool should be easy to use and understand and that is why the fourth requirement was created.

Requirement 4: Be simple to use and allow the user to easily understand the calculations leading to the suggested inventory levels.

The last requirement aims to give the functionality to simulate how changes in the factors' impact will affect the inventory levels.

Requirement 5: Allow the user to analyze how changes in the factors affect the inventory.

6.1.2 Scenarios

As mentioned in the introduction, two scenarios have been determined together with TAC for the decision support tool: a mean scenario and a max scenario. The usage of scenarios in the tool is derived from the theory of spreadsheet modeling (Smith, 2003). These scenarios are included to give the user a better understanding of how the factors affect the inventory levels by presenting two ways of interpreting their impact. The first scenario is based on that the inventory should cover the mean error for each factor, which should give the user an idea of how large the average inventory needs to be to cover the average error. The second scenario is based on that the inventory levels should cover for the max error for each factor. This scenario gives the user an idea of how the max-error for each factor would affect the inventor levels. In section 6.2 the results for the two scenarios are presented. This partly fulfills the second requirement.

6.1.3 Spreadsheet

The decision support tool will be based on a spreadsheet model. This method was chosen as it presents a baseline model together with scenarios and if designed according to Smith (2003) the model can be modified and enhanced to reflect new situations, which increases the user's understanding. The baseline model will be created to reflect the current situation in terms of average inventory and holding cost. This allows the user to gain knowledge that can be used to compare with alternative scenarios. The decision support tool will use alternative scenarios as Smith (2003) recommends. The scenarios are included to broaden the users understanding of what the need for inventory originates from. Moreover, the user should have the option to change individual input variables to allow the user to analyze how changes of the factors affect the inventory levels.

Smith (2003) favors calculating and comparing the cost for different scenarios and stresses the fact that it is important to include all costs in the model to get accurate results. But the spread sheet model in this thesis focuses less on costs and more on calculating inventory levels for different scenarios. Regarding costs, the model in this thesis will be delimited in the sense that only costs directly connected to the required inventory level will be considered.

The chosen program for the development of the decision support tool was Microsoft Excel, which is also the recommended program by Smith (2003). Excel was chosen because it is widely spread; almost all companies have access to the program. Many companies use Excel in the daily work with Supply Chain Management, which is also the case at TAC. Furthermore, Excel is suitable in this case as the data from TAC's ERP system is easily transferred into Excel. To structure the Excel document the six golden rules of spreadsheet design were used (Read & Batson, 1999). The first rule states that the input, calculations and results should be separated to avoid confusion when using and maintaining the model (ibid). In the support tool these are separated and to further help the user the cells have been color coded. The color coding is presented in Figure 40.

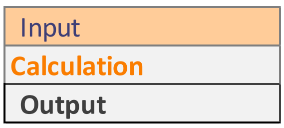


Figure 40. Color coding in the decision support tool.

The second rule states that only one formula should be used per row or column (ibid). There are examples of the structure deviating from this rule, but only in cases where it was considered by the authors to improve the overview of the tool. The third rule states that the input to the formulas only should come from cells to the left and above (ibid), which has been implemented throughout the model. The fourth rule says that multiple worksheets should be used (ibid). In this tool eight worksheets will be used, which can be viewed in Figure 41. The first one is the main sheet where the input of the general data (shown in Figure 42) is done and the results presented. The second worksheet presents the calculations and the result of the scenarios. The result of the scenarios in this worksheet differs from the main worksheet by giving a more comprehensive result. The other six worksheets each represent the input and calculation of the factors affecting the inventory levels.

Main	Scenarios	Forecast error	Quality defects	Delivery dependability CS1	Delivery dependability CS2	Delivery reliability CS1	Delivery reliability CS2

Figure 41. Worksheets in the support tool

The fifth rule says that each column should be used for the same purpose throughout the model (ibid). As the support tool includes several different factors, which require different input values, each worksheet is structured slightly different. Therefore the fifth rule is not fulfilled. To compensate for this, there are explanations above those cells that the authors deemed could be unclear to the user. The last rule is that a documentation sheet should be included, which should include a short description of the model's purpose – who built it, how to contact the persons responsible for the model, the model version, and when it was written (ibid). A documentation sheet is not included in the support tool but instead a user manual is included in the thesis. By following these rules the tool should meet the fourth requirement.

6.1.4 Simulation

To fulfill the sixth requirement the decision support tool should be able to analyze how changes in the factors affect the inventory levels. To exemplify, the user should be able to analyze how the inventory levels would be affected if the delivery dependability was improved by five percentage points. This will be done by adding input cells for the factors that overrides the calculations cell for each factor. If the input cells are left empty, they will not affect the model and the historical data will instead be used to calculate the factors' impact. This fulfills the sixth requirement. In terms of simulation, this method is a static-deterministic simulation (described in section 2.3.3). Static simulation is suitable in this case as the analyzed time period is fixed. Moreover, a deterministic simulation is simpler than a stochastic one and will fulfill the purpose of the tool, i.e. to illustrate the impact each factor has on the inventory levels and to determine an appropriate inventory level for each bottle cap.

6.1.5 Inventory Control at TAC

The decision support tool needs to take the inventory control theory into consideration to assure that the baseline model reflects the current situation and to calculate the output in accordance to the theory. From the inventory control theory in the chapter Frame of Reference, holding cost, inventory turnover and ordering system will be included in the support tool. The holding cost will be used to quantify the average inventory into cost. This is included to further allow the user to compare the baseline model with the scenarios. As mentioned in the chapter Frame of Reference, there are several methods for calculating the holding cost. Axsäter, Chopra & Meindl and Jonsson & Mattsson agree that the major part of the holding cost is the cost of capital. Chopra and Meindl (2013) stated that in addition to the cost of capital the obsolescence cost can have a significant impact on the holding cost. As the caps have a long product life cycle and can be stored a long time in the warehouse without going obsolete, the cost of obsolescence will not be included in the holding cost. Furthermore, TAC owns its own warehouses and the number of employees in the warehouses is not based on the inventory levels, which means that a higher inventory level does not require more warehouse space or more workers. The cost for material handling and storage will therefore not differ between the baseline model and the two scenarios, and the storage cost would only differ between the scenarios if the inventory increased to the level that the warehouses would need to be expanded. From discussions with TAC the possible expansion was considered unlikely and will therefore not be included in the tool. Axsäter (2006) stated that the cost of capital should be closely related to the return of an alternative investment, which in practice can be done by using the company's internal rate of return (IRR). There are benefits with using the IRR, it is relatively easy to obtain, as TAC' financial department uses it in their daily operations, and more importantly the IRR reflects TAC's opportunity cost. For this reason the holding cost in the tool will be calculated with the IRR. However, a drawback with the holding cost is that it is highly company specific and thus can be misleading when comparing to other companies. So in order to enable a comparison between companies, the inventory turnover will also be included in the decision support tool, as is suggested in Mattsson & Jonsson (2003). This fulfills the third requirement.

Theory regarding ordering systems will also be included in the tool to ensure that the ordering policy is correctly reflected. TAC uses a periodic review system where the inventory levels are reviewed manually several times per week. Furthermore, TAC uses a (R, Q) policy where Q is the batch size a truck can carry and R is a quantity derived from the forecasts (rather than a specific quantity). This complicates the process of specifying the ordering system, as there are few fixed factors to derive the daily operations from. The support tool will therefore use a number of forecasted orders for the coming two months to include the order frequency in the support tool. The order frequency will be used to calculate how many days one delivery should cover by dividing the forecasted quantity for the coming two months with the order frequency.

6.1.6 Input

The input process of the tool must be user friendly to fulfill the third requirement. It must be clear what format the data should be entered in and where it should be entered. This is partly solved with the color coding discussed earlier, but to further increase the user friendliness of the tool, each cell in the tool will be named. Furthermore, the input should only require the user to paste the input data into the tool, meaning that the user is not required to make any prior calculations. The input entered in the main sheet is presented in Figure 42. It consists of general data needed to create the baseline model. Regarding the historical data for the last twelve months, it will be entered into each factor's respective sheet. This data is used to calculate the impact of the forecast error, quality defects, delivery reliability, and delivery dependability.

Input							
Purchase cost per unit	**Forecast for the coming 2 months**	**Lead time**	**Purchased % CS1**	**Purchased % CS2**	**Order frequency**	**Lot sizes**	**Current inventory target in days**
Taken from the last invoice (SEK)	*Supplied from the Excel document for caps(units)*	*Tied to supplier (days)*	*Part of purchases made from CS1 (%)*	*Part of purchases made from CS2 (%)*	*Average amount of orders per two months (number of times)*	*Amount of units ordered from the supplier (units)*	
28 mm	28 mm	28 mm	28 mm	28 mm	28 mm	28mm	28mm
33 mm	33 mm	33 mm	33 mm	33 mm	33 mm	33 mm	33 mm
35 mm	35 mm	35 mm	35 mm	35 mm	35 mm	35 mm	35 mm
NRC	NRC	NRC	NRC	NRC	NRC	NRC	NRC
Internal rate of return							
All caps							

Figure 42. Input factors connected to the current conditions

6.1.7 Output

It is crucial that the tool presents the results clearly and in a simple manner, whilst also providing the user with as much information as possible. The output is presented both in the main sheet and in the scenario sheet. In the main sheet the most important results from the scenarios are presented together with the baseline; this is presented in numbers and in three graphs. Two graphs present the average days of inventory for the scenarios and in the graphs each factor's impact is visualized. The max scenario graph is presented in Figure 43. This fulfills the first requirement.

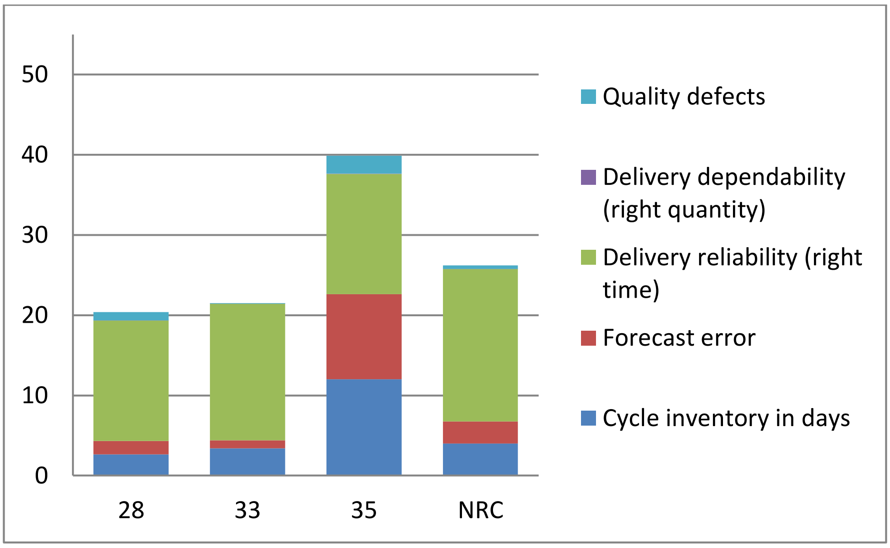


Figure 43. Max scenario in days of inventory.

The third graph, which can be viewed in Figure 44, presents the average inventory for the baseline and the two scenarios. With this graph the user can compare the baseline with the scenarios.

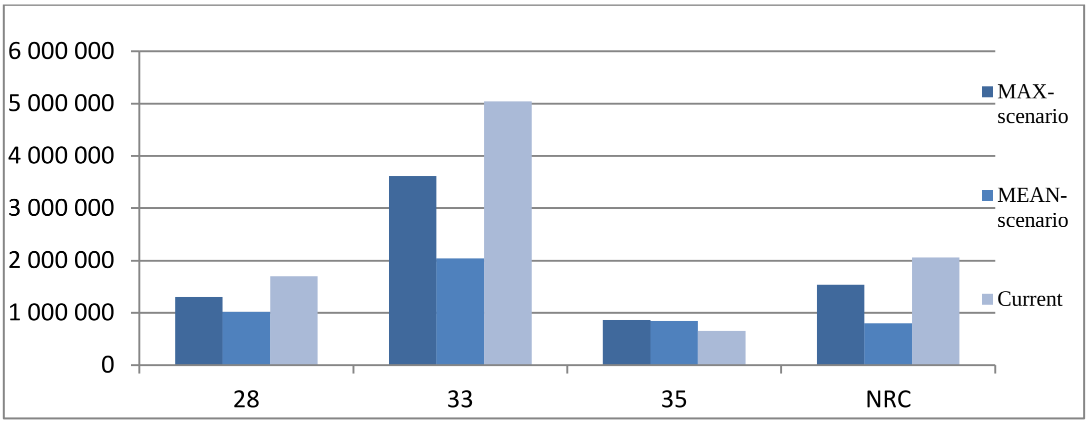


Figure 44. The baseline and the two scenarios average inventory in units.

The scenarios are further presented in the scenario sheet where each factors' impact is presented. Furthermore, the difference in holding cost between the scenarios and the baseline model is presented in the main sheet, along with inventory turnover.

6.2 Results

The results from the decision support tool are presented in Figure 45. In the figure the baseline and the two scenarios are presented. From the result it can be seen that the suggested inventory level in the mean scenario is considerable lower than the baseline. This is most apparent when looking at the results for the 33 mm cap, where the inventory level needs to be less than half of the baseline inventory to cover the average error. It is only for the 35 mm cap that the support tool indicates that the inventory should be higher than the baseline. This can be derived from the long interval between deliveries (23 days), leading to that each delivery should cover more days where errors might occur.

The max scenario is more similar to the baseline model and there is only a small difference between the inventory levels for each article. The suggested inventory levels for the max scenario also indicates that the inventory levels might be lowered for 28 mm, 33 mm and the NRC caps. For the same reason as in the mean scenario, the max scenario indicates that the inventory level for the 35 mm should be higher.

The holding cost is reduced for both scenarios in comparison to the baseline model. The mean scenario indicates a potential saving of 54 % in the cost of holding inventory. The max scenario, that requires more inventory than the mean scenario, indicates a potential saving of 22 % in comparison to the current inventory levels.

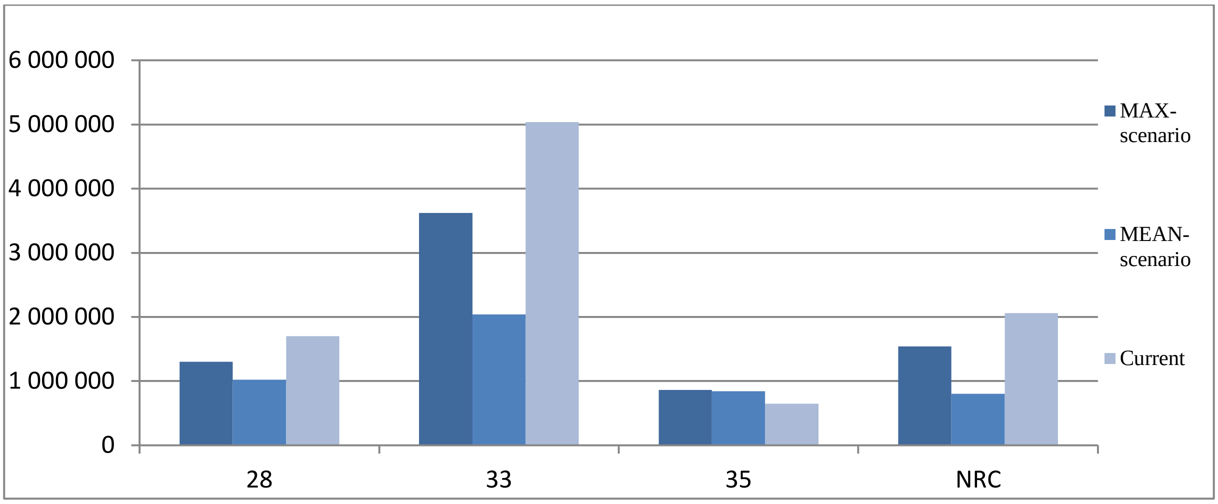


Figure 45. Results of the decision support tool presenting the baseline model and the two scenarios

6.3 Benefits with the Decision Support Tool

There are several benefits with the tool. Possibly the greatest being the overview, showing the impact each factor has on the inventory levels. By presenting all factors affecting the inventory levels in a single place a foundation for discussion among co-workers is created. This overview also allows cross-functional information sharing since it presents data from several departments. By spreading the information and creating understanding between the departments, communication can be encouraged and the problem where each department only focus on their own responsibilities, also known as functional silos, can be avoided.

The decision support tool can also be used to analyze how improvements or deteriorations of the factors would affect the inventory levels, in days of inventory and holding costs. This is done by testing how changes in the factors' impact will affect the inventory levels. This can be important when deciding which improvement project should be prioritized. The tool also gives the user the inventory turnover rate for the baseline model and the scenarios that can be used when comparing the inventory levels with similar companies in the Pernod Ricard group. From this comparison TAC can increase the understanding of which of the baseline model and the scenarios that are closest to the industry standard. By comparing the inventory level with similar companies TAC can get an insight of how appropriate their inventory levels are.

Lastly, the support tool is designed to be easy to understand and to use. As the structure of the tool is designed to be logical, a user with Excel knowledge should be able to adjust the tool for future requirements. This leads to that the tool, if updated when needed, does not get obsolete and is adaptable for changes of the factors affecting the inventory levels.

6.4 Limitations with the Decision Support Tool

In this section the major things to consider when using the decision support tool are discussed. It is important to be aware of the limitations when using the tool in practice in order for the user to draw the correct conclusions from the results presented. *Firstly*, the tool does not consider probabilities due to the choice of static-deterministic simulations technique. This limitation has the implication that the results are less accurate than if probabilities would have been used. However, the tool is developed to only act as support for the material planners; therefore it is considered sufficiently accurate. Moreover, due to this chosen simulation technique, the tool only analyzes the inventory levels at one given time, and does not consider future or historic events. *Secondly*, the decision support tool does not consider the service level towards production, previously referred to as the desired level of product availability. As briefly mentioned earlier, the cost of a shortage in caps, including the costs of machine downtime and lost sales, has not been calculated. Neither has the desired level of product availability and its appropriateness been investigated; instead the aim was to keep the condition that no shortage of caps should occur. The suggested inventory level, given by the decision support tool, is therefore probably higher than the “optimal” inventory levels, but this is considered acceptable since the cost of bottle caps is low, which decreases the need to find an optimal value. *Thirdly*, the tool is only made to support the material planners, which means that they cannot rely solely on the inventory levels suggested by the tool. However, it is believed that the people at TAC working with caps have the experience needed to be able to use the tool efficiently. *Fourthly*, the decision support tool only considers historic data from twelve months back in time. This choice was made to produce more accurate result, since it was assumed that more recent data would reflect the current situation better. However, this means that if TAC had major quality problems with one supplier two years ago, this information would not be considered in the tool. Consequently, the inventory levels would not be high enough if the problem occurred again today. In this case the tool would have benefited from a statistical analysis, in combination with data of what a shortage in caps would cost. With this information a calculation could be done to determine what inventory levels would be the most cost-efficient. *Fifthly*, the scope for identifying factors was narrow, which made it possible to perform the task within the time limits of a master thesis, but also resulted in factors outside of the scope not being considered. This includes factors at the suppliers, such as their stock of finished products or their supplier structure. Neither were factors downstream of TAC considered.

7 Conclusion

The final chapter contains the conclusion for this master thesis. It begins with presenting how the purpose and research questions have been answered, followed by the recommendation to the company and what implications this will bring, and lastly a concluding discussion and suggestions of future studies will be presented.

7.1 Reconnecting to the Purpose and Research Questions

The purpose of this master thesis was "to investigate which factors affect the inventory levels of bottle caps at TAC and to develop a decision support tool for the process of determining appropriate inventory levels for the bottle caps." It has been addressed by determining factors that affect inventory levels in theory and comparing these to the factors identified at TAC. The impact these factors had on the inventory levels were later quantified, when possible, and the results of the quantification were used as a basis for the calculations in the decision support tool. In addition to the calculations regarding the factors, the decision support tool was designed by doing a literature review of general inventory control and similar decision support tools, and finally combining this knowledge with the requirements from TAC.

In relation to the purpose of this study, three research questions were formulated; below it will be discussed how they have been answered in this thesis.

RQ 1: What factors are affecting the inventory levels at TAC?

As mentioned, a literature study was performed initially in order to gain knowledge of the most common factors affecting inventory levels in a producing company. A list of factors was created which was used when analyzing the characteristics of TAC's inventory of caps. Based on the knowledge gained during the data collection phase, many factors identified in the theory could be rejected, while other factors needed to be analyzed further in order to draw any conclusions as to whether they were important or not. In Table 16 the factors chosen for further analysis can be viewed, the so-called short list. This list of factors is also the answer to RQ 1.

Table 16. Factors identified to affect the inventory levels at TAC.

Factors
Lead time
Purchase batching (purchase orders)
Production batching (production orders)
Forecast accuracy
Desired level of product availability
Quality defects
Delivery reliability
Delivery dependability
Hidden problems and soft factors

RQ 2: How do the identified factors affect the inventory levels of bottle caps at TAC?

RQ 2 concerns how the factors on the short list affect TAC in terms of increased inventory levels of caps. To answer this question the factors on the short list were analyzed further. The results showed that some factors affect the inventory levels directly, adding to the inventory levels; others set a constraint on the inventory levels, which has to be fulfilled. The remaining factors were too complicated to quantify, in which case a discussion was held concerning what implication they could be assumed to have on the business. In Table 17 the factors from the short list can once again be viewed, together with an explanation of how each one affects the inventory levels. Table 18 shows the effect that each quantifiable factor has on the inventory levels of caps.

Table 17. Overview of how the factors affect the inventory levels of caps.

Factors	How they affect the inventory levels
Supplier lead time	Adds the constraints that purchases have to be done in batches.
Purchase batching (purchase orders)	Adds to the cycle inventory, see Table 18.
Production batching (production orders)	Adds the constraints that the inventory of caps must take larger production orders into consideration.
Forecast accuracy	Adds to the safety inventory, see Table 18.
Desired level of product availability	Could not be quantified
Quality defects	Adds to the safety inventory, see Table 18.
Delivery reliability	Adds to the safety inventory, see Table 18.
Delivery dependability	Adds to the safety inventory, see Table 18.

The lead time is the reason why purchases have to be made in batches and purchase batching contributes to the cycle inventory, which is seen in the table below. Production batching is not considered to contribute to the inventory levels; instead this factor adds a constraint, as the inventory of caps has to be able to manage large production orders. This should be solved by communication between the material planners and the production planners, so that production batches bigger than normal are also covered by the inventory. Forecast accuracy has a big impact on the inventory levels, which stresses the importance of making good forecasts. The desired level of product availability also affects the inventory levels considerably, but this effect is hard to quantify without making probabilistic simulations. Generally, it is more profitable to have a service level of almost 100 percent and on rare occasions have a shortage in goods, compared to aiming for no shortages at all and thereby have excess stock. As for quality defects and delivery dependability, it was found that they added very little to the inventory, while the delivery reliability factor added several days, all of which can be seen in the table below. There are also consequences or excess stock; it was found that it is harder to pursuit improvement projects, for example with quality defects, since there is always enough stock to continue production even though a large amount of quality defects emerge.

Table 18. Overview of how each factor contributes to the inventory levels.

Article	Purchase batching (days)	Forecast accuracy (days)	Quality defects (days)	Delivery reliability (days)	Delivery dependability (days)
28 mm	5.3	1.7	0.1	5.7	0.2
33 mm	3.4	0.5	0.0	4.3	0
35 mm	12.0	4.4	0.1	5.7	0.2
NRC	4.0	1.4	0.0	2.8	0

RQ 3: How should a tool for deciding appropriate inventory levels of the bottle caps at TAC be designed?

The last research question was answered by designing a decision support tool. As mentioned earlier, the tool was designed by using the calculations made in RQ 2, the requirements and wishes from TAC, and by using the tools gathered from the literature review on inventory control. In Appendix B: User Manual for the Support Tool, the tool is explained more in detail, showing screenshots and describing how to use it. It was important when developing the decision support tool that it should be simple to use and understand. However, simplicity also has a downside; the accuracy is decreased, but since the tool is meant to provide support for decisions on inventory levels rather than providing a final figure, this is not seen as a problem. The tool requires some input data, but the user is only required to copy raw data from their ERP-system into the tool – no prior calculations are needed, as all the calculations will be made by the tool. The decision support tool will generate suggestions of appropriate inventory levels and will also show in graphical representation how much each factor contributes to the inventory levels. Moreover, the tool has the most relevant data gathered in one place, including inventory holding cost and inventory turnover, which simplifies discussions between co-workers. An additional feature is that the user can test possible scenarios by changing the input values.

7.2 Recommendation

Our recommendation to TAC is that they should incorporate the decision support tool in their daily work, in order for it to support the process of deciding inventory levels for the bottle caps. In addition to suggesting inventory levels, the decision support tool gives a good overview of all the factors affecting the inventory levels of the caps, which will give a common ground for discussing the material flow of bottle caps. This will encourage discussions both within and across departments, which enhances the communication in the company and facilitates improvement projects concerning more than one department. Furthermore, the tool has the capacity to simulate changes in the factors' impact on the inventory levels in number of units and holding costs, which should be used when considering improvement projects. The tool can also be used to support the decision of which factor to improve and to estimate at which cost the improvement is justified. However, the tool has to be understood first, including its limitations. It should be used as support when determining inventory levels and to increase the user's comprehension of the factors' combined impact on the inventory levels, but also the factors' impact in relation to each other. To be able to use the tool properly, the user needs to collect the data for each of the identified factors and frequently evaluate the factors' impact to assure that the correct factors are processed in the tool. It is also recommended that cross-functional discussions between representatives from the departments connected to the article be conducted frequently, to assure that the correct factors are included. Additionally, it is of vital importance that the input data is accurate and up-to-date.

The results from the decision support tool implicate that TAC currently has high inventory levels for its caps and that a reduction is possible, which would reduce the inventory holding cost. However, the cost of a shortage in caps is assumed to be costly and the potential savings related to the reduced holding cost must therefore be compared to this risk of a shortage. The results from the tool moreover implies that the inventory levels for the caps should be differentiated for each article, or at least for the caps that are ordered the most frequently and the least frequently.

7.3 Concluding discussion

The decision support tool has been developed to suit the needs of TAC, and therefore the tool is not suited for other companies without modifications. If the tool was to be implemented at another company it is recommended that factors are identified and quantified again, and that the requirements of the company in focus are taken into consideration. Moreover, the decision support tool is designed only as support for the staff at TAC and therefore the suggested inventory levels have to be evaluated and combined with the staff's knowledge.

This master thesis' theoretical contribution is the process of identifying factors affecting inventory levels, calculating each factors impact and compiling the knowledge into a decision support tool. This process contributes to the theory of deriving the need of inventory to specific factors and is suitable for companies that want a better understanding of their inventory levels, but can also be used to reduce capital tied up in the supply chain. It would be especially beneficial for companies with expensive products, that results in a lot of money tied up in inventories, to execute the process and develop a decision support tool.

7.4 Future Studies

As discussed above, the decision support tool uses basic calculations for suggesting inventory levels, so if TAC needs more accurate suggestions they should adopt a more mathematically advanced model. Probabilistic simulation could be the solution to this. However, this solution would require more data, with higher accuracy, in order to provide results that can be trusted. The bottles are cheap to purchase and the induced inventory holding cost is rather low as a consequence, so that a more advanced model might be too costly in relation to the potential benefits.

The costs related to the bottle caps could also be investigated more thoroughly. Today it is not known how much it costs to store goods in the warehouse and the cost of a stock-out has not been investigated. Therefore it is hard to calculate if extra caps in the warehouse would be cost-effective, or have the opposite effect. In connection to this, the desired level of product availability of caps could be investigated to see if today's target of 100 percent is the best solution.

In this master thesis the scope was limited to TAC and, to some extent, the suppliers of TAC. By looking at a larger part of the supply chain, activities and stocks could be optimized based on the total cost in the supply chain, instead of just a small part. Additionally, the suppliers to TAC have not participated in this thesis, so perhaps a better solution could have been created by collaborating with them. An example of a possible solution to this project is a VMI-solution, in order to remove one stock location and lower the administration cost (e.g. order handling). Moreover, TAC could benefit from benchmarking the performance of the raw materials warehouse with other companies within the Pernod Ricard group. Key performance indicators such as product availability and inventory turnover could be compared.

As discussed earlier, TAC experiences high warehouse utilization in both of their warehouses. Today, there is enough space to manage the inventory of caps, but with increased production in the coming years the space would at some point become scarce if the inventory levels increase accordingly. Therefore a study should be performed to analyze the possible future need of additional warehouse space, to formulate a long-term plan of how to manage a larger flow of bottle caps.

References

Arbnor, I., & Bjerke, B. (2009). *Methodology for creating business knowledge* (3rd ed.). London: SAGE Publicatoins, Ltd. doi:http://dx.doi.org/10.4135/9780857024473

Axsäter, S. (2006). *Inventory control* (2nd ed.). Lund, Sweden: Springer.

Bartholdi, J. J., & Hackman, S. T. (2010). *Warehouse & distribution science* (0.93rd ed.)

Beheshti, H. M. (2010). A decision support system for improving performance of inventory management in a supply chain network. *International Journal of Productivity and Performance Management, 59*(5), 452-467.

Björklund, M., & Paulsson, U. (2003). *Seminarieboken - att skriva, presentera och opponera*. Studentlitteratur, Lund:

Braglia, M., Carmignani, G., & Zammori, F. (2006). A new value stream mapping approach for complex production systems. *International Journal of Production Research, 44*(18-19), 3929-3952.

Chopra, S., & Meindl, P. (2013). *Supply chain management. strategy, planning & operation* (5th ed.) Springer.

Cooper, M. C., & Ellram, L. M. (1993). Characteristics of supply chain management and the implications for purchasing and logistics strategy. *International Journal of Logistics Management, The, 4*(2), 13-24.

Davydenko, A., & Fildes, R. (2013). Measuring forecasting accuracy: The case of judgmental adjustments to SKU-level demand forecasts. *International Journal of Forecasting, 29*(3), 510-522.

Denscombe, M. (2003). *Forskningshandboken - för småskaliga forskningsprojekt inom samhällsvetenskaperna* [The Good Research Guide - for small-scale research projects] (P. Larsson Trans.). Lund: Studentlitteratur.

Denscombe, M. (2010). *The good research guide : For small-scale social research projects* (4th ed.). New York: Mc Graw Hill.

Disney, S. M., Naim, M. M., & Towill, D. R. (1997). Dynamic simulation modelling for lean logistics. *International Journal of Physical Distribution & Logistics Management, 27*(3/4), 174-196.

Dubois, A., & Gadde, L. (2002). Systematic combining: An abductive approach to case research. *Journal of Business Research, 55*, 553-560.

Esaiasson, P., Gilljam, M., Oscarsson, H., & Wängnerud, L. (2010). *Metodpraktiken konsten att studera samhälle, individ och marknad* (3:4 ed.) Elanders Sverige AB.

Farasyn, I., Perkoz, K., & Van de Velde, W. (2008). Spreadsheet models for inventory target setting at procter & gamble. *Interfaces, 38*(4), 241-250.

Fisher, M. L. (1997). What is the right supply chain for your product? *Harvard Business Review, ,* 104-116.

Gammelgaard, B. (2004). Schools in logistics research? A methodlogical framework for analysis of the discipline. *International Journal of Physical Distribution & Logistics Management, 34*(6), 479-491. doi:10.1108/09600030410548541

Gattorna, J., Day, A., & Hargreaves, J. (1991). Effective logistics management. *Logistics Information Management, 4*(2), 2-86.

Greis, N. P. (1994). Assessing service level targets in production and inventory planning*. *Decision Sciences, 25*(1), 15-40.

Hines, P., & Rich, N. (1997). The seven value stream mapping tools. *International Journal of Operations & Production Management, 17*(1), 46-64.

Hopp, W. J., & Spearman, M. (2001). *Factory physics: Foundations of manufacturing management* (2nd ed.). New York: Irwin/McGraw-Hill, Boston.

Höst, M., Regnell, M., & Runesson, P. (2006). *Att genomföra examensarbete*. Lund: Studentlitteratur AB.

Howard, K. (1984). Inventory management in practice. *International Journal of Physical Distribution & Logistics Management, 14*(2), 3-36.

Jonsson, P., & Mattsson, S. (2005). *Logistik - läran om effektiva materialflöden*. Malmö: Holmbergs.

Karwowski, W., & Orlowski, A. (2010, Information systems in managment IV. *WULS Press,*

Kogan, V., & Rind, T. (2011). Determining critical power equipment inventory using extreme value approach and an auxiliary poisson model. *Computers & Industrial Engineering, 60*(1), 25-33.

Kovács, G., & Spens, K. M. (2005). Abductive reasoning in logistics research. *International Journal of Physical Distribution & Logistics Management, 35*(2), 132-144.

Larson, P. D., & DeMarais, R. A. (1990). Psychic stock: An independent variable category of inventory. *International Journal of Physical Distribution & Logistics Management, 20*(7), 28-34.

Law, A. M., & Kelton, D. W. (1991). System, models, and simulation. In E. M. Munson, & M. Luhrs (Eds.), *Simulation modeling & analysis* (pp. 3-7)

Mattsson, S., & Jonsson, P. (2003). *Produktionslogistik* (1:8 ed.) Studentlitteratur.

Myers, S. C. (2001). Capital structure. *The Journal of Economic Perspectives, 15*(2), 81-102.

Nahmias, S. (2009). *Production and operations analysis* (Sixth ed.). New York: McGraw-Hill.

Onwubolu, G. C., & Dube, B. C. (2007). Production planning & control: The management of operations. *Production Planning & Control, 17*(1), 67-76.

Pepper, M., & Spedding, T. A. (2010). The evolution of lean six sigma. *International Journal of Quality & Reliability Management, 27*(2), 138-155.

Pernod Ricard. (2012). *Connected - annual report.* ().Pernod Richard.

Petrovic, D. (2001). Simulation of supply chain behaviour and performance in an uncertain environment. *International Journal of Production Economics, 71*(1), 429-438.

Read, N., & Batson, J. (1999). *Spreadsheet modelling best practise.* Unpublished manuscript.

Senge, P. M. (1997). THE FIFTH DICIPLINE. *Measuring Business Excellence, 1*(3), 46-51. doi:10.1108/eb025496

Silver, E. A., Pyke, D. F., & Peterson, R. (1998). *Inventory management and production planning and scheduling* Wiley New York.

Silverman, D. (2011). *Interpreting qualitative data* (4th ed.) SAGE Pbulications Ltd.

Smith, G. A. (2003). Using integrated spreadsheet modeling for supply chain analysis. *Supply Chain Management: An International Journal, 8*(4), 285-290.

Ståhl, J. (2012). *Industriella tillverkningssystem del II - länken mellan teknik och ekonomi* (2nd ed.). Lund:

Stock, J. R., & Lambert, D. M. (1987). *Strategic logistics management* Irwin (Homewood, Ill.).

Tapping, D., Luyster, T., & Shuker, T. (2002). *Value stream management: Eight steps to planning, mapping, and sustaining lean improvements* Productivity Press.

The Absolut Company. (2012). Retrieved 02/04, 2014, Retrieved from http://theabsolutcompany.com/en/brands/absolut/

Walker, J. (2000). Decision support for the single-period inventory problem. *Industrial Management & Data Systems, 100*(2), 61-67.

Weele, A. v. (2010). *Purchasing & supply chain management: Analysis, strategy, planning and practice* (5th ed.) Andover: Cengage Learning.

Winters, P. R. (1960). Forecastig sales by exponentially weigthed moving averages. *Management Science, 6*

Yin, R. K. (2007). *Fallstudier: Design och genomförande* (E. Persson Trans.). Liber AB.

Appendix A: Mergers of Factors

In Table 19 to Table 22 the mergers of factors are explained which was used to create Figure 9. It should be noted that obsolescence is not mentioned since it is the only factor in its group.

Table 19. How the merger of the factors was done for the group cycle inventory.

Cycle inventory						
Batching	*Batch production*	*Cycle stocks*	*Frozen stocks*	*Economies of scale*	*Transportation*	*Logistics*
Refers to purchase order batching in this case, which is the main reason for the occurrence of cycle inventory.	Refers to production order batching, which will not affect the inventory levels directly but will add a constraint that the production orders need to have coverage in the raw material warehouse.	This is just another definition of cycle inventory.	Frozen stocks are defined by Silver, Pyke & Peterson (1998) as lead times in the supply chain and process constraints. These are assumed to have the biggest impact on the cycle inventory and will therefore be included in this group.	It is the reason behind batching, that it is cheaper to procure and produce in batches to lower the fixed costs.	Nahmias (2009) defines transportation as pipeline inventory, and the size of this is affected by the batch sizes.	Logistics refers to constraints in the supply chain that forces the company to keep inventory, such as a minimum order quantity, which is assumed to affect the cycle inventory the most.

Table 20. How the merger of the factors was done for the group safety inventory.

Safety inventory					
Variability	*Production variability*	*Forecast error*	*Safety stocks*	*Uncertainties*	*Control cost*
The safety inventory is used to counter variability.	The safety inventory is seen as a strategy to counter all variability in the supply chain and therefore is also production variability included in safety inventory.	Forecast error can be seen as variability in demand and is therefore also meant to be countered with the safety inventory.	Safety stock is just a different definition of safety inventory.	Uncertainties are another word for variability.	Control cost is the cost of maintaining the inventory control system. If the safety inventory would be unnecessary big the control cost would be low; therefore the control cost is included as a factor in the

			safety inventory.

Table 21. How the merger of the factors was done for the group seasonal inventory.

Seasonal inventory			
Seasonality	*Anticipation stock*	*Speculation*	*Smoothing*
Seasonality is the reason for keeping seasonal inventory.	Anticipation stock is created to cover for peaks in the demand, which is similar to the strategy of seasonal inventory. The difference is that anticipation stock is not only held to counter for seasonal variations but also to speculate in market fluctuations (Nahmias, 2009).	As mentioned in the cell above, anticipation stock is held as a consequence of speculation.	Nahmias (2009) refers to smoothing as a technique to levels the needed production capacity, by for example storing finished goods to use in the future. This is linked to anticipation stock and seasonal inventory.

Table 22. How the merger of the factors was done for the group desired level of product availability.

Desired level of product availability
Customer responsiveness
Desired level of product availability is affected by how responsive the company wants to be towards their customers, which is why these two factors are merged.

Appendix B: User Manual for the Support Tool

The Absolut Company
Pernod Ricard

User Manual

May 2014

Purpose of the document

This user manual is intended to introduce the user to the interface of the decision support tool and how it functions.

Intended Audience

This document is created by Anton Adolfsson and Erik Lundin for the supply chain department of The Absolut Company and is intended for users with basic knowledge of MS Excel.

Introduction

The support tool is developed as a spreadsheet model. It means that the tool present the current situation as a baseline for comparison and two scenarios to further understand the impact from the factors affecting the inventory levels. The two scenarios calculated in the support tool are: the inventory level needed to cover the average error and the maximum error for each factor.

Structure of the Tool

The support tool is structured over eight sheets. Each sheet has a different functions but the functions can be divided in three categories; input, output and calculations. The color coding used in the tool is presented in Table 23. The input cells are where the user inserts data, the calculations cells shows the calculation performed in the tool and the output presents the result of the calculations.

Table 23. Color coding used in the support tool.

Input
Calculation
Output

The sheets are presented in the following pages, and instructions for each sheet are given. The sheets are presented in Figure 46. There are two sheets for the delivery dependability and the delivery reliability. This to include both suppliers, but as the sheets are designed identically only the sheets for the CS 1 will be presented. The instructions can be directly transferred to the sheets covering CS2.

Main	Scenarios	Forecast error	Quality defects	Delivery dependability CS1	Delivery dependability CS2	Delivery reliability CS1	Delivery reliability CS2

Figure 46. Sheets in the support tool

Main Sheet

The main sheet includes the general input in the upper left corner. The simulations input are used to override the calculations done in the left down corner. If the simulation inputs are left empty the calculated impact from the historical data will be used in the baseline model and the scenarios. The general output of the tool is presented to the right in the main sheet. For each scenario the most important results are presented in numbers and in graphs. The graphs for each scenario present each factors impact on the total inventory. The last graph in the bottom right corner presents the current situation and the two scenarios in inventory levels in units.

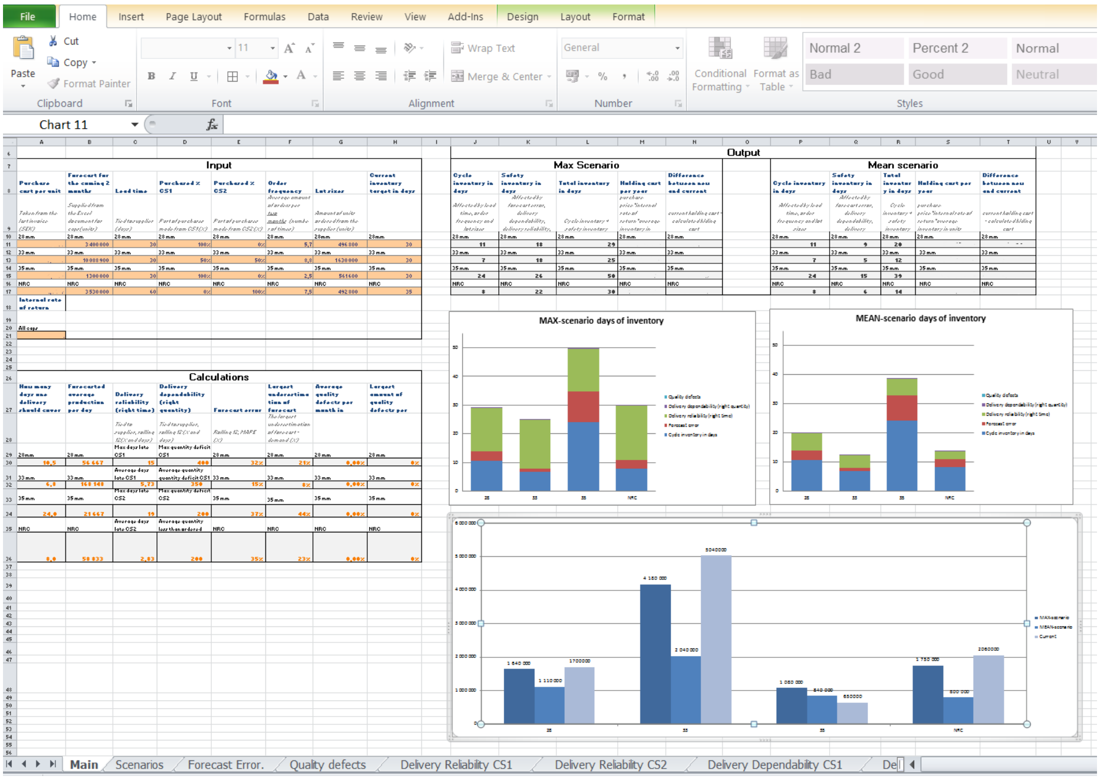
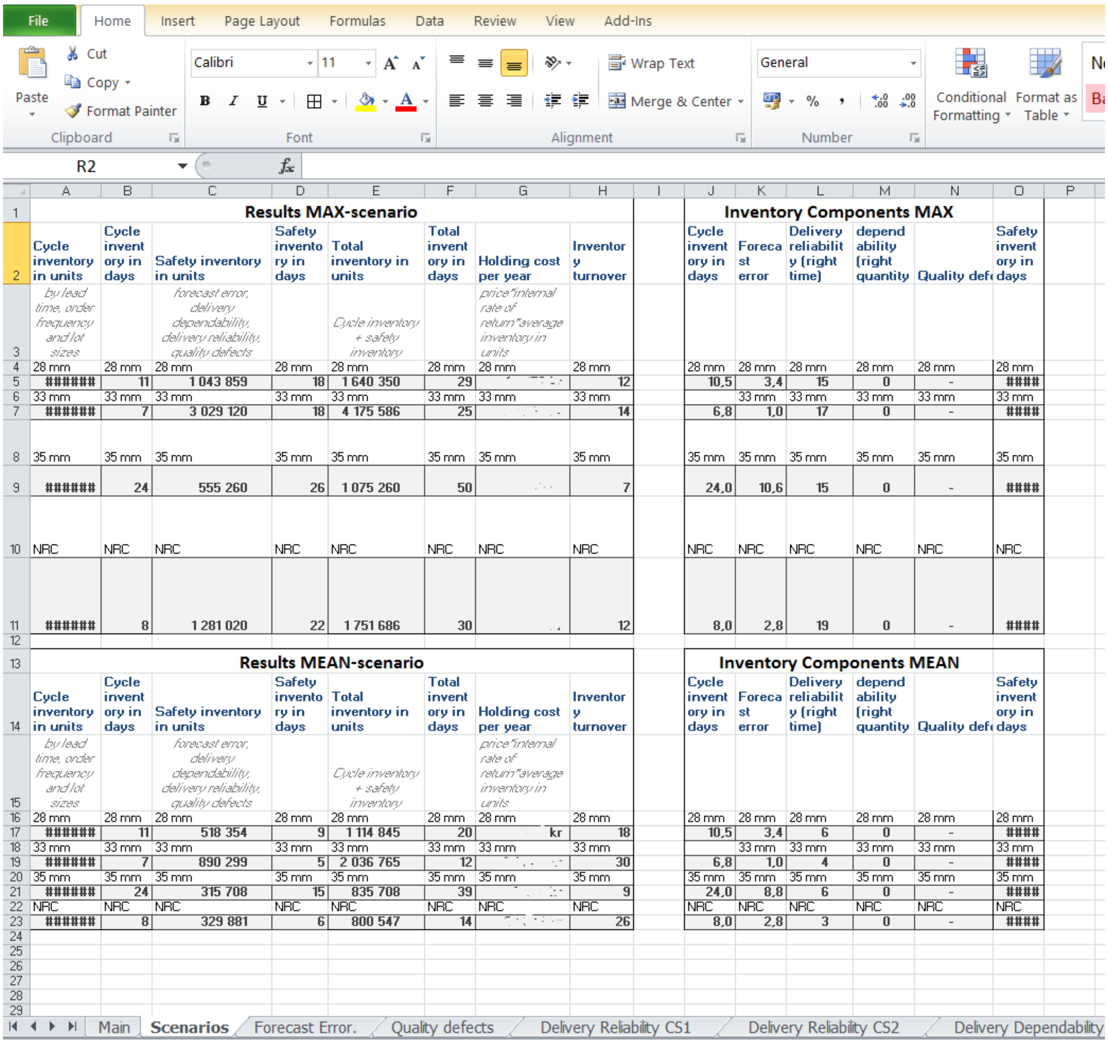


Figure 47. Main sheet in the decision support tool

Scenarios

The scenario sheet further presents the scenarios and the inventory components connected to each scenario. This sheet is used to investigate each scenario further.



Results MAX-scenario

Cycle inventory in units	Cycle inventory in days	Safety inventory in units	Safety inventory in days	Total inventory in units	Total inventory in days	Holding cost per year	Inventory turnover
by lead time, order frequency and lot sizes		*forecast error, delivery dependability, delivery reliability, quality defects*		*Cycle inventory + safety inventory*		*price*internal rate of return*average inventory in units*	
28 mm	28 mm	28 mm	28 mm	28 mm	28 mm	28 mm	28 mm
######	11	1 043 859	18	1 640 350	29		12
33 mm	33 mm	33 mm	33 mm	33 mm	33 mm	33 mm	33 mm
######	7	3 029 120	18	4 175 586	25		14
35 mm	35 mm	35 mm	35 mm	35 mm	35 mm	35 mm	35 mm
######	24	555 260	26	1 075 260	50		7
NRC	NRC	NRC	NRC	NRC	NRC	NRC	NRC
######	8	1 281 020	22	1 751 686	30		12

Inventory Components MAX

Cycle inventory in days	Forecast error	Delivery reliability (right time)	dependability (right quantity	Quality defe	Safety inventory in days
28 mm	28 mm	28 mm	28 mm	28 mm	28 mm
10,5	3,4	15	0	-	####
	33 mm	33 mm	33 mm	33 mm	33 mm
6,8	1,0	17	0	-	####
35 mm	35 mm	35 mm	35 mm	35 mm	35 mm
24,0	10,6	15	0	-	####
NRC	NRC	NRC	NRC	NRC	NRC
8,0	2,8	19	0	-	####

Results MEAN-scenario

Cycle inventory in units	Cycle inventory in days	Safety inventory in units	Safety inventory in days	Total inventory in units	Total inventory in days	Holding cost per year	Inventory turnover
by lead time, order frequency and lot sizes		*forecast error, delivery dependability, delivery reliability, quality defects*		*Cycle inventory + safety inventory*		*price*internal rate of return*average inventory in units*	
28 mm	28 mm	28 mm	28 mm	28 mm	28 mm	28 mm	28 mm
######	11	518 354	9	1 114 845	20	kr	18
33 mm	33 mm	33 mm	33 mm	33 mm	33 mm	33 mm	33 mm
######	7	890 299	5	2 036 765	12		30
35 mm	35 mm	35 mm	35 mm	35 mm	35 mm	35 mm	35 mm
######	24	315 708	15	835 708	39		9
NRC	NRC	NRC	NRC	NRC	NRC	NRC	NRC
######	8	329 881	6	800 547	14		26

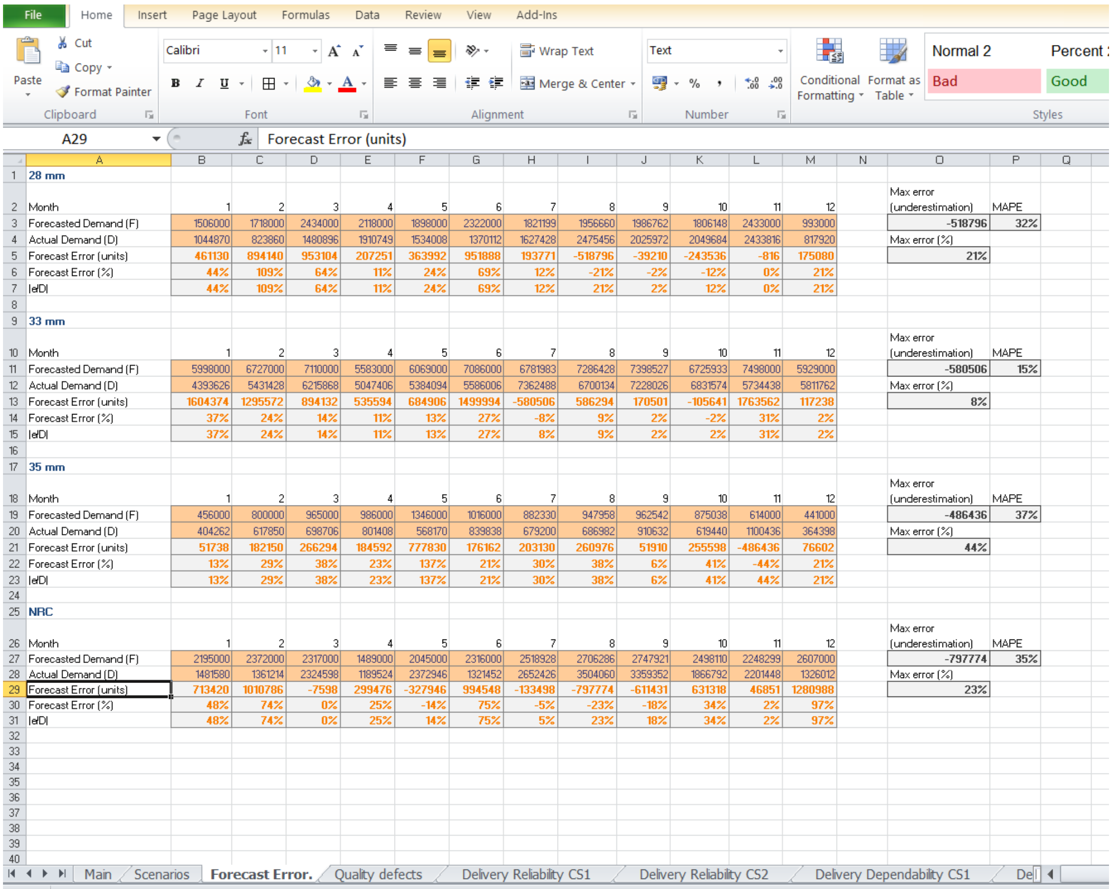
Inventory Components MEAN

Cycle inventory in days	Forecast error	Delivery reliability (right time)	dependability (right quantity	Quality defe	Safety inventory in days
28 mm	28 mm	28 mm	28 mm	28 mm	28 mm
10,5	3,4	6	0	-	####
	33 mm	33 mm	33 mm	33 mm	33 mm
6,8	1,0	4	0	-	####
35 mm	35 mm	35 mm	35 mm	35 mm	35 mm
24,0	8,8	6	0	-	####
NRC	NRC	NRC	NRC	NRC	NRC
8,0	2,8	3	0	-	####

Figure 48. Scenario sheet in the decision support tool

Forecast Error

The forecast error sheet is the first sheet specialized on a factor. In this sheet the historical data for each factor is inserted. The historical data should consist of the forecasted demand for each factor for the last twelve months and the actual demand for the last twelve months.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	28 mm															
2	Month	1	2	3	4	5	6	7	8	9	10	11	12		Max error (underestimation)	MAPE
3	Forecasted Demand (F)	1506000	1718000	2434000	2118000	1898000	2322000	1821199	1956660	1986762	1806148	2433000	993000		-518796	32%
4	Actual Demand (D)	1044870	823860	1480896	1910749	1534008	1370112	1627428	2475456	2025972	2049684	2433816	817920		Max error (%)	
5	Forecast Error (units)	461130	894140	953104	207251	363992	951888	193771	-518796	-39210	-243536	-816	175080		21%	
6	Forecast Error (%)	44%	109%	64%	11%	24%	69%	12%	-21%	-2%	-12%	0%	21%			
7	|e/D|	44%	109%	64%	11%	24%	69%	12%	21%	2%	12%	0%	21%			
8																
9	33 mm															
10	Month	1	2	3	4	5	6	7	8	9	10	11	12		Max error (underestimation)	MAPE
11	Forecasted Demand (F)	5998000	6727000	7110000	5583000	6069000	7086000	6781983	7286428	7398527	6725933	7498000	5929000		-580506	15%
12	Actual Demand (D)	4393626	5431428	6215868	5047406	5384094	5586006	7362488	6700134	7228026	6831574	5734438	5811762		Max error (%)	
13	Forecast Error (units)	1604374	1295572	894132	535594	684906	1499994	-580506	586294	170501	-105641	1763562	117238		8%	
14	Forecast Error (%)	37%	24%	14%	11%	13%	27%	-8%	9%	2%	-2%	31%	2%			
15	|e/D|	37%	24%	14%	11%	13%	27%	8%	9%	2%	2%	31%	2%			
16																
17	35 mm															
18	Month	1	2	3	4	5	6	7	8	9	10	11	12		Max error (underestimation)	MAPE
19	Forecasted Demand (F)	456000	800000	965000	986000	1346000	1016000	882330	947958	962542	875038	614000	441000		-486436	37%
20	Actual Demand (D)	404262	617850	698706	801408	568170	839838	679200	686982	910632	619440	1100436	364398		Max error (%)	
21	Forecast Error (units)	51738	182150	266294	184592	777830	176162	203130	260976	51910	255598	-486436	76602		44%	
22	Forecast Error (%)	13%	29%	38%	23%	137%	21%	30%	38%	6%	41%	-44%	21%			
23	|e/D|	13%	29%	38%	23%	137%	21%	30%	38%	6%	41%	44%	21%			
24																
25	NRC															
26	Month	1	2	3	4	5	6	7	8	9	10	11	12		Max error (underestimation)	MAPE
27	Forecasted Demand (F)	2195000	2372000	2317000	1489000	2045000	2316000	2518928	2706286	2747921	2498110	2248299	2607000		-797774	35%
28	Actual Demand (D)	1481580	1361214	2324598	1189524	2372946	1321452	2652426	3504060	3359352	1866792	2201448	1326012		Max error (%)	
29	Forecast Error (units)	713420	1010786	-7598	299476	-327946	994548	-133498	-797774	-611431	631318	46851	1280988		23%	
30	Forecast Error (%)	48%	74%	0%	25%	-14%	75%	-5%	-23%	-18%	34%	2%	97%			
31	|e/D|	48%	74%	0%	25%	14%	75%	5%	23%	18%	34%	2%	97%			

Figure 49. Forecast error sheet in the main sheet

Quality Defects

The quality sheet is used to insert the historical data for the quality defects. The input area is to the left in the sheet and in this area the historical data for the quality defects for the last twelve months should be entered. The attributes the data is required to be entered with are: number of articles with quality defects, date and article type.

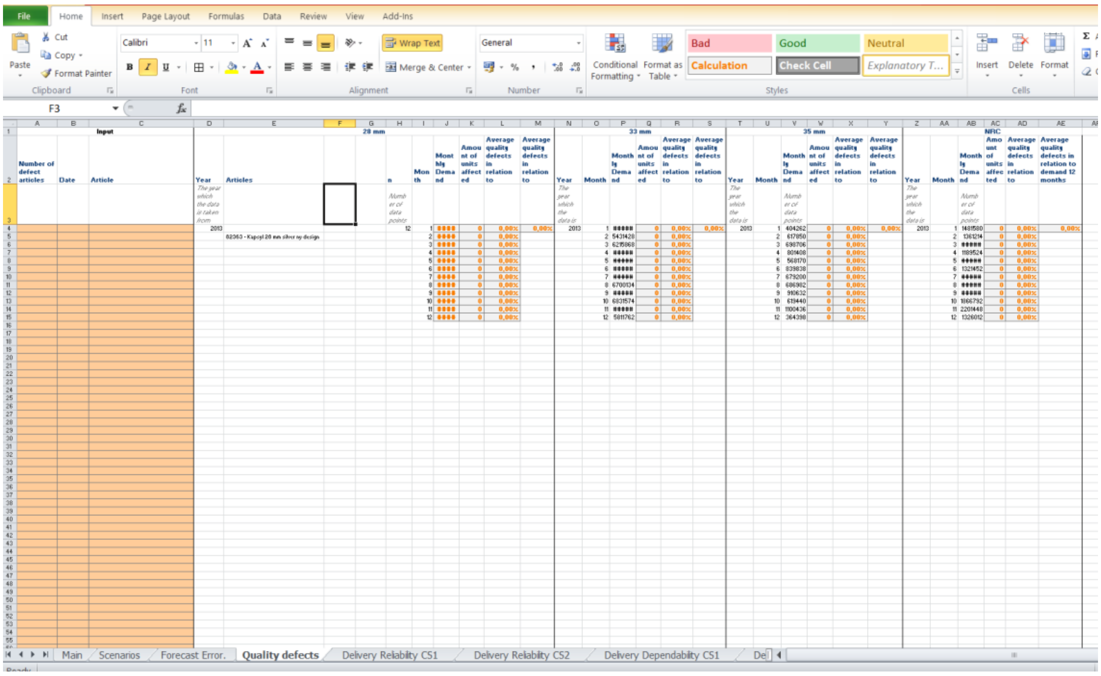
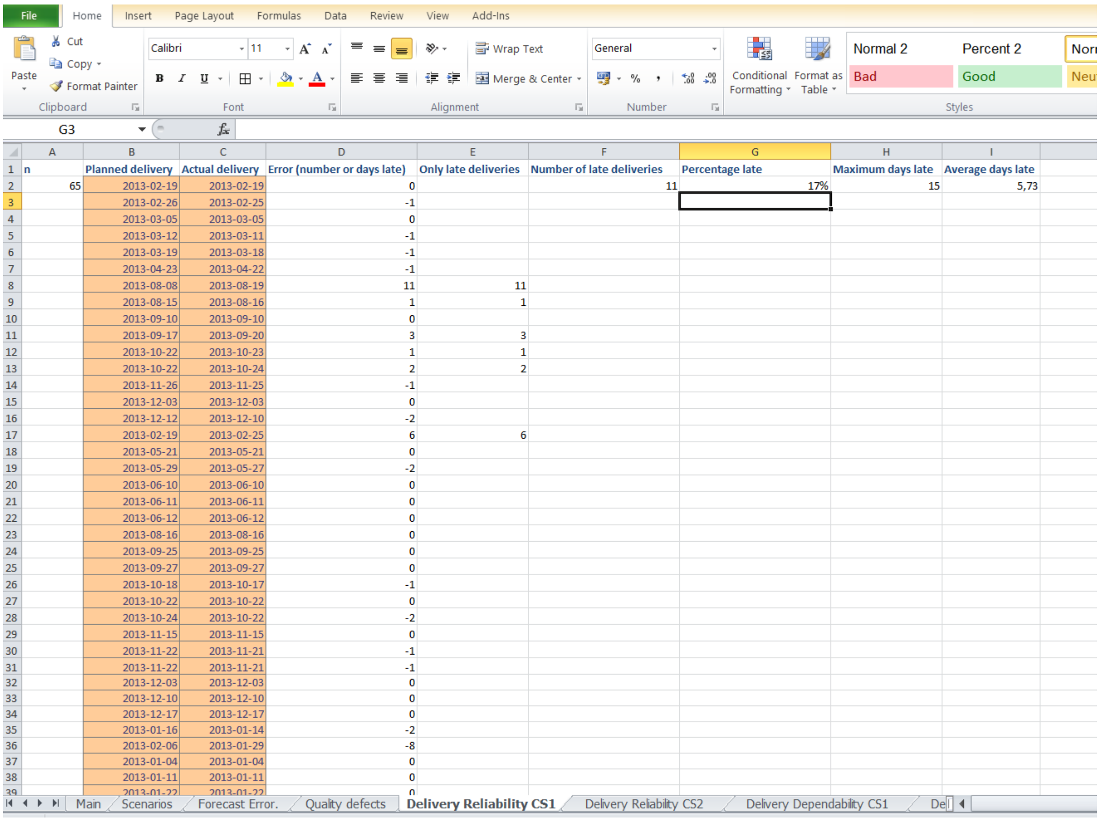


Figure 50. Quality defect sheet

Delivery Reliability

The delivery reliability sheet also has the input area to the left in the sheet. The data inserted in this sheet is the delivery reliability for each cap supplier for the last month. For example in Figure 51 the delivery reliability sheet covers the CS 1. The data entered should have the attributes: planned delivery and actual delivery.

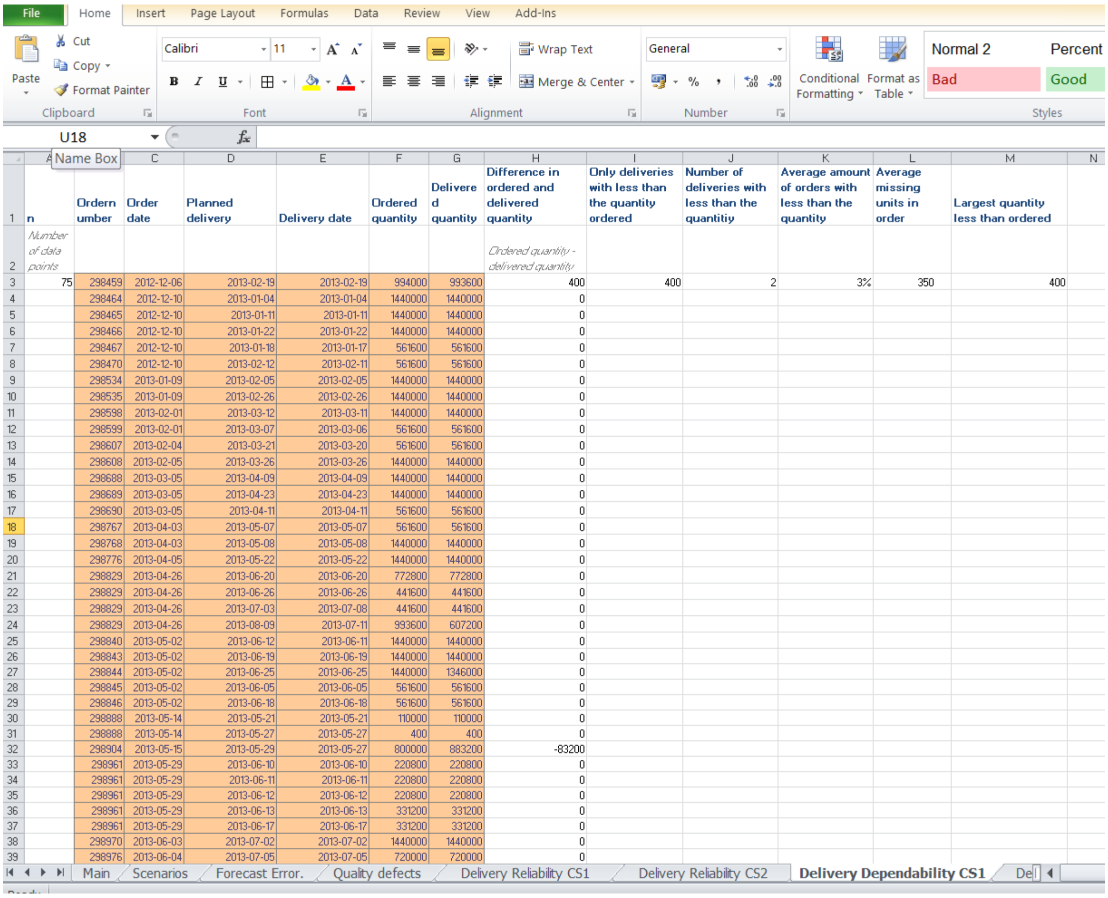


	A	B	C	D	E	F	G	H	I
1	n	Planned delivery	Actual delivery	Error (number or days late)	Only late deliveries	Number of late deliveries	Percentage late	Maximum days late	Average days late
2	65	2013-02-19	2013-02-19	0		11	17%	15	5,73
3		2013-02-26	2013-02-25	-1					
4		2013-03-05	2013-03-05	0					
5		2013-03-12	2013-03-11	-1					
6		2013-03-19	2013-03-18	-1					
7		2013-04-23	2013-04-22	-1					
8		2013-08-08	2013-08-19	11	11				
9		2013-08-15	2013-08-16	1	1				
10		2013-09-10	2013-09-10	0					
11		2013-09-17	2013-09-20	3	3				
12		2013-10-22	2013-10-23	1	1				
13		2013-10-22	2013-10-24	2	2				
14		2013-11-26	2013-11-25	-1					
15		2013-12-03	2013-12-03	0					
16		2013-12-12	2013-12-10	-2					
17		2013-02-19	2013-02-25	6	6				
18		2013-05-21	2013-05-21	0					
19		2013-05-29	2013-05-27	-2					
20		2013-06-10	2013-06-10	0					
21		2013-06-11	2013-06-11	0					
22		2013-06-12	2013-06-12	0					
23		2013-08-16	2013-08-16	0					
24		2013-09-25	2013-09-25	0					
25		2013-09-27	2013-09-27	0					
26		2013-10-18	2013-10-17	-1					
27		2013-10-22	2013-10-22	0					
28		2013-10-24	2013-10-22	-2					
29		2013-11-15	2013-11-15	0					
30		2013-11-22	2013-11-21	-1					
31		2013-11-22	2013-11-21	-1					
32		2013-12-03	2013-12-03	0					
33		2013-12-10	2013-12-10	0					
34		2013-12-17	2013-12-17	0					
35		2013-01-16	2013-01-14	-2					
36		2013-02-06	2013-01-29	-8					
37		2013-01-04	2013-01-04	0					
38		2013-01-11	2013-01-11	0					
39		2013-01-22	2013-01-22	0					

Figure 51. Delivery reliability sheet

Delivery Dependability

The sheet for delivery dependability is presented in Figure 52 and as for the delivery reliability the data entered should only represent the supplier written in the sheet name. The input area is to the left in the sheet and the data entered should have the attributes: order number, order date, planned delivery, delivery date, ordered quantity and delivered quantity. The reason that this factor requires six attributes is that orders can be partially delivered and for high error values it needs to be validated that the error is real and not partially delivered during a week.



	n	Ordernumber	Order date	Planned delivery	Delivery date	Ordered quantity	Delivered quantity	Difference in ordered and delivered quantity	Only deliveries with less than the quantity ordered	Number of deliveries with less than the quantitiy	Average amount of orders with less than the quantity	Average missing units in order	Largest quantity less than ordered
2	Number of data points							Ordered quantity - delivered quantity					
3	75	298459	2012-12-06	2013-02-19	2013-02-19	994000	993600	400	400	2	3%	350	400
4		298464	2012-12-10	2013-01-04	2013-01-04	1440000	1440000	0					
5		298465	2012-12-10	2013-01-11	2013-01-11	1440000	1440000	0					
6		298466	2012-12-10	2013-01-22	2013-01-22	1440000	1440000	0					
7		298467	2012-12-10	2013-01-18	2013-01-17	561600	561600	0					
8		298470	2012-12-10	2013-02-12	2013-02-11	561600	561600	0					
9		298534	2013-01-09	2013-02-05	2013-02-05	1440000	1440000	0					
10		298535	2013-01-09	2013-02-26	2013-02-26	1440000	1440000	0					
11		298598	2013-02-01	2013-03-12	2013-03-11	1440000	1440000	0					
12		298599	2013-02-01	2013-03-07	2013-03-06	561600	561600	0					
13		298607	2013-02-04	2013-03-21	2013-03-20	561600	561600	0					
14		298608	2013-02-05	2013-03-26	2013-03-26	1440000	1440000	0					
15		298688	2013-03-05	2013-04-09	2013-04-09	1440000	1440000	0					
16		298689	2013-03-05	2013-04-23	2013-04-23	1440000	1440000	0					
17		298690	2013-03-05	2013-04-11	2013-04-11	561600	561600	0					
18		298767	2013-04-03	2013-05-07	2013-05-07	561600	561600	0					
19		298768	2013-04-03	2013-05-08	2013-05-08	1440000	1440000	0					
20		298776	2013-04-05	2013-05-22	2013-05-22	1440000	1440000	0					
21		298829	2013-04-26	2013-06-20	2013-06-20	772800	772800	0					
22		298829	2013-04-26	2013-06-26	2013-06-26	441600	441600	0					
23		298829	2013-04-26	2013-07-03	2013-07-08	441600	441600	0					
24		298829	2013-04-26	2013-08-09	2013-07-11	993600	607200	0					
25		298840	2013-05-02	2013-06-12	2013-06-11	1440000	1440000	0					
26		298843	2013-05-02	2013-06-19	2013-06-19	1440000	1440000	0					
27		298844	2013-05-02	2013-06-25	2013-06-25	1440000	1346000	0					
28		298845	2013-05-02	2013-06-05	2013-06-05	561600	561600	0					
29		298846	2013-05-02	2013-06-18	2013-06-18	561600	561600	0					
30		298888	2013-05-14	2013-05-21	2013-05-21	110000	110000	0					
31		298888	2013-05-14	2013-05-27	2013-05-27	400	400	0					
32		298904	2013-05-15	2013-05-29	2013-05-27	800000	883200	-83200					
33		298961	2013-05-29	2013-06-10	2013-06-10	220800	220800	0					
34		298961	2013-05-29	2013-06-11	2013-06-11	220800	220800	0					
35		298961	2013-05-29	2013-06-12	2013-06-12	220800	220800	0					
36		298961	2013-05-29	2013-06-13	2013-06-13	331200	331200	0					
37		298961	2013-05-29	2013-06-17	2013-06-17	331200	331200	0					
38		298970	2013-06-03	2013-07-02	2013-07-02	1440000	1440000	0					
39		298976	2013-06-04	2013-07-05	2013-07-05	720000	720000	0					

Figure 52. Delivery dependability sheet