Campaigns and seasonality's effect on the batch size

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Abstract

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Background The Nordic headquarter at Campbell Soup has been commissioned by the management to review their inventories and to asses' optimal inventory levels under the prerequisite to still achieve agreed customer service levels and not get higher total costs. The capital tied is believed to be too high, therefore Campbell Soup wants to lower their inventory levels.

Purpose The purpose of this study is to do an extensive research resulting in long term suggestions on feasible batch sizes which are affected by campaigns and seasonality. The outcome of the study will be suggestions on how to lower the capital tied, while adhering to agreed customer service levels and looking at the total costs.

Method Ten bouillons within the group Bong Dry Bouillon produced at the production line 102 were investigated. The data for the study was collected by interviews, direct observations and by collecting quantitative and qualitative data. The methodical view used was the analytical view.

Analysis The theories presented in the thesis were used to construct two models of the production and inventory of finished products of one year. The first one, called Current Situation Model, was based on real data and was used as a validation tool for the second model called Cost Analysis Model. In the Cost Analysis Model a distribution function was used to simulate a random stochastic demand and the Current Situation Model was used to validate if the chosen distribution function was good enough. Different scenarios were analyzed with the Cost Analysis Model to investigate the batch sizes sensitivity to different changes. With the Cost Analysis Model a batch size for each investigated product could be determined, which fulfills the case fill rate and has the lowest total varying cost.

Conclusion Campbell Soup Nordic has very low inventory costs in comparison to the setup costs and manufacturing costs. It means it is more profitable for Campbell Soup Nordic, with regards to the summation of the varying costs depending on volume, to produce in larger batches for the products with high turn-over. The products with low turn-over should on the other hand be produced in smaller batches. If Campbell Soup Nordic wants to fulfill the gold standard of the service level in case fill rate they should continue with a safety time of two weeks. They should do this since a shorter safety time gives more lost sales which leads to not being able to fulfill the gold standard of a case fill rate of 99%.

Table 1: Optimal batch sizes for setup time of 30min and two mechanics

Product	Current batch size (SU)	Current Varying costs (SEK)	Recommended batch size (SU)	Recommended batch Varying costs (SEK)	Savings (SEK/year)
4900	194	37101	385	30963	6137
4901	239	18444	338	17288	1155
4902	195	6862	195	6862	0
4903	266	18966	479	16959	2007
4904	219	39340	448	33311	6029
4906	736	48458	1507	44777	3681
4907	657	35700	1223	33099	2601
4908	873	41822	1582	39420	2402
4909	969	33124	1745	31374	1750
4910	911	14258	813	14199	59

Keywords Batch size, campaign, case fill rate, gamma-distribution, holding cost, manufacturing cost, seasonality, setup cost and simulation model.

Preface

This master thesis is written at the Department of Production Management at the Faculty of Engineering of Lund University in Sweden. This master thesis is the concluding part of the authors´ Master of Science in Mechanical Engineering with a focus on Production Management and Engineering Logistics. The study was performed in cooperation with Campbell Soup Nordic, recently acquired and in the future known as Continental Foods. Working with the master thesis has given us an opportunity to implement our theoretical knowledge at a traditional manufacturing company and has been a great learning experience.

We are particularly grateful for the assistance given by our supervisors Fredrik Ödegaard and Peter Berling at the department of Production Management. They have supported us during the master thesis and have given us constructive feedback that helped us to improve the outcome of this thesis. Further, we would like to take the opportunity to thank the employees at Campbell Soup Nordic, for their time and good attitude. Especially thanks to Henrik Rosdahl, Agneta Frisk, Josefine Johansson, Torgny Holmström, Johan Nilsson, Mona Ljungberg, Stefan Lundh and Pontus Sturk, who made the extra effort to provide us with data and information about the company.

Finally we would like to thank the people around us, especially family and friends that have supported us during our education.

Lund, January 16 2014

Linda Rundqwist

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1 Introduction

This chapter describes and introduces the background of Campbell Soup. It also presents the problem definition, purpose, targets and objectives of the study.

1.1 Background

Campbell Soup Company was founded 1869 in the United States. Today Campbell Soup is an international company with 22,000 employees and a turnover of SEK 53 billion. Campbell Soup's products are bouillons, soups, sauces which are sold in more than 100 countries worldwide. Some of the brands that are included in Campbell Soup Company are Campbell's, Bong, Blå Band, Varma Koppen and Touch of Taste. In Europe, Campbell Soup has businesses in Belgium, Finland, France, Germany and Sweden. The Nordic headquarter is located in Kristianstad, Sweden, and it is responsible for the supply of Campbell Soup's products in the Nordic countries.

The Nordic headquarter has been commissioned by the management to review their inventory levels for packaging material, raw material and finished products and to assess optimal inventory levels under the prerequisite to still achieve agreed customer service levels. Today, they use two different safety time parameters: one for retail products and one for out-of-home products. Campbell Soup Nordic is in need of a tool to calculate unique safety time levels for each product, without negatively affecting the service level. Furthermore they are currently producing all products against forecast and they have permanent safety time levels for all their products.

1.2 Problem definition

Nowadays many companies are interested in how they should handle their inventories. Inventory is seen as something driving up costs and therefore should be avoided. The capital tied is believed to be too high, therefore Campbell Soup wants to lower their inventory levels. Consequently Campbell Soup wants to lower their costs by finding a tool to calculate more appropriate inventory levels. They also want to investigate production planning principle such as batch sizes and how many times the product should be produced per year. Campbell Soup also wants to divide the different products in different groups and adapt different safety time policies for them. Currently they have the same safety time for all of their out-of-home products.

The tool should be able to take the changing demand during different seasons and campaigns into consideration. The main challenge is to find the tradeoff between low inventory levels and still keep a high service level without increasing the total cost.

A simulation model of Campbell´s production, line 102, which produces out-of-home products that are sold to restaurants and the public sector, will be constructed in Excel 2010. A model of the current situation with data from previous years will be used as a validation tool for the simulation model of the production process of line 102. The cost of the finished goods inventory will also be investigated.

A sensitivity analysis is an analysis on how different factors affect the total cost of the production and inventory. With the simulation model a sensitivity analysis will be executed with different scenarios. The different scenarios are:

- Unexpected sales during campaigns
- Decreasing one machine operator at line 102
- Decreasing machine costs for the mixing machine and machines at production line 102
- Increasing the safety time
- Decreasing the safety time
- Increasing setup times and taking the mechanics into consideration

The results of the sensitivity analysis will lead to suggestions on new batch sizes and safety times with the production process's limitation taken into consideration.

1.3 Purpose

The purpose of this study is to do an extensive research resulting in long term suggestions on feasible batch sizes. The outcome of the study will be suggestions on how to lower the capital tied, while adhering to agreed customer service levels and looking at the total costs.

1.4 Delimitations and focus area

The following delimitations and focus areas are determined keeping in mind the limited time frame and the broad scope of the study.

The study will only consider the Nordic part of Campbell Soup. The tool for calculating the inventory levels will evaluate the variable costs of some carefully chosen products which are sold and produced in Sweden. The products are picked from the production line 102 that produces out-of-home products within the group Bong Dry Bouillon[1]. In this product group fast-, medium- and slow mover products will be examined. The products examined are selected from established products that have been on the market at minimum of five years and products that are/or will be delisted will not be investigated.

It is assumed that the purchasing of raw materials is working very well and that raw materials always are available for the production. The process for forecasts and campaigns are assumed to be correct and will not be analyzed. The study will only consider the production and finished goods inventory. The interest rates and machine costs given by the finance department are considered to be correct. There are no customer data available for an analysis of lost sales therefore the authors decided to perceive the products that could not be delivered as lost sales.

1.5 Targets and objectives

The target and objective of this study is to find suggestions on how to lower the inventory levels and capital tied for Campbell Soup products without lowering the customer service level measured in case fill rate or increasing the total cost.

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[1] The products studied are bullions and have the following part numbers: 4900, 4901,4902,4903,4904,4906,4907,4908,4909 and 4910

1.6 Roles

The authors will assist the supply chain team at Campbell Soup Nordic to try to find a solution to lower their inventory and capital tied. The role of the authors is to contribute their knowledge in inventory management, production economics and logistic and produce suggestions on improvements for the Supply Chain department at Campbell Soup Nordic.

1.7 Interested parties

The concerned parties of this study are employees at Campbell Soup were the Supply Chain department is the key audience. This study also targets engineering students with knowledge within the field of production economics, logistics and with a profound interest of inventory control.

1.8 Disposition of the study

The disposition and objective of each chapter is presented below to guide the reader through the study.

1.8.1 Chapter 1: Introduction

The first chapter will introduce the reader to the background, purpose, target, objective, delimitations, roles and stakeholders of the study.

1.8.2 Chapter 2: Methodology

The second chapter presents the methods used in the study.

1.8.3 Chapter 3: Theory

The third chapter presents theories that are relevant to the study and the background of the construction of the models in the study.

1.8.4 Chapter 4: Empery

The fourth chapter presents the company Campbell Soup Nordic´s out-of-home products and business. The aim is to introduce the reader to the company and provide an understanding of the company's condition and limitations.

1.8.5 Chapter 5: Analysis

The fifth chapter presents the analysis tools. Two models have been constructed to investigate the batch sizes impact on the different costs varying with the volume. The models are called Current Situation Model and Cost Analysis Model. The Current Situation Model will be a validation tool for the Cost Analysis Model. In this chapter a sensitivity analysis is presented to investigate the different batches sensitivity in different scenarios.

1.8.6 Chapter 6: Result

The sixth chapter presents the result of the validation and sensitivity analysis. The chapter will also present final recommendations of batch sizes for the different products.

1.8.7 Chapter 7: Conclusion

The seventh chapter discusses the result and findings of the validation and sensitivity analyses. It will also discuss how well the purpose of the master thesis was fulfilled. Final recommendations will be given to Campbell Soup Nordic describing how they should continue with the investigation and suggestions on how to further improve their business.

2 Methodology

The chapter will present the theoretical foundation of the methodology approach. This includes the research methods and data collection techniques used in the study. The methods were selected by analyzing which methods were best suited for the given data and would give credible results. This chapter aims at giving a better understanding on how the results were analyzed and executed.

2.1 Research process

The research process of the study started with investigating and mapping the current situation and its difficulties, ending with trying to pinpoint the most important difficulty. Then a model was built to simulate the current situation and finds ways to improve it.

2.2 Problem Identification

The problem identification was determined by discussions and interviews with the Supply Chain Manager at Campbell Soup Nordic. Interviews were also held with other employees familiar with the difficulties in the supply chain and more importantly the inventory control. The most important problem identified, was then broken down and delimited to a feasible problem. Discussing with different key employees in the supply chain gave an overview of the different opinions of the problem, and what people thought could be the root cause for it. It also gave a hint as to who had the information that could be useful when trying to analyze it. The problem was then mapped to get a better idea of how to address it and subsequently help identify the focus areas and the theory and literature needed to solve it.

2.3 Methodological Views

There are different methodological views that will be described and they are based on different assumptions and concepts.

2.3.1 The analytical view

The analytical view is based on the notion that the reality is known and that the observations are independent of the observer. There are objective and subjective facts which both are considered to be true. The objective facts are circumstances which are not influenced by opinions and are therefore considered indisputable. When using an analytic approach, elements like things, events and opinions have to be consistent in spite of changes in the environment and variations in perceptions among different individuals. Logic and mathematics are naturally the most common tools when using an analytical approach.

The objective in an analytical approach is to create a model of the problem which shares the characteristics of the total system. These models should be valid for more than one case in real life. An assumption in the analytical view is that the reality is seen as a sum of different parts that are known and can be summated to solve the problem. The analytical view tends to contain quantitative elements[2].

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[2] Arbnor, Ingeman & Bjerke, Björn, *Företagsekonomisk metodlära*, 2., [omarb. och utök.] uppl., Studentlitteratur, Lund, 1994, p.81

2.3.2 The system view

The system view sees all phenomena as a web of relationships among its components which can be described as a system. The approach assumes systems have common patterns, properties and behaviors which can be better understood when analyzing the whole system. This system approach is different from the analytical approach which considers the observations as individual instead of interacting and dependent on each other as described in the system approach. The basic idea is that the whole not always can be known from an analysis of its components in isolation[3].

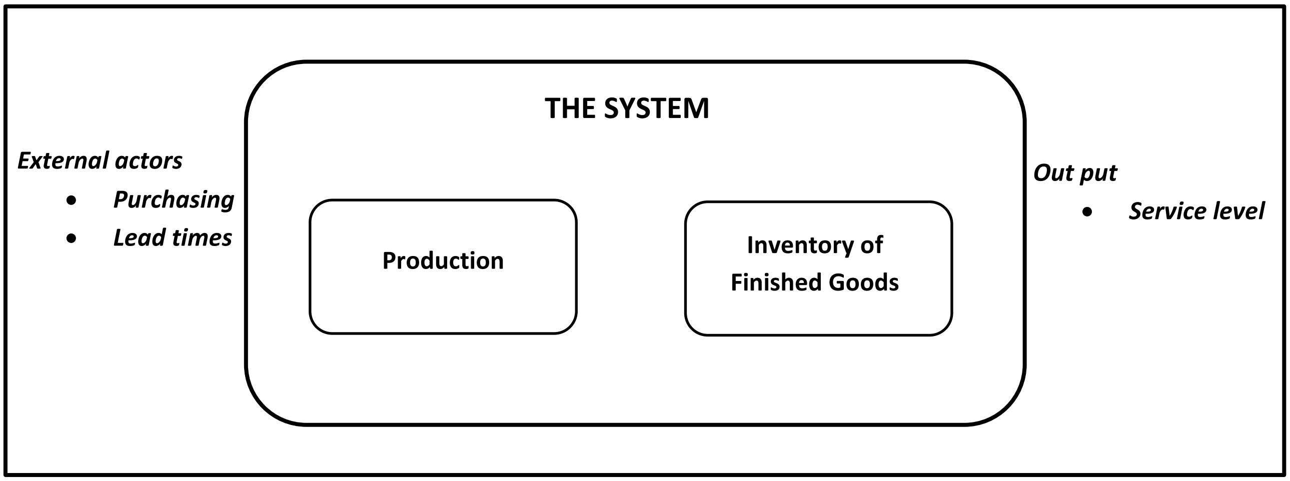

Figure 1: The system of the study and its external factors and out puts

2.3.3 The actors view

In the actors view the reality is presumed to be a social construction which is affected and influenced by the actors in a specific situation. The reality is constantly changing with the actors in it. The knowledge is dependent on the actors and how they experience and interpret the reality. Studies that use this view are more dependent on the involved people in the process than studies that use the analytical and system approaches[4].

2.3.4 The view of the research

During this study a combination of an analytical and system view was used. Both approaches were needed to fully understand the process of the supply chain. An analytical view was used when analyzing the data. Measurements on costs and the production process were made and analyzed to find patterns and a way to estimate a good way to simulate the demand and how it varies during campaigns. The different costs were measured to find the most optimal batch sizes for Campbell Soup Nordic. At the same time it was important to have interviews with the people working with the processes and data to understand how they were measured. There were also unavailable data were estimations had to be

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[3] Arbnor, Ingeman & Bjerke, Björn, *Företagsekonomisk metodlära*, 2., [omarb. och utök.] uppl., Studentlitteratur, Lund, 1994, p.102

[4] Arbnor, Ingeman & Bjerke, Björn, *Företagsekonomisk metodlära*, 2., [omarb. och utök.] uppl., Studentlitteratur, Lund, 1994, p.131

made. These estimations were discussed with the people involved to come up with valid estimations. The system analyzed included the production and the finished goods warehouse.

2.4 Data collection and literature

Different data collections should be used in different studies. The way the data is collected, emerge and what data that is available strongly influence how the study will be executed. With Campbell Soup Nordic´s situation clearer it was necessary to deepen the understanding to find ways to improve it. To get a comprehensive view of the problem the use of literature applicable to the subject were examined. This was done by researching different literature, dissertations, academic research papers, articles and textbooks to find theories, ideas and models. Research on closely related problems was also studied to find suggestions on appropriate approaches for this study.

2.4.1 Data collection

Data can be primary or secondary depending on how it is gathered. Primary data is data that has been assembled for the purpose of a specific study. Secondary data is data that has been gathered for another purpose. While handling secondary data it is important to considerer that it might be biased and that the data has been intended for another purpose[5]. Primary data can be collected by questionnaires, interviews and observations. Ways to collect secondary data are by collecting data through literature such as books and articles. Literature is advantageous since it is available at libraries and on the internet. However, finding the right literature can be time consuming depending on what is researched and how much has been explored in the specific area.

In this study primary data was gathered from interviews with different employees and observations in the production but also by collecting statistics from SAP. Secondary data was collected by using different literature and studies on closely related studies. Secondary data was also used from other investigations that Campbell Soup Nordic has made in the past.

2.4.2 Quantitative and qualitative

There are two kinds of studies. There is the quantitative and the qualitative study. Quantitative studies are in general aligned with the analytical approach. The qualitative studies are mostly used using the system and actors approach with in-depth interviews as to understand a person’s inner thoughts and feelings about an entity. If the data and information can be measured and evaluated numerically it is quantitative. Although not everything can be measured then qualitative data can be used. Qualitative studies are used when a deeper understanding for a specific problem is needed. However the possibility to generalize from qualitative studies is lower and sometimes impossible. A research which is built upon quantifiable data and measurable data can be generalized and are often presented as statistics[6].

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[5] Björklund, Maria & Paulsson, Ulf, *Seminarieboken: att skriva, presentera och opponera*, 2. uppl., Studentlitteratur, Lund, 2012, p.69.

[6] Björklund, Maria & Paulsson, Ulf, *Seminarieboken: att skriva, presentera och opponera*, 2. uppl., Studentlitteratur, Lund, 2012, p.65.

2.4.3 Interviews

Interview is a good way to acquire primary data and is commonly used in the system and actor approach. The interviews can be executed in four different ways and they are personal interviews, telephone interviews, surveys and group surveys. During the study the preferred technique was personal interviews. The personal interview has a face to face setup with personal interaction with the researcher and the person being interviewed. Depending on how much preparation an interview needs it is structured, semi-structured or none structured. During the study semi-structured interviews were used which gave those interviewed a possibility to answer the questions asked as how they found fit[7]. The interviews were held with different key personnel involved in the production and the supply chain. The interviews took between 40 minutes to an hour to conduct. The interviews helped the authors understand who had the data and know how to help with gathering the needed data for the analysis and also understand the whole process of the supply chain and its limitations[8].

Interviews	Outcome of interview
Supply Chain Manager Henrik Rosdahl	Explained the daily business and the fiscal year including different durations of the periods at Campbell Soup Nordic. Gave out the recipes of the studied products.
Demand Planner Josefine Johansson	Understanding of Campbell Soup Nordic´s forecast process and how they use SAP and Qlickview.
Plant Manager Torgny Holmström	Explained the production process and gave a tour at the plant and showed the different steps in the production process
Production Manager Stefan Lundh	Gave a tour in the plant were they have the different lines in the production process. Showed the production Line 102 when they produced Bong Dry Bullion.
Production Planning Jan-Inge Jönsson	Explained the production planning and the conditions in which order the products should be produced.
Planning Manager Agneta Frisk	Gave data such as sales data, inventory data, demand data, forecast data, campaign data etc.
Coordinator Administration Johan Nilsson	Gave time data for production of Bong Dry Bullion such as mixing time, production time at line 102, setup time, stop time, break time and cleaning time setup time,
Sales Manager OOH Charlotte Nilsson	Explained the complexity of the out-of-home products and the characteristics of specific products.
Plant & Logistics Controller Nordic Pontus Sturk	Gave cost data such as labor cost, mixing machine cost, machine cost at line 102, setup cost, stop costs, break costs and cleaning costs.
Warehouse & Facility Manager Ewe Göransson	Gave a tour at the different inventories and explained the daily operations
Purchaser Mona Ljungberg	Explained the purchasing of raw material and the contracts they have today with their suppliers.
IT Manager Nordic Joanna Rönnholm Gardelli	Explained how they use SAP and showed were interesting data could be found.

Table 2: The interviewed employees at Campbell Soup Nordic and the outcomes of the interviews.

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[7] Trost, Jan. (2010), Kvalitativa intervjuer. (4:e uppl.). Lund: Studentlitteratur.

[8] Björklund, Maria & Paulsson, Ulf, *Seminarieboken: att skriva, presentera och opponera*, 2. uppl., Studentlitteratur, Lund, 2012, p.70.

2.4.4 Direct observations

Direct observations are separated into four categories: participant observation, complete participant observation, slight participant observation and full observation. The categories are dependent on the observer's interactions in the observation and that the people being observed knew that they were being observed.[9] During the study the authors used full observation. The production process was observed to better understand what makes the production costs rise and to compare it with the description that had been given by the Production Manager and the Coordinator Administrator.

2.5 Credibility

A study is only credible if the findings and how the study was executed are fully explained. The reader should easily comprehend how the study was done and how the results were obtained. The study should be explained in a way that the readers could replicate the study or/and judge the credibility of the study. The credibility of a study can be measured in validity, reliability and objectivity[10]. The validity measures if the study has studied what it was intended to measure. A way to guarantee the validity of the study is to use more than one method to examine what is being studied. In this way several different perspectives is displayed.

This approach is called triangulation, and can also have several other people examine and determine if the material is valid[11]. Reliability is the degree of trustworthiness of the way the data has been measured. In other words if the study is repeated it should give the same results. The reliability also has to do with the trustworthiness of how the data has been collected and preventing and overseeing of random variation. Objectivity is to what extent the involved researcher's values are affecting the study and the results. Therefore it is important to always motivate decisions and assumptions during the study. Ways to ensure the reader how the conclusions were reached and which sources the study draws on must be quoted so that the reader knows were the information came from. The credibility during this study was made by constructing and using a validation model to show that the constructed model lead to credible results. The authors also interview a lot of different people to get an objective opinion on the production process and its costs.

2.6 The study process

The figure below explains the process of the study. The first step was to define the problem, purpose and objective of the study. After the first step the decisions of how to do the limitations and how to define the problem in the study were made. The second and third steps of the study process were done simultaneously. It was important that both parties, Campbell Soup Nordic and Lunds Tekniska Högskola, were satisfied with the study's objective and how the study was executed. During this process the introduction chapter was written. It was then approved by both parties.

First in the data collection articles and literature were read to give an understanding of the theories needed in the study. Thereafter the interviews with the employees at Campbell Soup Nordic and tours at

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[9] Höst, Martin, Regnell, Björn & Runeson, Per, *Att genomföra examensarbete*, Studentlitteratur, Lund, 2006, p.93.

[10] Höst, Martin, Regnell, Björn & Runeson, Per, *Att genomföra examensarbete*, Studentlitteratur, Lund, 2006, p.109.

[11] Höst, Martin, Regnell, Björn & Runeson, Per, *Att genomföra examensarbete*, Studentlitteratur, Lund, 2006, p.118.

the plant were made. Data were collected for the models. Some data was gathered from SAP and some data were measured in production. The measurements in production were made to validate the given data. Some adjustments of the measurements were made during a consultation with the Coordinator Administrator[12]. When the data was collected the models, Current Situation Model and Cost Analysis Model, were constructed based on the theories and collected data.

In the sixth step of the study process the model was validated. Thereafter the Cost Analysis Model was used for a sensitivity analysis. The analysis was used to investigate the costs sensitivity of different batch sizes in different scenarios. Finally the results from the different simulations were discussed and recommendations based on the results were given to Campbell Soup Nordic.

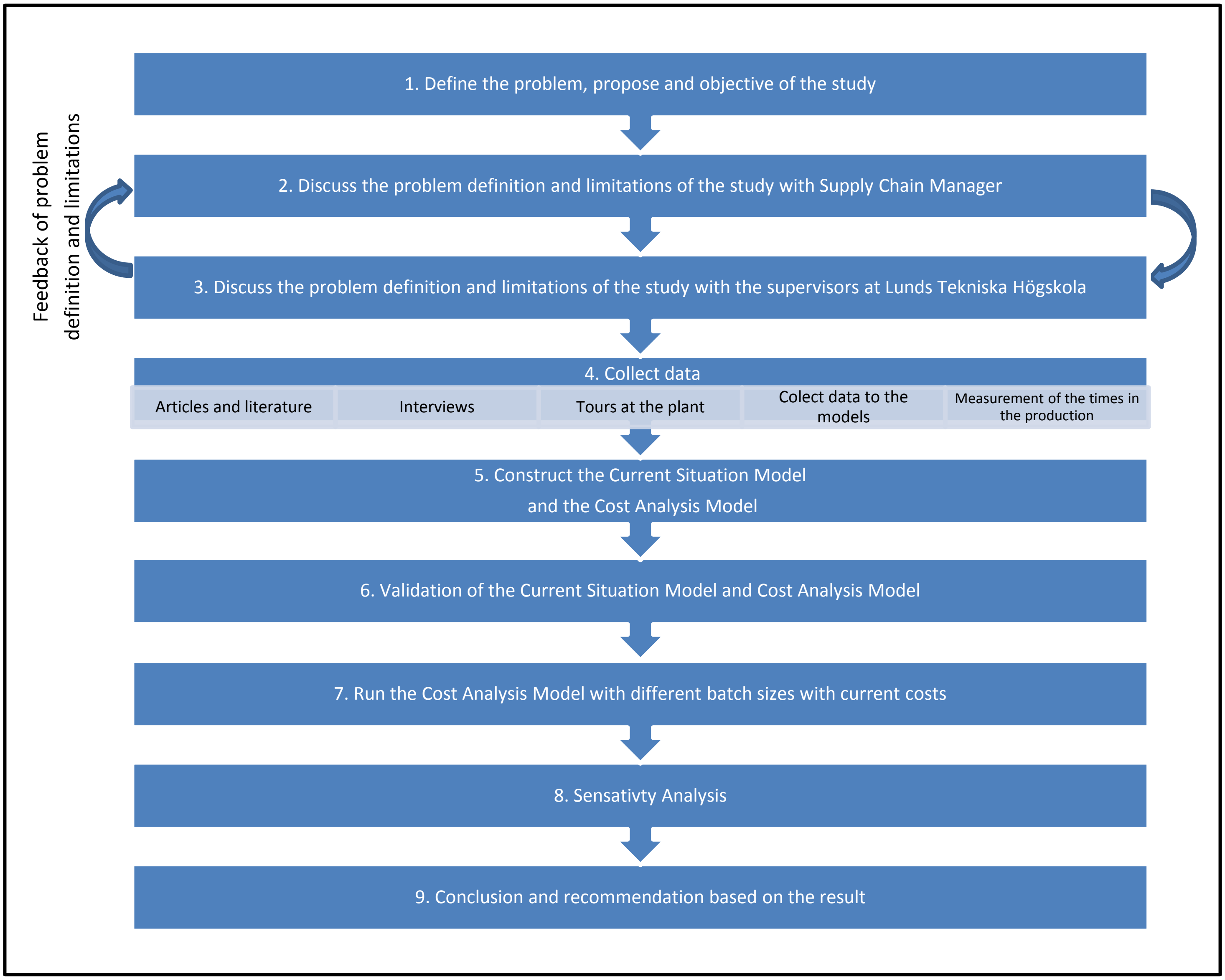

Figure 2: The study process of the master thesis

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[12] Nilsson, Johan 2013-12-17

3 Theory

This chapter contains the theory used in the study. The theories are used for calculating the optimal batch sizes and taking the right costs into consideration. The theories mentioned are mostly associated with inventory and production costs. The theories give a good description of the area investigated. The collection of theories will ensure the quality of the study and validate the results found in the analysis.

3.1 Total Cost Concept

The total cost concept is the best way for managing logistics. The goal is to look at the organization and try to reduce total cost rather than focusing on each activity in isolation. Reducing costs at one activity may drive up costs in other areas. Management should consider all the costs shown in Figure 3[13]. The six cost categories are the key logistics activities that drive the major logistics costs[14].

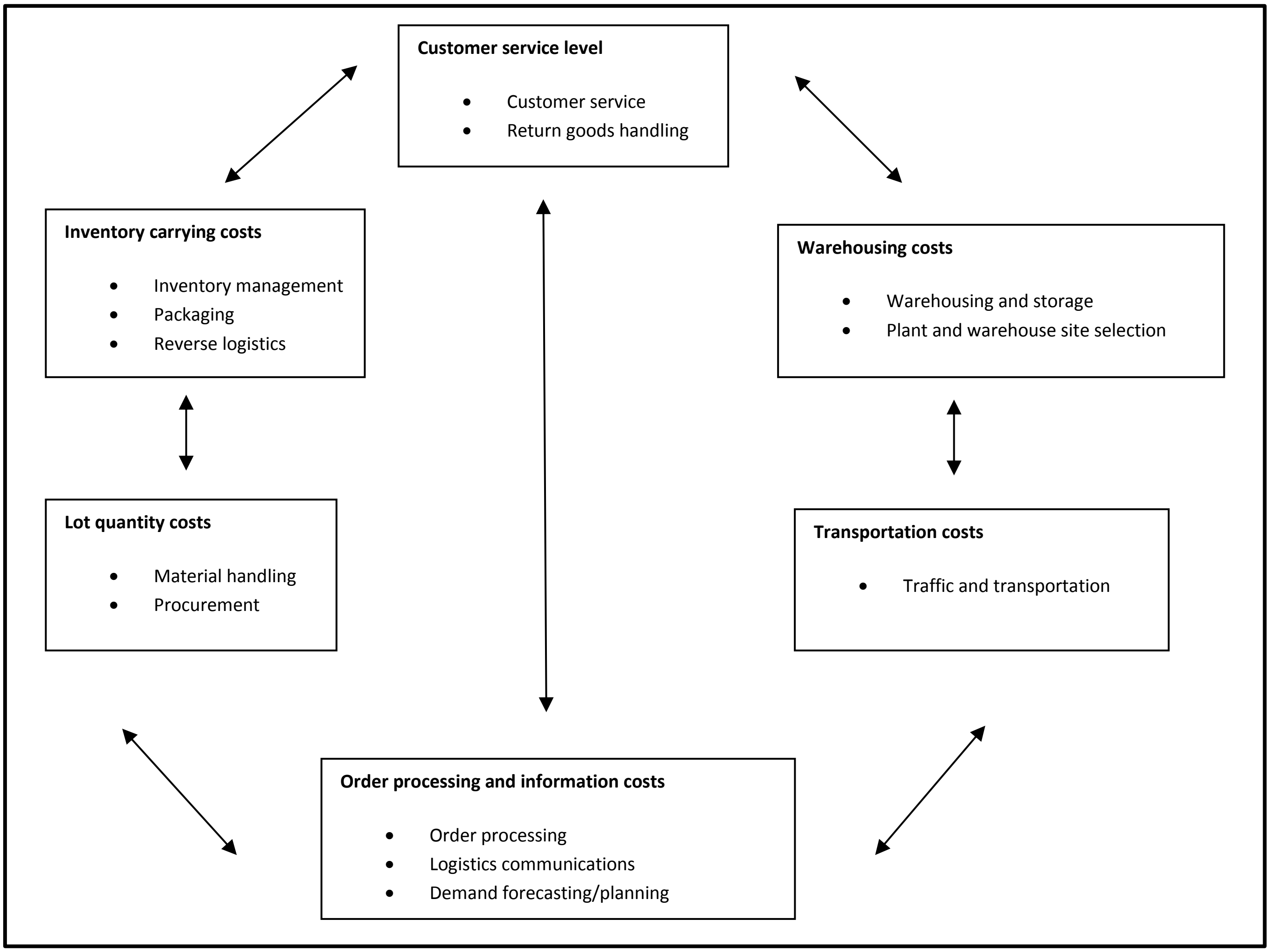

Figure 3: How logistics activities drive total costs

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[13] Figure based on Grant, David B., *Fundamentals of logistics management*, European ed., McGraw-Hill Education, Maidenhead, Berkshire, 2006, p.149.

[14] Grant, David B., *Fundamentals of logistics management*, European ed., McGraw-Hill Education, Maidenhead, Berkshire, 2006, p.149.

3.2 Inventory

Nowadays a lot of people are talking about inventory as something that should be avoided and something that is driving costs up but the opinions differ especially depending on who is being asked. The Finance Manager wants the inventory to be small to keep down costs however the Marketing Manager wants it to be larger to be able to satisfy the customers. In production it is important to utilize the machines as much as possible which often lead to large production series but at the same time large inventory. The Supply Chain Manager wants the products to be available for the customers but at the same time want to avoid large capital binding inventories with a risk of obsolescence. Inventories can be classified based on the purpose for which they are held. The different inventories are cycle stock, in-transit inventories, safety or buffer stock, speculative stock, seasonal stock and dead stock.

3.2.1 Cycle stock

Cycle stock is a stock for replenishment of inventory sold or used in production. This stock is required to meet a known demand and predictable lead times. This means there are no fluctuations in demand nor lead time hence no need for additional stock[15].

3.2.2 In-transit Inventories

In-transit inventories are inventory that is on its way from one location to another. The inventory is not available for sale or shipment until after they arrive at their destination. This inventory can be included in inventory carrying costs.[16]

3.2.3 Speculative stock

Speculative stock is inventory detained for reasons other than satisfying current demand. A forecast might say that the prices of material or packaging are expected to increase and can make it desirable to order bigger volumes[17]. During different economies companies can prepare with higher stocks this is also the case before campaigns periods when higher sales are expected.

3.2.4 Safety stock or Buffer Stock

It is increasingly important to be able to handle customer's different demands and wishes. It is vital to be able to deliver on time with the right quality and quantity. An accurate forecast can help bring the inventory level down but if there are uncertainties it can be important to keep lager safety stocks. Uncertainties can be problems with production, deliver accuracy from suppliers and unpredictable demand.[18]

3.2.5 Seasonal stock

For seasonal products there often are higher demands during a shorter period. Seasonal stock is kept to be able to have a high and even capacity utilization[19]. To be able to deliver products at the right service level products are manufactured gradually. Examples of products that are seasonal are ice-cream,

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[15] Grant, David B., *Fundamentals of logistics management*, European ed., McGraw-Hill Education, Maidenhead, Berkshire, 2006, p. 131.

[16] Ibid

[17] Grant, David B., *Fundamentals of logistics management*, European ed., McGraw-Hill Education, Maidenhead, Berkshire, 2006, p. 133.

[18] Ibid

[19] Lumsden, Kenth, *Logistikens grunder*, 2., [utök. och uppdaterade] uppl., Studentlitteratur, Lund, 2006

gingerbread and agricultural products. When change over costs and setup costs are high it is favorable to keep a buffer between production and sales.

3.2.6 Dead stock

Dead stock is for products that do not have a demand during a specified period of time. Dead stock can also be products which are obsolete and these products are sometimes transported to another location to avoid the obsolescence penalty at the current location[20].

3.2.6 The purpose of having inventory

Inventory is costly as described before but can also lower other costs. Often purchase, transport and production get economical with larger volumes. If the machines have to be altered for one product the setup will have to be done more times than if bigger batches were produced which result in higher production costs. This also leads to additional manual work and less utilization of the machines compared to production of lager volumes. It is important to compare the costs to find the most economical batch sizes.[21]

Conclusively inventory is kept to be able to offer good delivery service and in an effective way satisfy customer's whishes by having good stock availability, delivery time, delivery precision and supply reliability. Stock availability is the ability to deliver directly from the inventory. The delivery time is the time from the customer makes the order until it is delivered on the time agreed. The delivery precision is how well the order corresponds to what was ordered. Supply reliability is how well the products are delivered on the right time to the right place with the right quality and quantity[22].It is important to take all the costs included in the different activities and compare them to motivate how well the different factors can be satisfied. The different activities can be seen in the Figure 4[23].

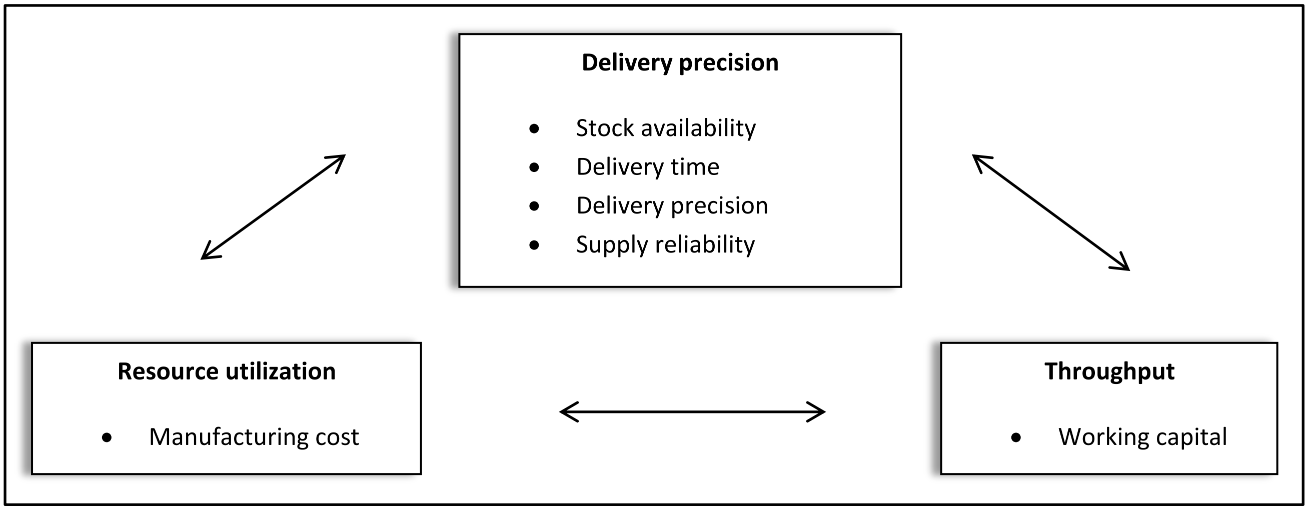

Figure 4: The relationship between delivery precision, throughput and resource utilization

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[20] Grant, David B., *Fundamentals of logistics management*, European ed., McGraw-Hill Education, Maidenhead, Berkshire, 2006, p. 135.

[21] Lumsden, Kenth, *Logistikens grunder*, 2., [utök. och uppdaterade] uppl., Studentlitteratur, Lund, 2006

[22] Ibid

[23] Figure based on Lumsden, Kenth, *Logistikens grunder*, 2., [utök. och uppdaterade] uppl., Studentlitteratur, Lund, 2006

3.3 Inventory costs

Products need to be stored for a long or short period and employees are needed for deposition, registration and picking. The inventory also needs to be stored in a warehouse. Equipment for handling the inventory is also needed and a system to keep track on everything being stored. All these activities run higher costs and are independent of the volume of the inventory on a short term basis. These costs are called warehouse costs. Warehouse costs can get higher in the long run if the inventory volume grows past a certain point. For example if a company stores large volumes of products it may need additional storage space and warehouse workers.[24]

3.3.1 Holding costs

Products stored are tied resources. Resources have been used for the raw materials and packaging of the products. The products will hopefully be sold but as long as the products stay at the warehouse they bind capital. Holding cost is an opportunity cost for capital tied up in inventory that could be available for other investments for example interest rates or increased marketing resulting in better sales[25]. The holding cost can be estimated on the return on an alternative investment. It cannot exactly be compared to the expected return of an alternative investment since financial risks associated with the investment has to be taken into consideration. A lot of companies use the cost of capital rate which corresponds to the best or expected return on the investment[26]. This assumption is best for products with low risks[27]. The holding costs are mostly the capital cost but can also include storage space cost, inventory service cost, and inventory risk costs[28].All the costs that vary with the inventory level should be included in the holding cost. Often the holding cost is calculated with a carrying charge κ times the variable replenishment cost per unit C. The reason for this is that the capital cost captures the main part of the holding cost.

$$h = \kappa \cdot C \tag{1}$$

Some companies' uses inventory carrying costs that are based on benchmarking with industry averages but this assumption is problematic[29]. Although two companies are similar in terms of manufacturing and distribution the availability of capital can differ and will lead to two different inventory strategies. Shortages of money may make it expensive to invest in inventory and a higher interest hence higher cost of money. The cost of money pre-tax is the interest rate the company is earning on its cash. Companies with plenty capital will get a low cost of money. If these companies are managed properly the company whose cost of money is low will have more inventories[30].

Having a large inventory also means different risks. The products can get damaged in conjunction with handling. Shrinkage can occur if products disappear or get stolen. There is also a risk for fires or other

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[24] Oskarsson, Björn, Ekdahl, Bengt & Aronsson, Håkan, *Modern logistik: för ökad lönsamhet*, 4., [omarb. och utök.] uppl., Liber, Stockholm, 2013

[25] Ibid

[26] Ibid

[27] Berling, Peter, *On determination of inventory cost parameters*, Univ., Diss. Lund : Univ., 2005,Lund, 2005

[28] Ibid

[29] Grant, David B., *Fundamentals of logistics management*, European ed., McGraw-Hill Education, Maidenhead, Berkshire, 2006, p. 142.

[30] Ibid

disasters, and a risk that the products get outdated if the design of the labels and packages changes. How big the risks are depends on the product. It is obvious that the capital cost increases with the volume but not as clear for the risk costs. Often costs for obsolescence and scrapping get higher with the volume[31]. To be able to calculate the inventory rate the capital cost and the risk costs have to be estimated. Normally the costs are evaluated yearly and since the inventory level differs during the year an average inventory level has to be estimated. The inventory level calculation can be seen in formulas (2) and (3)

$$stock\ interest, r\ (\%) = \frac{\sum \frac{capital\ cost}{year} + \frac{risk\ cost}{year}}{average\ inventory} \cdot 100 \tag{2}$$

$$stock\ interest, r\ (\%) = discounte\ rate\ \cdot \frac{risk \frac{cost}{year}}{average\ inventory} \cdot 100 \tag{3}$$

The yearly cost of risk is estimated by adding the cost for obsolescence, theft, scrapping and other revenue losses and decreased value of the products during a year. These facts are often difficult to get a hold of because most of the systems do not keep track of them in an easily accessible manner. It is usual that companies protect themselves by signing insurances that cover these risks. If the insurance is proportional to the inventory level it can be calculated depending on the size.[32]

$$stock\ rate, r\ (\%) = cost\ of\ capital (\%)\ + insurance\ premium\ (\%) + \frac{\sum \frac{other\ risks}{year}}{average\ inventory} \cdot 100 \tag{4}$$

The stock rate is calculated with the total holding costs and is then used for calculating the holding costs for specific products.[33]

3.3.2 Insurance

Insurance cost is a cost for estimated risk. Hazardous products are products with high value which are easy to steal and can result in high insurance costs. Insurance cost is influenced by the facilities characteristics such as security cameras that help reduce risk. Products with low risk are cheap products which are difficult to steal.[34]

3.3.3 Obsolescence

Obsolescence cost is a cost that occurs when products get damaged in storage, have passed their sell-by date or when the package design has gotten out dated. This cost is mostly estimated from previous years and experience, concerning markdowns and quantity scrapped. The costs are then used for calculating a yearly average obsolete inventory cost[35]

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[31] Oskarsson, Björn, Ekdahl, Bengt & Aronsson, Håkan (2013). *Modern logistik: för ökad lönsamhet*. 4., [omarb.och utök.] uppl. Stockholm: Liber

[32] Ibid

[33] Ibid

[34] Ibid

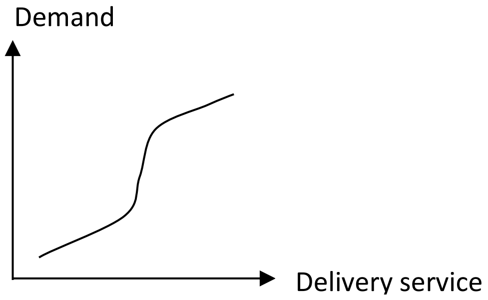
[35] Bowersox, Donald J., Closs, David J. & Cooper, M. Bixby, *Supply chain logistics management*, 3. ed., McGraw-Hill Higher Education, New York, 2010, p. 163.

3.3.4 Reasons for lowering the inventory

An additional reason for lowering the inventory except reducing the capital cost is to find problems that are hidden because of the high inventory. By lowering the inventory the problems can be found and corrected. The concept is called the Japanese Sea. On the other hand a low inventory level will not always mean lower costs. If there are problems that cannot be solved and the inventory levels get lowered it can mean increased inventory costs. The whole process should be evaluated to find the optimal inventory level. A high carrying charge will lead to smaller batch sizes. The smaller batches can help even the workload however setup costs will increase[36].

3.4 Service level

Service level is a performance target that defines performance objectives. It can be measured by case fill rate, line fill rate and order fill rate[37]. The case fill rate is the percentage of cases ordered that is delivered as agreed. The line fill rate is the percentage of order lines filled entirely and order fill rate is the percentage of customer orders filled entirely. It is not always the case that a high service level is better. In some cases it costs more than it gives. There is a connection between delivery service and demand, and it is known to be s-shaped. On the most markets there is a minimum level of service required to be able to compete on the market. When this level has been reached a small increase in delivery service will lead to a great increase in demand. This continues until another level where an increased delivery service only gives a slight increase in demand. A reason for this is that costs for the customers often increases to be able to fulfill the high service level. The level for which the demand for service stops depends on what is the standard for the specific product. A strategy could be to place ones level slightly over competitors (in the Graph 1) but not over the breaking point level[38].



Graph 1: The S-curve

3.5 Order Costs

Normally there are costs associated with a replenishment of a product and its batch size. Different ordering costs can be setup and learning costs which are common in production. Setup costs occur when an expensive machine has to be stopped during the setup. Order costs can also be costs that occur in connection to transportation and material handling. For example it takes the same time for a purchaser to make an order for a thousand units as it takes for ordering a hundred units resulting in higher labor

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[36] Berling, Peter (2005). *On determination of inventory cost parameters*.Diss. Lund : Univ., 2005

[37] Bowersox, Donald J., Closs, David J. & Cooper, M. Bixby, *Supply chain logistics management*, 3. ed., McGraw-Hill Higher Education, New York, 2010, p. 159.

[38] Mattsson, Stig-Arne, *Effektivisering av materialflöden i supply chains*, Institutet för transportekonomi och logistik, Univ., Växjö, 1999, p. 149.

costs per sales unit. This cost has to be compared with the increased holding and scrapping cost of having the additional units stored. In some cases most of the setup can be done during the time the machine is running which reduces costs.

When ordering from outside suppliers there are various costs for an order depending on how the supplier handles their orders. Some suppliers may be more time consuming than order suppliers which can result in higher order handling costs. Typical cost can be the costs for handling authorization, receiving, inspection and handling invoices from the suppliers.[39]

3.6 Setup costs

Sometimes a production line produces more than one product. In this case it takes some time and work called setup time between the productions of the different products. These activities could be picking the needed raw material for the new order, preparing the order lists, setting the machine and the initial running of the machine. All these activities drive cost up. During the time all of these activities are done the machine cannot run which leads to production loss and costs. The setup costs are often treated as constant costs per production change. Since these costs are constant it is an encouragement to produce as much as possible to lower the setup cost per produced unit[40]. Setup cost varies depending on the time required to set up a line, the scrap due to setting up the production line and operating inefficiency as the line begins to run.

3.7 Lot quantity Costs

The logistics lot quantity costs are mostly due to procurement and production quantities which are costs that vary depending on size and frequency[41] . The quantity costs include the cost for

- capacity lost due to downtimes during the changeover of the production line
- cost for materials handling, scheduling and expediting
- price differentials due to buying in different quantities and order costs associated with order placement and handling

3.7.1 MTS

Make-to-stock is a strategy of economics of scale gained from long production runs. Large finished goods inventory is manufactured anticipating future customer demand. To support a make-to-stock strategy warehouse capacity is needed to store finished products in all the combinations a customer might want since the products usually are produced before the customer's order them[42].

3.8 SMED

One way to make smaller batch sizes more profitable is to simplify the production by eliminating unnecessary work which in the just-in-time philosophy is called "waste". The wastes are all those

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[39] Oskarsson, Björn, Ekdahl, Bengt & Aronsson, Håkan (2013). *Modern logistik: för ökad lönsamhet*. 4., [omarb.och utök.] uppl. Stockholm: Liber

[40] Mattsson, Stig-Arne, *Effektivisering av materialflöden i supply chains*, Institutet för transportekonomi och logistik, Univ., Växjö, 1999, p. 147.

[41] Grant, David B., *Fundamentals of logistics management*, European ed., McGraw-Hill Education, Maidenhead, Berkshire, 2006, p. 20.

[42] Bowersox, Donald J., Closs, David J. & Cooper, M. Bixby, *Supply chain logistics management*, 3. ed., McGraw-Hill Higher Education, New York, 2010, p. 87.

activities that do not bring any worth to the customer. Ohno has identified seven different wastes, waste because of

- Over production
- Waiting
- Unnecessary transportation
- Processing
- Putting products into stock
- Unnecessary handling
- Obsolescence

A common opinion in the industry is that there are no unnecessary activities in the supply chain and its as optimal as possible however this rarely is the case. The main two reasons for this are that processes not always are developed in a systematical or conscious way. The processes are mostly developed since they have to be done and the activities have been created ad hoc[43] not thinking of what would be the most effective way. The second reason is that the demands from customers and technical opportunities always are improving. Often the way of working does not change at the same speed as technology does. The outcome of this is that there almost always are ways to improve processes.

3.8.1 Reduce the support activities from the critical flow

The process contains different activities and these activities are not always value adding nevertheless still necessary for the process. Examples of this are machine change over time and picking the materials for the order. Sometimes these activities can be done during the process and in this way save time and shorten lead times. This way of thinking is often call SMED. SMED focuses on changing external set-up times to internal set-up times.[44]

3.9 Trade-offs

Sometimes tradeoffs have to be made when planning for the whole supply chain to get the optimal total cost. Common tradeoffs in the supply chain are logistic cost connected to setups versus capital tied in inventory. Tradeoffs can also consider delivery service and capital tied in safety stocks, lead times versus utilization level in the production, the delivery time and delivery precision, delivery flexibility and lead times[45]. Some of the tradeoffs are illustrated bellow in Graph 3, Graph 2 and Graph 4.

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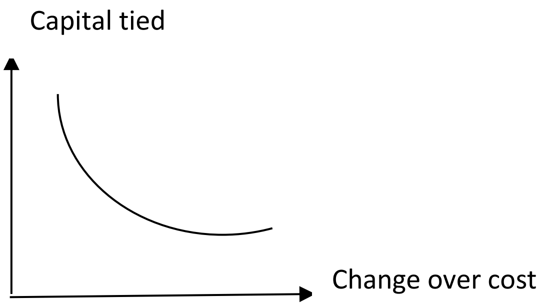
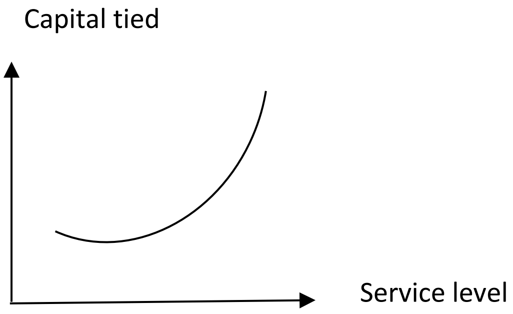
[43] Mattsson, Stig-Arne, *Effektivisering av materialflöden i supply chains*, Institutet för transportekonomi och logistik, Univ., Växjö, 1999, p.166.

[44] Ibid

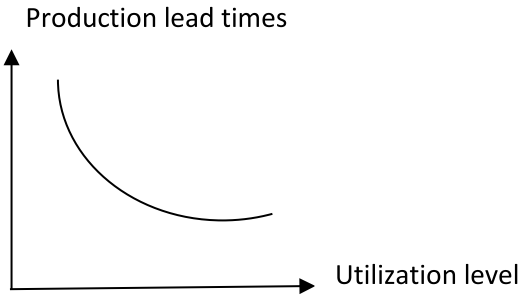
[45] Mattsson, Stig-Arne, *Effektivisering av materialflöden i supply chains*, Institutet för transportekonomi och logistik, Univ., Växjö, 1999, p. 152-153.



Graph 3: Capital tied versus change over costs



Graph 2: Capital tied versus service level



Graph 4: Production lead times versus utilization level

The tradeoffs often concerns the capital tied. If the setup times are expensive and needs to be reduced and delivery service has to be improved a higher capital tied has to be accepted. Just like lower lead times means that lower utilization levels have to be accepted. Often an optimal order quantity is calculated to compare and weigh the costs against each other.

It is important to not only look at which tradeoffs that result in the best order quantity it is also important to look why some tradeoffs result in better costs. For example if it is more profitable to invest in higher inventory it is smart to find out why and if there is some way to lower the setup cost. In some situations the money spared on having larger inventory can be used to invest in equipment or methods to make the setups less costly. It is vital to look at the whole picture and not only sub improve. Not seeing the whole picture often result in hostility between different departments in the company.[46]

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[46] Mattsson, Stig-Arne, *Effektivisering av materialflöden i supply chains*, Institutet för transportekonomi och logistik, Univ., Växjö, 1999, p. 152-153

3.10 Lost sales and stock out costs

Lost sales and stock out costs are costs that appear when the demand cannot be delivered because of lack of stock or delays in production. Studies have shown that a cost penalty occur for the manufacturers and retailers when a stock out occurs on the shelf[47].The studies found that the customers when facing a stock out

- do not purchase the item
- substitute with different brands
- substitute with the same brand
- buy the item at another store
- delay purchase

This can result in a revenue loss for the manufacturer and bad reputation that in the long run can make the customers choose another supplier. It can also result in penalty costs for special transportations or contribution for what losses the customers have made. A study claims that an unhappy customer on average will tell nine others about his or her dissatisfaction with the service[48]. Shortages and stock out costs in the production occurs when machine break downs or shortages of the raw materials happen. These costs can be difficult to calculate and the size and impact varies a lot and therefore a lot of “estimations" do not take them into consideration.

Customers are continuously demanding shorter delivery times and delivery reliability which result in a demand for better performances from the manufacturers. The manufactures have to be able to deliver at the wanted service level to be competitive. A lot of companies have suffered from the increased competition. The traditional aspects of the market have been more directed to the end customer with activities like product development, promotional activities and price competition. These aspects are still important but good customer service has become an important order winner. Since a swing of power in many market channels has occurred were power is taken away from the manufacturer and towards the distributors, it is now important to develop strong relationships with the wholesalers. [49]

3.10.1 Constraints

The processes today reflect a balance between economy of scale and economy of scope. Volume and variety drive logistical support requirements which drive costs. Capacity is a measure of how many units can be produced per time unit. The primary constraints which influence the manufacturing are capacity, equipment, and setup/changeovers. Tradeoffs between these activities have to be made to get an ideal manufacturing operation. These compromises should be made taking forecasted sales, planned promotions and seasons into consideration. [50]

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[47] Christopher, Martin (2011). *Logistics & supply chain management*. 4. ed. Harlow: Financial Times Prentice Hall

[48] Grant, David B., *Fundamentals of logistics management*, European ed., McGraw-Hill Education, Maidenhead, Berkshire, 2006, p. 19.

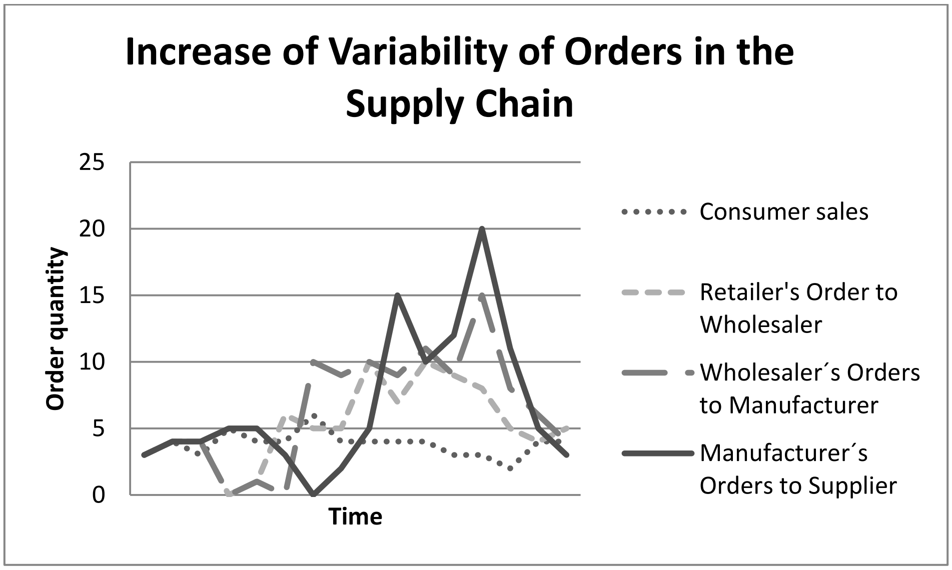
[49] Mattsson, Stig-Arne, *Effektivisering av materialflöden i supply chains*, Institutet för transportekonomi och logistik, Univ., Växjö, 1999, p. 146.

[50] Bowersox, Donald J., Closs, David J. & Cooper, M. Bixby, *Supply chain logistics management*, 3. ed., McGraw-Hill Higher Education, New York, 2010, p. 84.

3.11 The Bullwhip Effect

The demand of a certain product may not vary much at the retailer but the inventories and back-order-levels fluctuate considerably across the supply chain. When the retailers place their orders to the wholesalers, the fluctuations of the demand will increase in comparison to the retailer's sales and when the wholesalers place their orders the distributers demand will fluctuate even more. This behavior continues across the supply chain. The variability increases throughout the supply chain. This phenomenon is called the Bullwhip Effect. [51]

Graph 5 shows a four stage supply chain with customers, one retailer, one wholesaler and one manufacturer. When the retailer observes a demand they place an order to the wholesaler which in turn places an order to the manufacturer. This graph shows the bullwhip effect which is the increase of variability, across the four stage supply chain.[52]



Graph 5: The increasing variability of orders in the supply chain

3.11.1 Sources for the Bullwhip Effect

There are four sources for Bullwhip Effect and they are price fluctuations, order batching, demand signal processing and rationing game.

When the manufacturer gives promotion to the retailers it can lead to unpredictable order patterns and this is connected to the source called price fluctuation. Promotions can also lead to distorted "true demand data". A way for the manufactures to avoid making wrong forecasts and get a better picture of the reality is to get sales information from the retailers.

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[51] Simchi-Levi, David., Kaminsky, Philip. & Simchi-Levi, Edith. *Managing the supply chain [Elektronisk resurs] the definitive guide for the business professional*. New York: McGraw-Hill, 2004.

[52] Figure based on Lee, Hau L. Padmanabhan, V. Whang, Sheunjin. *The Bullwhip Effect In Supply Chains*. Stanford, 1997.

Order batching is the result of when the retailer orders in larger batches. Therefore, orders occur infrequently which leads to that the upstream suppliers also receive the order information infrequently. It can become problematic for the supplier to provide good customer service if they cannot share sales information with the retailers that enable the supplier to be prepared for the unpredictable demand.

When the retailer tries to predict the demand with a forecasting method based on the previous order data and the sales and the demand is larger than average in a single period the retailer might adjust the forecast upward. Then the retailer´s order placed upstream will be even larger. The companies upstream will then do their forecast based on the distorted orders from the companies downstream and the sales that were larger than average can be significantly amplified. Actual sales data and inventory information can be shared to avoid double or triple forecasting.

During shortages retailers often inflate their orders into one order to short their lead time and this is called order rationing. By doing so the retailers might gain a better share of their wanted items in short supply. But, this behavior can be misleading for the manufacturers that may believe that the demand is higher than usual. The manufacturers would be in a better position if they have sales data and are able to differentiate the so called "phantom" demands and the real demands.[53]

3.12 (R, Q)- Policy with continuous review

An inventory control system can have a continuous review and this means that the inventory position is monitored constantly. In practice it is common to use continuous review for items with low demand. An order is trigged in the system when the inventory position has reached a certain low level.

The lead-time includes the time from the ordering decision until the order is available on the shelf. When calculating the lead time the following times has to be taken into consideration, the order preparation time, transit time for the order, administrative time at the supplier, production time, transit time from an external supplier and time for inspection after receiving the order.

Let,
$L =$ Lead-time

When the inventory position reaches the reorder point R an order is trigged. The trigged order is a batch quantity of size Q. Sometimes the policy is denoted as (R,nQ) policy. The policy is used when more than one batch is needed to trigger an order to get above R. In a continuous review when a unit is revised one unit at a time the reorder point will always be triggered exactly. The inventory position should guard against demand variations during the lead-time L in a continuous review system. In a periodic review and when the triggering demand is for more than one unit the inventory position can be below the reorder point when an order is ordered. [54]

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[53] Lee, Hau L. Whang, Seungjin. Information Sharing in a Supply Chain. Graduate School of Business, Stanford University, 1998.

[54] Axsäter, Sven, *Inventory control*, Springer, New York, 2006

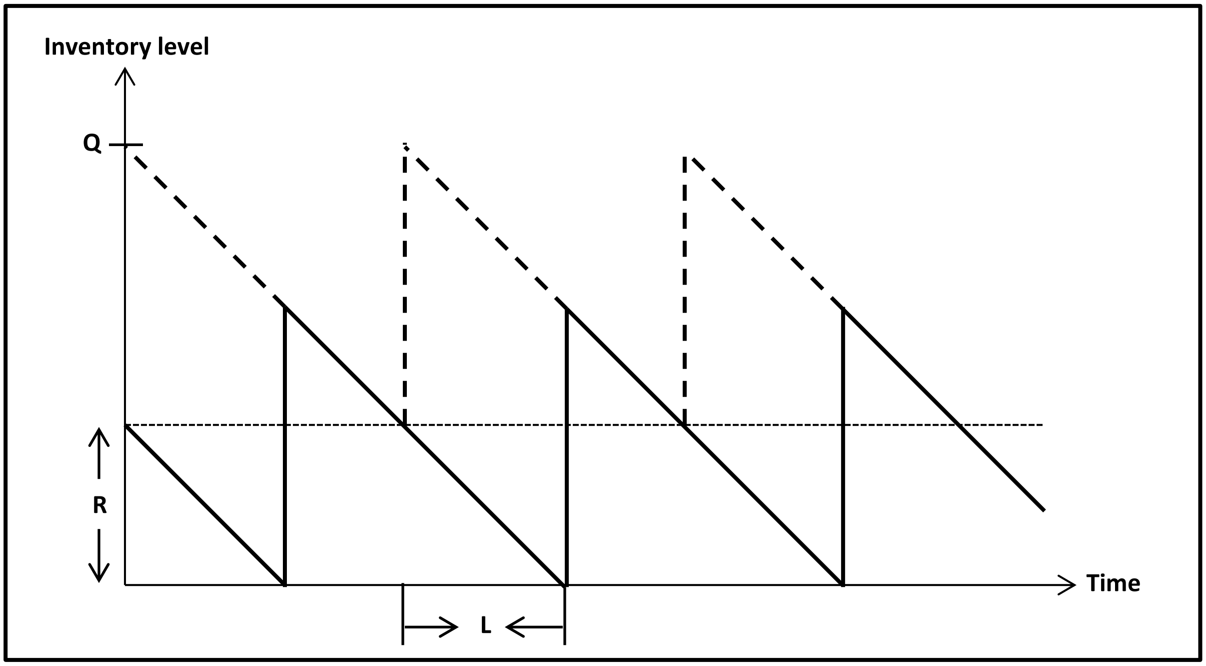

Figure 5: The change of inventory level over time in a continuous review system

3.13 Probability Density Function

Let the variable X be a continuous random variable that exists in the nonnegative function $f(x)$. The function $f(x)$ is called the *probability density function* and is defined for all real $x \in (-\infty, \infty)$. The function state that the probability that X will be B may be attained by integrating $f(x)$ [55]. The property for any set of B of real number is stated as

$$P\{X \in B\} = \int_B f(x)dx \quad (5)$$

Following function must be satisfied, since X must assume some value.

$$1 = P\{X \in (-\infty, \infty)\} = \int_{-\infty}^{\infty} f(x)dx \quad (6)$$

By letting $B = [a, b]$, the probability statements about X can be explained in terms of $f(x)$ in the following equation.

$$P\{a \leq X \leq b) = \int_a^b f(x)dx \quad (7)$$

By letting a=b in the equation above it results in the following equation

$$P\{X = a\} = \int_a^a f(x)dx = 0 \quad (8)$$

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[55] Ross, Sheldon M., *Introduction to probability models*, 4. ed., Academic Press, Boston, 1989, p.32

The equation (8) states that the probability is zero when a continuous random variable assumes a particular value. [56]

3.14 Cumulative Distribution Function

The following equation states the relationship between the cumulative distribution $F(\cdot)$ and the probability density $f(\cdot)$

$$F(a) = P\{X \in (-\infty, a)\} = \int_{-\infty}^{a} f(x)dx \tag{9}$$

Differentiation of the equation gives

$$\frac{d}{da}F(a) = f(a) \tag{10}$$

The probability density function is the derivate of the cumulative distribution function. [57]

3.15 Goodness of fit

There are different tests of "goodness of fit" and χ^2 –test is one of them. The "goodness of fit"- test is a test that investigates if the observations come from a certain distribution. Except for the χ^2 –test, Kolmogorov-Smirnov is a common "goodness of fit"- test.[58]

For further studies of different "goodness of fit"-test like the χ^2 –test and the Kolmogorov-Smirnov the book "Matematisk statestik" is recommended.[59]

3.16 The right supply chain for different products

Different supply chains are appropriate for different products. One way to decide which supply chain suits the products produced the best is by looking for the supply chain that can satisfy the demand. Aspects that are important to consider are product life cycle, demand predictability, product variety, and market standards for lead times and service. Products can either be functional or innovative and they need two different supply chains. The functional product needs a physically efficient process and an innovative product needs a market-responsive process. A functional product is a product with a product life cycle which is more than two years. Functional products are products such as groceries that are bought to satisfy basic needs, which do not change over time. The demand is relatively stable and predictable. The stability invites competition which often leads to low profit margins. The contribution margin is 5% to 20%. The product variety and the average stock out rate are very low. The primary purpose of the physically efficient process is to supply demand efficiently at the lowest possible cost. The manufacturing focus is to maintain a high utilization rate and the inventory strategy is to generate high turns and minimize inventory throughout the chain. The lead-time focus is to shorten lead times as long

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[56] Ross, Sheldon M., *Introduction to probability models*, 4. ed., Academic Press, Boston, 1989, p.31

[57] Ross, Sheldon M., *Introduction to probability models*, 4. ed., Academic Press, Boston, 1989, p.32

[58] Vännman, Kerstin, *Matematisk statistik*, 2., [omarb.] uppl., Studentlitteratur, Lund, 2002, p.284

[59] Vännman, Kerstin, *Matematisk statistik*, 2., [omarb.] uppl., Studentlitteratur, Lund, 2002

is does not increase cost. The approach for choosing suppliers is to select them primarily for cost and quality.[60]

3.16.1 Gamma

A common problem in inventory control is to determine stock re-ordering at a certain level or point in time and the probability of a stock out. The probability for this depends upon the distribution of the demand for the product and the lead time which may be fixed or distributed. There are a variety of statistical distributions used to describe the demand distribution. The gamma distribution is applicable in many cases but is rarely used because of lack of awareness about the distribution. [61]

3.16.2 Usability of the gamma distribution in inventory control

A problem in inventory control is to find a frequency distribution that will represent the observed frequency distribution of demand for an item satisfactorily. A study has shown that frequency distributions of demand have the following general characteristics[62]:

- They occur simply for non-negative values of demand
- As the mean demand of items increases the observed distributions change from:
    - Monotonic decreasing to
    - Unimodal distributions heavily skewed to the right, and lastly to
    - Normal type distributions (truncated at zero)

The necessity is to find a statistical frequency distribution with the mentioned characteristics. A survey of known literature on inventory control illustrates that of the continuous frequency distributions the most commonly used are the normal and negative exponential distributions. The disadvantages of the normal distribution when having the characteristics described above are:

- The distribution is defined for $-\infty \leq x \leq \infty$. The concept of negative demand is unrealistic for many situations for inventory control work. Truncating the distribution at zero to remove this difficulty greatly increases the mathematical complexity when going forward with future calculations.
- Since the distribution is symmetrical it is only suitable for representing the demand of very fast-moving items.

The negative exponential distribution is defined only for non-negative values and is monotonically decreasing. Hence it fulfils the general requirements for representing the demand of slow-mowing items. Nevertheless, for medium- and fast moving items it is not a viable distribution.

The gamma distribution is not mentioned as frequently as one would expect since its general characteristics are:

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[60] Fisher, Marshall L. What is the right supply chain for your product?. Harvard Business Review, Harvard University, 1997.

[61] Burgin,T.A. .The Gamma Distribution and Inventory Control. Palgrave Macmillian Journals, Birmingham, 1997.

[62] Ibid

- Defined only for non-negative values:
- Varies according to values of a parameter of the distribution called the modulus from a monotonic decreasing function, through unimodal distribution skewed to the right, to normal type distributions
- The probability integral of the distribution is well tabulated;
- The distribution is generally mathematically tractable in its inventory control applications.

The reason for the distribution not being used is believed to be unawareness of its existence since it is not mentioned as often in statistical theory as the normal distribution. The properties of the distribution are somewhat scattered in the statistical literature. The mathematical equation of the distribution includes an unfamiliar function in the denominator which may suggest a highly abstract distribution having little application to reality even though this is not the case. Finally it must be pointed out that, resourceful as the gamma distribution may be, it is not a universal distribution to be employed in all circumstanced and its usefulness should be examined when used as for all the distributions[63].

3.17 Software

SAP

SAP is application software that helps companies to run their business effectively, from warehouse to storefront.[64] SAP´s supply chain management solutions can help a company to build a resistant and flexible supply network and gain improved collaboration, responsive planning and seamless execution. By using SAP the company can[65]

- Respond quickly to changes in supply and demand
- Determine accurate customer delivery dates
- Optimize inventory, labor, resources, and space
- Leverage analytics to monitor and measure performance
- Ensure compliance with international trade regulations

Easy Fit Professional 5.5

Easy Fit is a simulation and data analysis software. The software fits data to the best suited probability distributions function. Easy Fit can be used with Microsoft Excel or as a stand-alone Windows application. Product features included in the software are[66]

- support for more than 50 continuous and discrete distributions
- powerful automated fitting mode combined with flexible manual fitting capability
- interactive graphs
- goodness of fit tests.

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[63] Burgin,T.A. .The Gamma Distribution and Inventory Control. Palgrave Macmillian Journals, Birmingham, 1997.

[64] http://global.sap.com/corporate-en/index.epx

[65] http://www.sap.com/solution/lob/scm/software/overview/highlights.html

[66] http://www.mathwave.com/help/easyfit/index.html

4 Empiri

This chapter contains the empirical study and it is based on collected data. The objective is to describe Campbell Soup Nordic's reality and give an understanding of Campbell Soups business and the complexity of their out-of-home products. The chapter will also describe how Campbell Soup Nordic works with production planning, production and their inventory control.

4.1 Campbell Soup Nordic

Campbell Soup Nordic has its headquarter and production outside of Kristianstad at Karpalund in Sweden. At Karpalund the company produces dry products for the Nordic market. Campbell Soup Nordic has offices in Finland and use a third part logistic company to stock their products for the Finnish market. Today there are approximately fifty officials working and twenty workers at the production, warehouse and office in Karpalund. Campbell Soup Nordic only produces dry products and purchases the liquid products from other Campbell Soup sites in Europe. All sites in Europe have the same purchasers who are responsible for all the procurements from suppliers. The purchasers are responsible for the contracts and decide the minimum order quantities and which suppliers the companies have to order from. By doing this they want to get advantages, by getting beneficial contracts when they order lager volumes from the same supplier. This means that Campbell Soup Nordic cannot decide which supplier they would like to collaborate with and they have to order a minimum order volume which often is larger than their needs. It is problematic to order large volumes since the design of the packages changes and the ingredients can expire.[67]

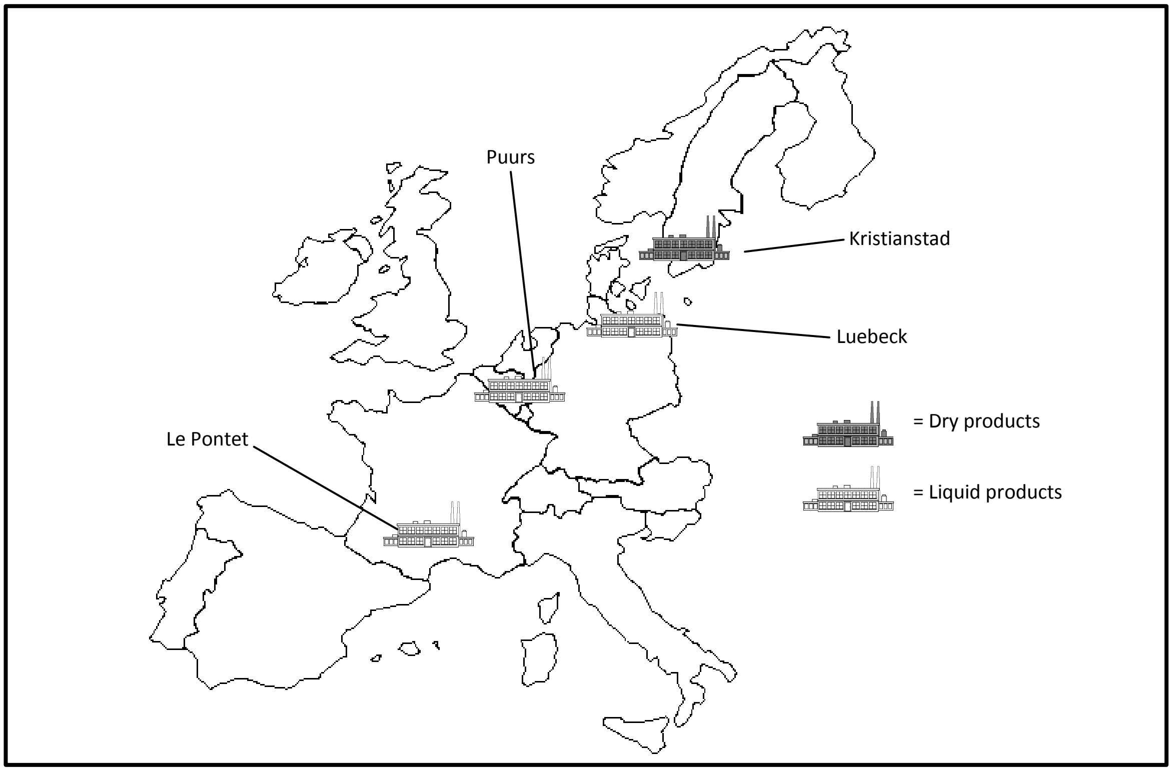

Figure 6: The sites of Campbell Soup in Europe

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[67] Ljungberg, Mona 2013-10-02

Another challenge Campbell Soup Nordic has are the volume constraints of their mixer. The mixer used for products at the production line 102, needs a certain volume to be able to run. The mixer is not adjusted for the needs the company has today. The production volumes are adjusted to the market needs for twenty to thirty years ago when Campbell Soup Nordic produced high volumes of fewer products. Today Campbell Soup needs to have a large variety in their assortment with a larger number of soups and flavors to meet the customer's needs.[68]

4.2 The complexity of the OOH-products manufactured at Karpalund

OOH-products are an abbreviation of out-of-home products. These products have two target markets. The first is the public sector and the second the restaurant business. In Sweden the school canteens, hospitals, elderly care and correctional establishments is managed by public procurement. Important aspects which have to be satisfied in the public sector are the quality of the product, ethical values and limited amount of additives added in to the products. The food cooked in the public sector needs to be prepared in a short time and Campbell Soup Nordic can offer this with their dry products. It is important that Campbell Soup Nordic can meet their customer's needs. The public sector often decided their menus a long time in advance. It is very difficult to influence the customer's menu and therefore they need to have a wide range of products to satisfy the customer's needs. In the public sector the quotes are made for a period of between two and four years. During this period Campbell Soup Nordic has a possibility to investigate how well they can meet and fulfill their customers demand. If Campbell Soup Nordic cannot satisfy the customer's needs in some aspect they will lose the customers to their competitor's.[69]

Campbell Soup Nordic´s challenges are to be able to offer a wide range of products and operate affordable batch volumes. If a product is removed from the assortment another product needs to cover the lost sales which automatically arise with the removal of a product. If Campbell Soup Nordic removes a product there is a risk that their competitors can offer a replacement instead and they may lose the whole bid. A product is removed from the market when neither Campbell Soup Nordic nor their distributers make earnings on the product.[70]

Campbell Soup Nordic offers different volume sizes of their products since their customers have different needs and polices. There are different polices which can affect the volume size and one policy is for instance lifting regulations. The employees in kitchens in the public sector have regulations on the weight they are allowed to lift according to the sales manager. Some public sectors also want to have the opportunity to order in both smaller and larger package sizes and if Campbell Soup Nordic cannot offer different sizes of their products they will lose the bid.[71]

Campbell Soup Nordics out-of-home products in Sweden are presented in the figure below. In this study the products from the product group Bong Bouillon Dry was investigated.

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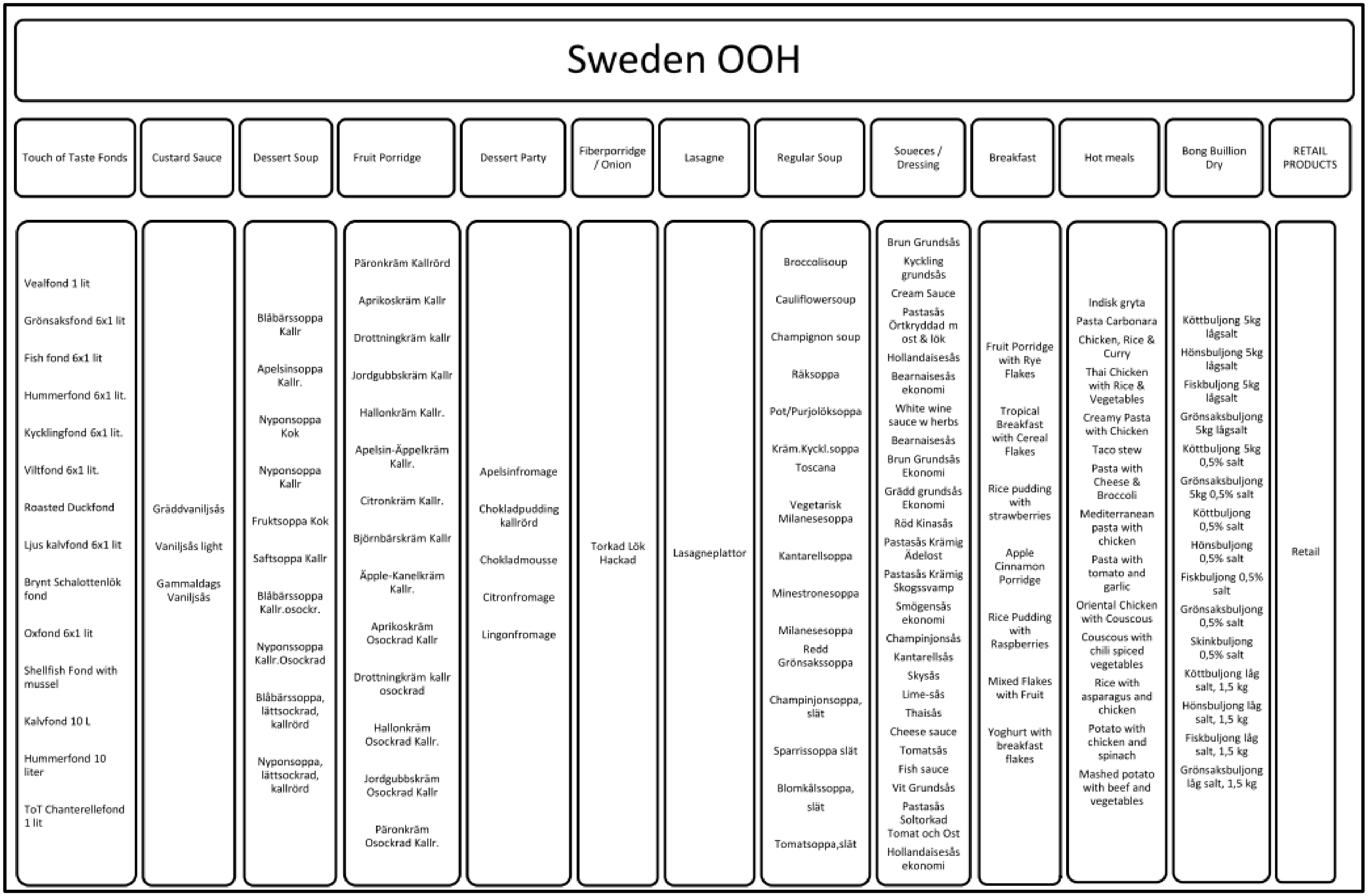
[68] Nilsson, Charlotte 2013-09-27
[69] Ibid
[70] Ibid
[71] Ibid



Sweden OOH

Touch of Taste Fonds
- Vealfond 1 lit
- Grönsaksfond 6x1 lit
- Fish fond 6x1 lit
- Hummerfond 6x1 lit.
- Kycklingfond 6x1 lit.
- Viltfond 6x1 lit.
- Roasted Duckfond
- Ljus kalvfond 6x1 lit
- Brynt Schalottenlök fond
- Oxfond 6x1 lit
- Shellfish Fond with mussel
- Kalvfond 10 L
- Hummerfond 10 liter
- ToT Chanterellefond 1 lit

Custard Sauce
- Gräddvaniljsås
- Vaniljsås light
- Gammaldags Vaniljsås

Dessert Soup
- Blåbärssoppa Kallr
- Apelsinsoppa Kallr.
- Nyponsoppa Kok
- Nyponsoppa Kallr
- Fruktsoppa Kok
- Saftsoppa Kallr
- Blåbärssoppa Kallr.osockr.
- Nyponssoppa Kallr.Osockrad
- Blåbärssoppa, lättsockrad, kallrörd
- Nyponsoppa, lättsockrad, kallrörd

Fruit Porridge
- Päronkräm Kallrörd
- Aprikoskräm Kallr
- Drottningkräm kallr
- Jordgubbskräm Kallr
- Hallonkräm Kallr.
- Apelsin-Äppelkräm Kallr.
- Citronkräm Kallr.
- Björnbärskräm Kallr
- Äpple-Kanelkräm Kallr.
- Aprikoskräm Osockrad Kallr
- Drottningkräm kallr osockrad
- Hallonkräm Osockrad Kallr.
- Jordgubbskräm Osockrad Kallr
- Päronkräm Osockrad Kallr.

Dessert Party
- Apelsinfromage
- Chokladpudding kallrörd
- Chokladmousse
- Citronfromage
- Lingonfromage

Fiberporridge / Onion
- Torkad Lök Hackad

Lasagne
- Lasagneplattor

Regular Soup
- Broccolisoup
- Cauliflowersoup
- Champignon soup
- Räksoppa
- Pot/Purjolöksoppa
- Kräm.Kyckl.soppa Toscana
- Vegetarisk Milanesesoppa
- Kantarellsoppa
- Minestronesoppa
- Milanesesoppa
- Redd Grönsakssoppa
- Champinjonsoppa, slät
- Sparrissoppa slät
- Blomkålssoppa, slät
- Tomatsoppa,slät

Souces / Dressing
- Brun Grundsås
- Kyckling grundsås
- Cream Sauce
- Pastasås Örtkryddad m ost & lök
- Hollandaisesås
- Bearnaisesås ekonomi
- White wine sauce w herbs
- Bearnaisesås
- Brun Grundsås Ekonomi
- Grädd grundsås Ekonomi
- Röd Kinasås
- Pastasås Krämig Ädelost
- Pastasås Krämig Skogssvamp
- Smögensås ekonomi
- Champinjonsås
- Kantarellsås
- Skysås
- Lime-sås
- Thaisås
- Cheese sauce
- Tomatsås
- Fish sauce
- Vit Grundsås
- Pastasås Soltorkad Tomat och Ost
- Hollandaisesås ekonomi

Breakfast
- Fruit Porridge with Rye Flakes
- Tropical Breakfast with Cereal Flakes
- Rice pudding with strawberries
- Apple Cinnamon Porridge
- Rice Pudding with Raspberries
- Mixed Flakes with Fruit
- Yoghurt with breakfast flakes

Hot meals
- Indisk gryta
- Pasta Carbonara
- Chicken, Rice & Curry
- Thai Chicken with Rice & Vegetables
- Creamy Pasta with Chicken
- Taco stew
- Pasta with Cheese & Broccoli
- Mediterranean pasta with chicken
- Pasta with tomato and garlic
- Oriental Chicken with Couscous
- Couscous with chili spiced vegetables
- Rice with asparagus and chicken
- Potato with chicken and spinach
- Mashed potato with beef and vegetables

Bong Buillion Dry
- Köttbuljong 5kg lågsalt
- Hönsbuljong 5kg lågsalt
- Fiskbuljong 5kg lågsalt
- Grönsaksbuljong 5kg lågsalt
- Köttbuljong 5kg 0,5% salt
- Grönsaksbuljong 5kg 0,5% salt
- Köttbuljong 0,5% salt
- Hönsbuljong 0,5% salt
- Fiskbuljong 0,5% salt
- Grönsaksbuljong 0,5% salt
- Skinkbuljong 0,5% salt
- Köttbuljong låg salt, 1,5 kg
- Hönsbuljong låg salt, 1,5 kg
- Fiskbuljong låg salt, 1,5 kg
- Grönsaksbuljong låg salt, 1,5 kg

RETAIL PRODUCTS
- Retail

Figure 7: The product range of Swedish out-of-home products

4.2.1 Campaigns of OOH-products

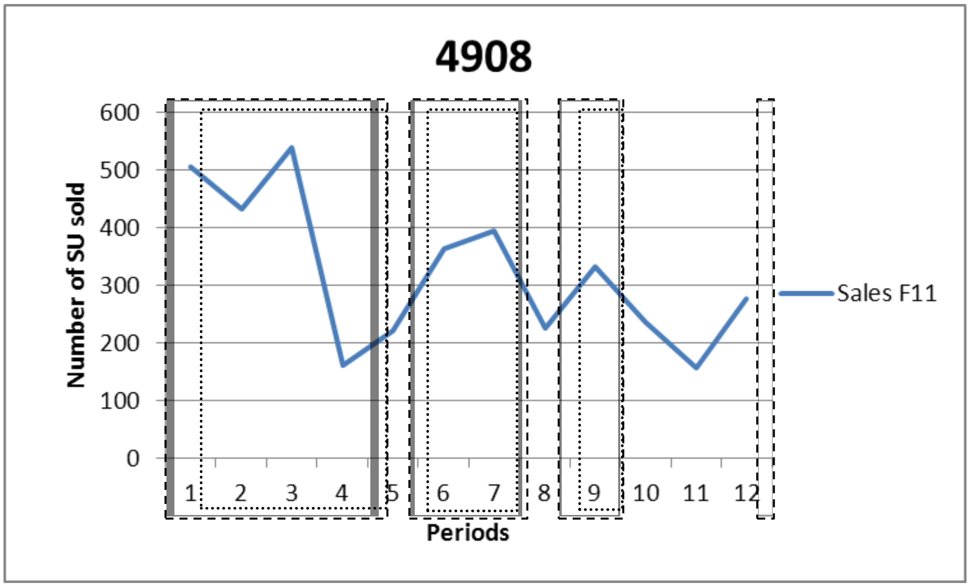
Campaigns and commercials are used to show products and achieve additional sales.

"However, the impact of the campaigns is not that high and the campaigns are mostly used to remind the customers that the products exist and to introduce new products to the market" according to the Sales Manager for the Swedish out-of-home products.[72]

The products which have the most campaigns are the products of the brands Bong and Touch of Taste. These products are more expensive and of high quality which make them compete with other competing high quality products. Some restaurants take the opportunity to buy these products when they are on campaign.[73]

Campbell Soup Nordic often uses campaign magazines to show new comings and sell products. They use advertisements with a picture of the product and the price to attract interest in the magazines. The out-of-home products have four wholesalers who use different brand magazines. Campbell Soup Nordic has to advertise in the different magazines to reach these wholesalers. The campaigns sometimes run simultaneously in the magazines during the same time span but not always. The magazines they use for their campaigns are hotels-, restaurants- and inspiration magazines.[74]

The sales department at Campbell Soup Nordic has a strategy to use campaigns when they know there is a high season coming up. In the sales of the article called 4908 the effects of the campaigns are visible and increased sales are shown during the campaign periods see Graph 6. The vertical axis shows the number of sales units sold and the horizontal axis shows the different periods of the fiscal year of Campbell Soup Nordic. In Graph 6 below the larger squares show which weeks Campbell Soup Nordic sell their products to a reduced price and the smaller squares show the weeks the wholesalers have their campaigns to their customers.



Graph 6: The campaigns of the fiscal year 2011 for 4908

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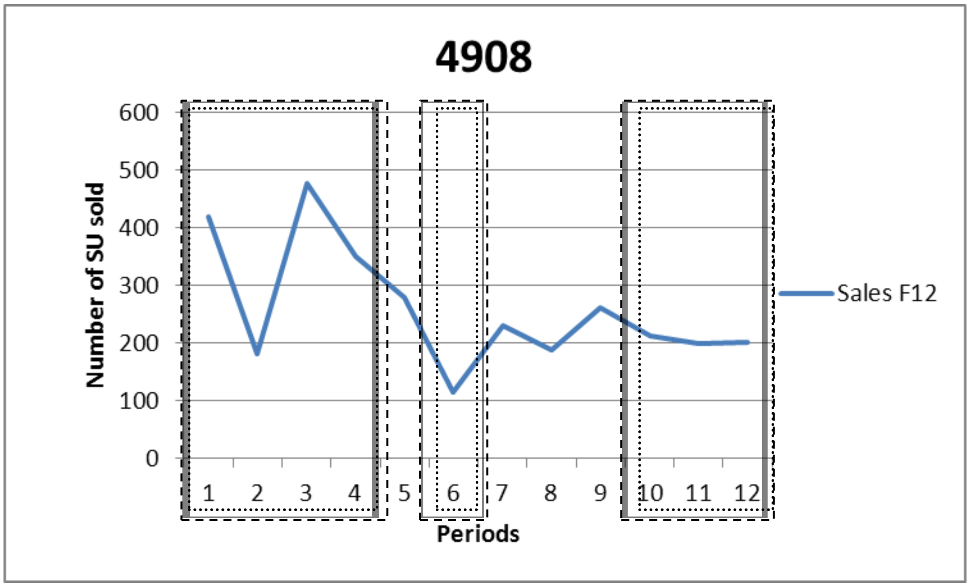
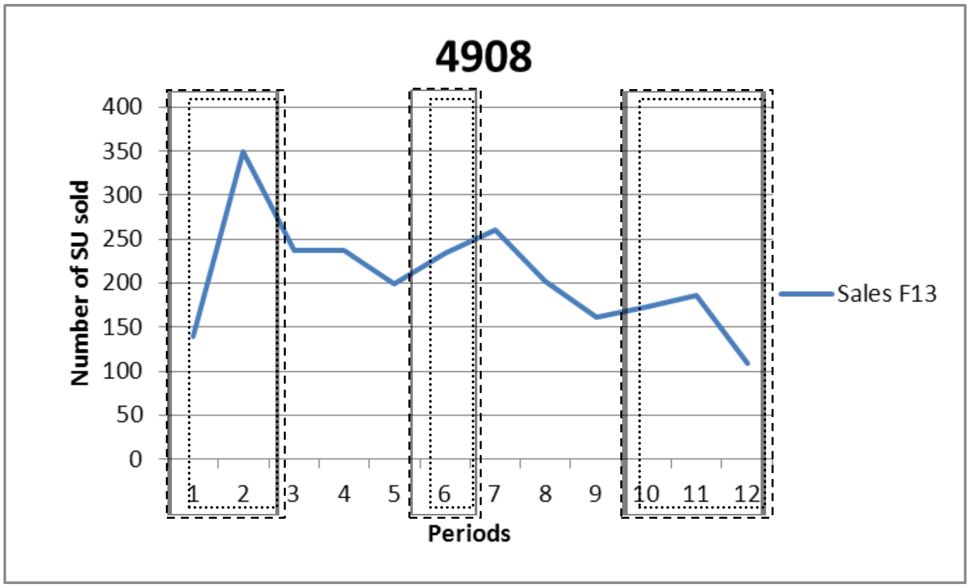
[72] Nilsson, Charlotte 2013-09-27
[73] Ibid
[74] Ibid

However as can be seen in the fiscal year of 2012, Graph 7, the sales are below the average number of sales units sold even though there is a campaign period. However in most cases there are increased sales see Appendix 1.



Graph 7: The campaigns of the fiscal year 2012 for 4908

The campaigns occur when the wholesalers want them to therefore they sometimes differ between the years. The wholesalers have the power to change the campaign periods. Campbell Soup Nordic has during the three fiscal years studied had campaigns for four different wholesalers and they are Martin & Servera, Menigo, M Olsson cl and Svensk Cater.[75]



Graph 8: The campaigns of the fiscal year 2013 for 4908

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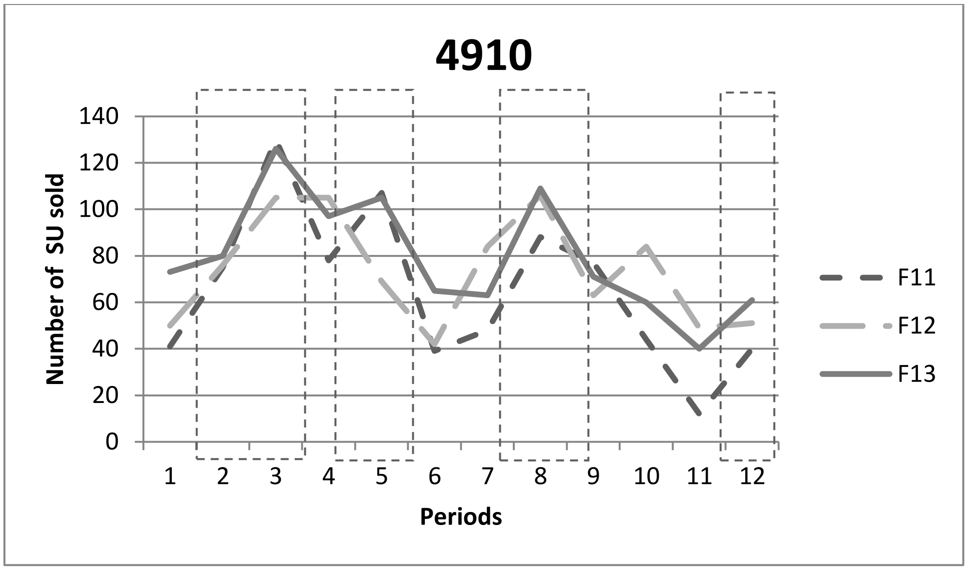
[75] Nilsson, Charlotte 2013-09-27

4.2.2 Seasonality of OOH-products

Campbell Soup Nordic notices that their OOH-products have some seasonality, in the beginning of the school semester. The OOH-products also have a season in November when companies often have conferences at restaurants. The bids from the communities decrease in the end of the school semester in May and increases in the summer when bids from restaurants increase when outdoor restaurants open.[76]

Campbell Soup Nordic´s fiscal year starts in August and ends in July the following year. In the Graph 9 below the first month corresponds to August and the twelfth month to July.[77] The sales of product 4910, increases in the second and third month. The first month is August when the school starts. The bouillons have increasing sales in November and December when there are many conferences and it is Christmas time. In the seventh month and eight (February and Mars) the sales increase again during Easter according to the employees at Campbell Soup Nordic[78]. The sales decreases in April and May when the school kitchens order less since they try to use up the products they already have in their pantries before the summer holiday starts. In June and July the sales increase when the outdoor restaurants opens.



Graph 9: The sales of 4910 during the fiscal years F11, F12 and F13.

4.2.3 Different OOH-products in Sweden verses Finland

Campbell Soup Nordic has different OOH-products in Sweden and Finland. The products are similar but since there are different restrictions in Finland and Sweden the products need to be different. In Finland a larger proportion of the population is lactose intolerant in comparison to the Swedish population. It is more expensive to produce food that is free from lactose and therefore they have different products for

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[76] Nilsson, Charlotte 2013-09-27
[77] Rosdahl, Henrik 2013-09-17
[78] Johansson, Josefine 2013-09-17

the Swedish market and the Finnish market. It is more expensive to produce lactose free products since they require special handling like being stored at a dedicated area during the storage. These products are only produced in the smaller mixer in the production at Campbell Soup Nordic. In Finland they also have a restriction of how much salt is allowed in the products. In Sweden the customers expect the food to taste in a certain way and it requires a certain amount of salt.[79]

Sweden and Finland also have different restrictions on environment and quality which have to be taken into consideration. In Sweden cardboard boxes are not allowed in the kitchens. The packaging needs to manage water and be closable and therefore they sell buckets in Sweden. The bucket is more expensive than the cardboard box which is the reason they have different packaging in Sweden and Finland.[80]

Figure 8: OOH-products in buckets for the Swedish market

4.3 The production process

Campbell Soup Nordic produces products after forecasts of believed sales and therefore produces after a make-to-stock (MTS) policy.[81] The production is flexible since the ERP system (SAP) calculates well in advance which products should be produced so the purchaser can purchase ingredients, packaging material and labels. The raw materials are purchased four to five weeks ahead. The amounts of the different materials are based on an overall production plan of three months.[82]

A production plan of one week is constructed of available forecasts in SAP and sales, every Tuesday, a week ahead the production plan will be used. The plan is made one week in advance to be able to adjust to changes in sales. The production plan triggers a need of raw materials in SAP and the employees at the warehouse get a list every day of what they will produce and how much of each raw material is needed for certain products.[83]

A warehouse worker picks up the raw material in the warehouse and transports it to the conveyor and the measure and weighing station. The first worker in the production loads the conveyor with the bags of

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[79] Nilsson, Charlotte 2013- 09-27

[80] Ibid

[81] Rosdahl, Henrik 2013-09-17

[82] Ljungberg, Mona 2013-10-02

[83] Jönsson, Jan-Inge 2013-09-24

raw material and a second worker measures that the raw materials have the right weight for the recipe. A third worker is at the end of the conveyor and cuts up the bags of raw material and pours down the dry ingredients into a mixing machine.

When the dry ingredients are mixed in the machine the mixture is stored in a metal container. The third worker cleans the mixing machine and the container is then moved by the first worker from the mixing machine to a designated place where the mixture will "rest". The mixture needs to rest since the mixture needs to sag and get rid of air inside the mixture. It is important that the mixture is compact for the filling machine so that the correct volume of the mixture can be divided in the packages.[84]

When the mixture has rested a fifth worker moves the metal container to the filling machine. When the metal container has been emptied into the filling machine it is cleaned. The filling machine is connected to the packaging machine and is controlled by the fifth and sixth worker. The workers are responsible for setting and cleaning the machine. A warehouse worker transports packaging materials and labels to the filling machine and packaging machine. The seventh and eighth workers are at the same time as the fifth and sixth workers finishing the last produced products of the earlier order line. They are also preparing labels and packages for the new products.

Two technicians help with the changes that have to be done for the new product in the production line. The technicians are only needed if a different packaging is needed. Sometime the following products have the same buckets and then only the labels are changed. The production planner tries as far as possible to place products that have the same packaging after each other to avoid the time consuming changeovers. When the preparations are done the sixth worker puts the plastic buckets on the conveyor that leads to the filling machine. The buckets get filled by the machine and are then transported to the seventh worker that is putting on the lids on the buckets and at the same time controlling that the buckets have the right weight by looking at a monitor. The buckets are then transported to the eighth worker that puts the ready packed bouillons on a pallet. A bucket is a sales unit (SU). The pallets are then moved by a worker to a dedicated location in the warehouse for finished products.[85] The production process is showed in Figure 9.

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[84] Holmström, Torgny 2013-09-23

[85] Holmström, Torgny 2013-09-23

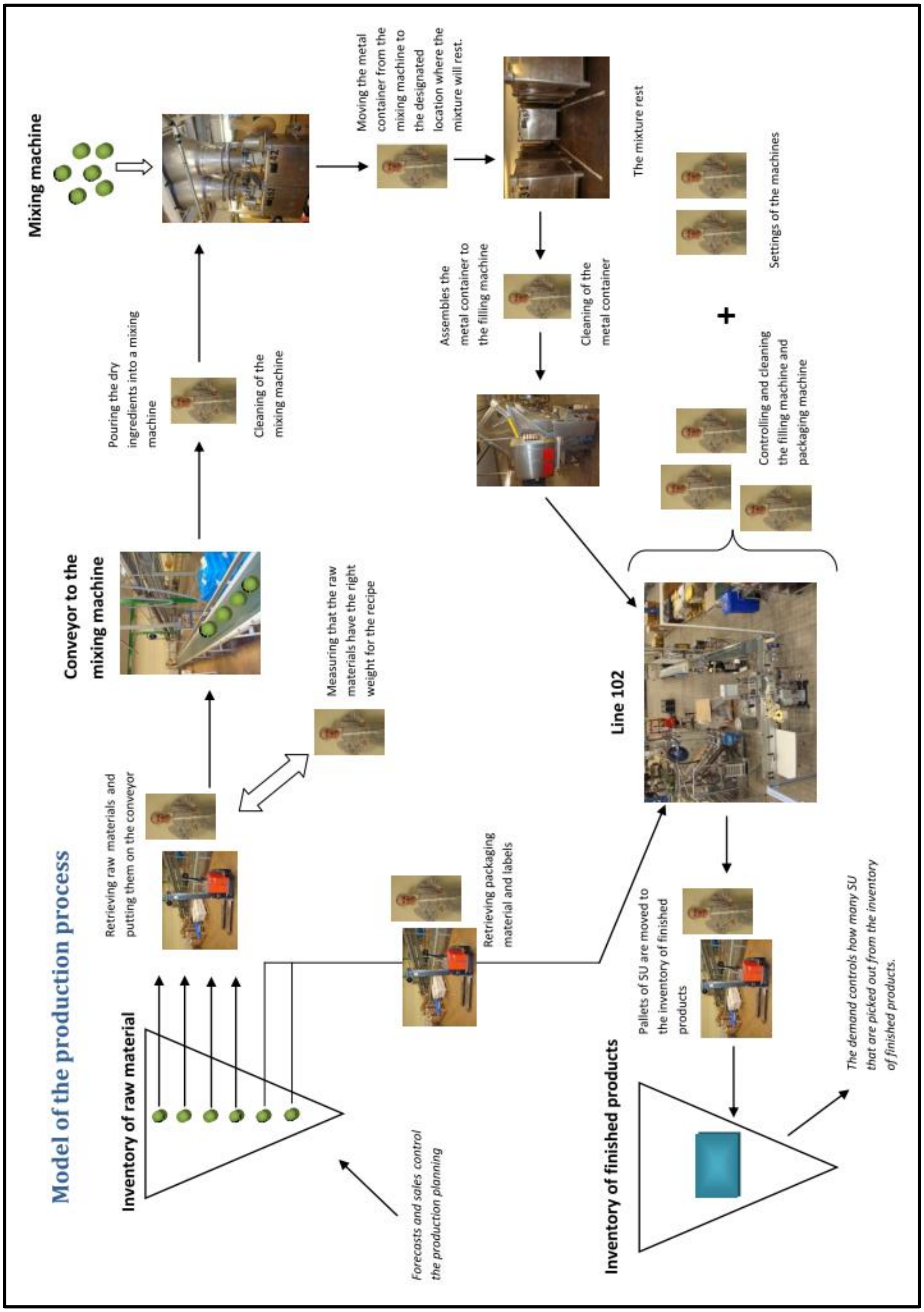

Figure 9: The production process

4.4 The inventory control

4.4.1 Safety time

Campbell Soup Nordic uses different safety times for their retail products and out-of-home products. The retail products have five days safety time and out-of-home products have ten days safety time. These days are based upon their experience and have manually been determined. The actual range of coverage is equivalent to the safety time in work days.

4.4.2 Order quantity

Campbell Soup Nordic uses a common software system called SAP. When the inventory level for the finished products reaches the quantity covering the forecast of two weeks SAP triggers an order in the system. SAP adds the product to the production plan and gives a suggestion of when and how much Campbell Soup Nordic should produce of the product. [86] The number of sales units produced is a batch quantity. SAP is an important tool for the company´s inventory control and can show the actual inventory level continuously. A batch size often covers a lot more than the sales of two weeks and in some cases it even covers more than the sales over a whole year depending on the product produced. [87] The vertical axis shows the number of sales units sold and the horizontal axis shows the different periods of the fiscal year of Campbell Soup Nordic.

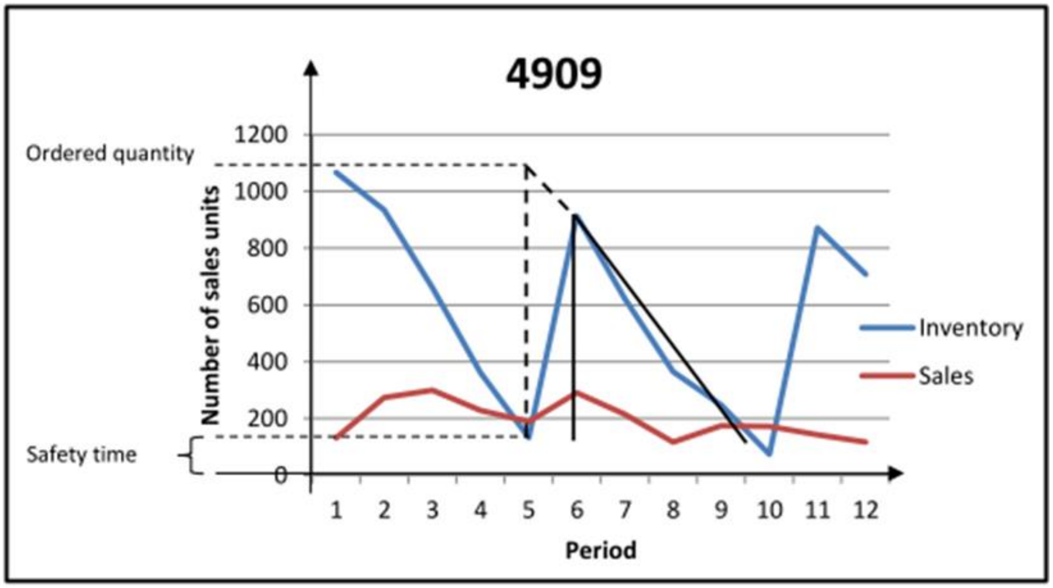

Figure 10: The inventory control of 4909 in the fiscal year 2013

4.4.3 Forecast model

SAP calculates the reorder point and safety stock based on historical consumption values and forecasts. Firstly the forecast is executed and the reorder point and safety stock are proposed. In SAP different forecast models can be chosen. However Campbell Soup uses the constant model. The forecast period is

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[86] Rosdahl, Henrik 2013-09-18

[87] Johansson, Josefine 2013-09-17

set and it is currently five forecast periods which means that the system will calculate the forecast for five periods.[88]

A smoothing factor for basic value called alpha. Alpha (α) is used for smoothing the basic value from the previous period to the current period. α is currently set to 0.2. The formula for the constant model is as follows[89]:

$$\text{Basic Value (t)} = \alpha \cdot X_{(t-1)} + (1-\alpha) \cdot X_{b(t-1)} \qquad (11)$$

Where the denotations are,

$X_b =$ basic value for the forecast period e.g. it is the forecast consumption value
$\alpha =$ the smoothing factor of basic value
$X =$ actual consumptions
$t =$ current period

4.5 Service level

Campbell Soup Nordic uses the key performance indicator (KPI) Case Fill Rate. The company has a gold standard of 99%.[90]

The objective of the KPI is to improve their customers' satisfaction. This is done by measuring the frequency of orders on a case basis that are filled completely. A case is the same as a sales unit for the investigated products.[91]

Campbell Soup Nordic calculates their Case Fill Rate as

$$Case\ Fill\ Rate = \frac{Total\ Case\ Ordered - Case\ Not\ Shipped}{Total\ Cases\ Ordered} \cdot 100\% \qquad (12)$$

4.6 Sales

Sales data was collected for the fiscal years of 2011, 2012, 2013 so that an appropriate amount of data could be collected. Three years of past data was needed to analyze the effects of seasons and campaigns. The data had to be collected by weeks and not in periods since the different campaigns and seasons could be divided over more than one period. The sales data was collected from the SAP system. The sales show a trend of decreasing sales every year. An example can be seen in Graph 10. The vertical axis shows the number of sales units sold and the horizontal axis shows the different periods of the fiscal year of Campbell Soup Nordic.

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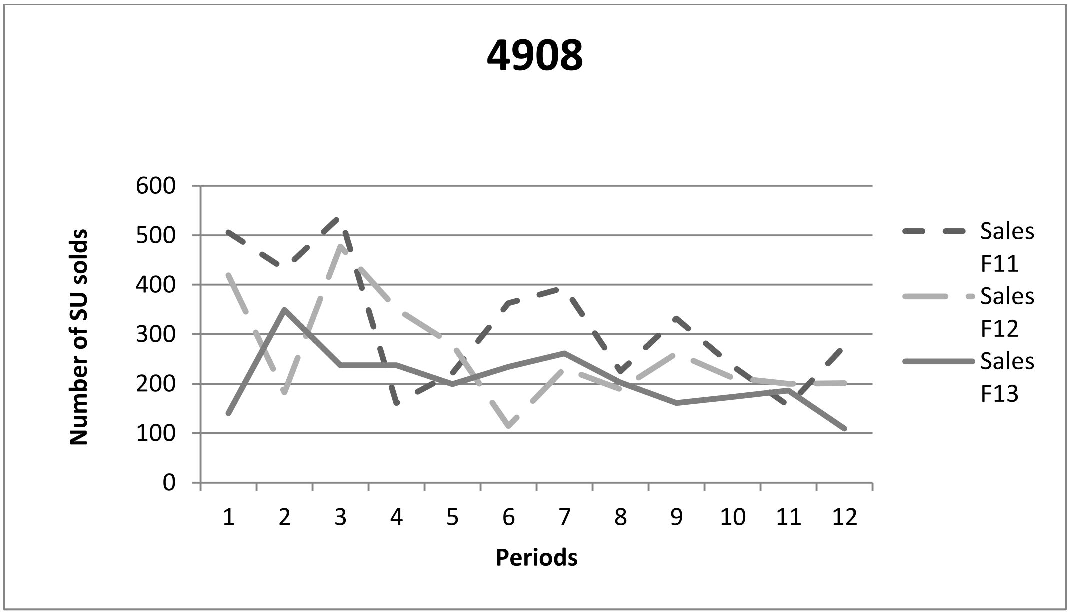
[88] Rönnholm Gardelli, Joanna 2013-09-18
[89] Ibid
[90] Rosdahl, Henrik 2013-09-27
[91] Frisk, Agneta 2014-01-09



Graph 10: The sales of 4908 for the fiscal years F11, F12 and F13

The sales during the periods differed from the years studied however some trends could be spotted but not always. The seasons were not as obvious as they were first described by the sales department. Increased sales seemed mostly be affected by campaigns. During the campaigns Campbell Soup Nordic sell their products to a reduced price.

4.7 Lost Sales

When an item is ordered by a customer and cannot be delivered, due to shortages a cost of lost sales can occur. It depends on if the customer is willing to wait for the product while the order is backlogged or not. Campbell Soup Nordic does not take backorders so if they cannot deliver the customer have to wait to order until products are available again.[92] This is considered to be misleading since you cannot see if the customer orders, more the next time or if it does not. There are no data available for an analysis of lost sales, therefore the authors decided to perceive the products that could not be delivered as lost sales. Campbell Soup Nordic also has experienced that the customers keep on ordering until they get what they want even though they know the order will be cancelled since Campbell Soup Nordic does not have the products available which result in biased numbers. Some employees the authors interviewed think that the KPI of case fill rate is more appropriate than the order fill rate.[93] See Appendix 2 for the lost sales of the fiscal years 2011 and 2012.

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[92] Rosdahl, Henrik 2013-09-27

[93] Rosdahl, Henrik 2013-09-27

Table 3: The lost sales of the fiscal year 2013[94]

Fiscal year 2013				
Material	Demand	Sales	Lost sales	Unit
4900	1411	1379	32	SU
	100%	98%	2%	
4901	710	655	55	SU
	100%	92%	8%	
4902	292	292	0	SU
	100%	100%	0%	
4903	1028	1028	0	SU
	100%	100%	0%	
4904	1664	1464	200	SU
	100%	88%	12%	
4906	2728	2728	0	SU
	100%	100%	0%	
4907	1859	1859	0	SU
	100%	100%	0%	
4908	2309	2309	0	SU
	100%	100%	0%	
4909	2251	2251	0	SU
	100%	100%	0%	
4910	974	969	5	SU
	100%	99%	1%	

4.8 Holding costs

Campbell has an internal rate of 9.5%[95] and a cost of capital of 7%. The cost of capital was used when calculating an alternative cost to the given warehouse cost by the finance department. An alternative was needed since the origin and the components of the warehouse cost could not be explained in detail. There were no calculations of the total holding costs per sales unit. The warehouse cost is fixed and is based on the costs of handling pallets which was stated in the budget.[96] The warehouse cost was not used during the analysis since it is fixed and do not change with volume.

The alternative cost was calculated by taking the capital tied in the finished goods and multiplies with the cost of capital. The storage costs of the Swedish products are not affected by the volume since the company owns their warehouse and the cost for it is permanent. The insurance is paid as a lump sum which includes all the products, the buildings and more.[97] Therefore it is very difficult to calculate how a single product affects it. Since the study is trying to lower the inventory levels and the batch sizes it will decrease obsoletes. Today obsoletes are unusual and very low so it is considered to be negligible as a holding cost. The material handling is difficult to measure the handling will decrease if less products are produced but can also increase if the products get produced more often because of the smaller batch sizes. The authors have chosen to disregard the changes of the material handling costs.

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[94] Frisk, Agneta 2013-10-09
[95] Sturk, Pontus 2013-09-27
[96] Ibid
[97] Ibid

4.9 Order Costs

When determining the order costs for the different products investigated, it was difficult to determine a specific order costs since there had not been any calculations of how much the different products acquired of the purchasers time or set ups in the production. It was explained that an analysis was difficult to do since there was individual set up times of the packaging machines and the mixing machine. These set up times are different depending on which products are produced before and after. There are many products produced in the mixer and they have different cleaning restrictions and set ups. An example is that some products have allergens. This means that the products produced after require a more time consuming cleaning process before they can be produced in the same machine. Some products have different colors that have to be taken into consider. If for example a tomato soup is produced the red color can stick on the walls inside of the mixing machine and discolor the following products if the machine is not cleaned correctly. Another example is if an organic vegetarian bouillon is produced a non-organic vegetarian bouillon can follow and after a meat bullions can be produced. This means that three products can be produced without any cleaning. The production always try to take this into consideration while planning the production but it always differs a bit from time to time which products get the long setup costs.[98] The authors have studied the production and tried to investigate and find the costs of the specific products that have been investigated in this study.

4.10 Scrapped products

The scrap cost is low for the investigated products. The table below shows the products scrap cost of two years and only two sales units have been scrapped. The reason for the scrapping was that the product had been damage in the inventory. There were no expired products. In the analysis scrapped products are not taken into consideration since the scrapping occurs rarely. This decision was made during a consultation with the Supply Chain Manager.[99]

Table 4: Scrapped products of the fiscal years F12 and F13

Material	Actual scrap 2012 in SU	Cost 2012 in SEK	Reason 2012	Actual scrap 2013 in SU	Cost 2013 in SEK	Reason 2013
4900	0	0	-	0	0	-
4901	0	0	-	0	0	-
4902	0	0	-	0	0	-
4903	0	0	-	1	184,71	Damage of SU in the inventory of finished products
4904	0	0	-	0	0	-
4906	0	0	-	0	0	-
4907	0	0	-	0	0	-
4908	0	0	-	0	0	-
4909	0	0	-	0	0	-
4910	0	0	-	1	124,42	Damage of SU in the inventory of finished products
Total Cost in SEK		0			309,13	

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[98] Jönsson, Jan-Inge 2013-09-24

[99] Rosdahl, Henrik 2013-09-11

5 Analysis

This chapter describes the models that are used to investigate the impact of different batch sizes on the total costs of the production and inventory. The objective of the models is to find batch sizes that are the most cost effective and can handle unexpected demand and limitations in the production. The models are constructed in Microsoft Excel. The models mostly focus on costs which are affected by the volume and not so much on the constant costs. This chapter will also compare Campbell Soup Nordic's situation with the theory discussed in the theory chapter.

5.1 Construction of the analytical models

Order to investigate the batch sizes effect on the holding cost, setup cost and manufacturing cost two types of models where constructed. Both of the models are similar however the first is constructed on demand data during the fiscal years 2011, 2012 and 2013. This model is called the Current Situation Model and the second model is a simulation model called the Cost Analysis Model in which the demand has a gamma distribution and different batch sizes are tested. The Current Situation Model is used to validate the Cost Analysis Model. The constructions of these are explained step by step in this chapter. This chapter is divided into two parts, the first part describes the conceptual models and the second part describes how the models were implemented in Excel.

5.1.1 Conceptual Models

5.1.1.1 Current Situation Model

This model is based of real data from Campbell Soup Nordic. The aim with this model is to use it as a validation tool to the Cost Analysis Model that uses a gamma distribution for the demand. The Current Situation Model will give an indication of how well the gamma distribution of the demand fits the reality. There are three versions of the Current Situation Model and each model is based on data from the fiscal years 2011, 2012 or 2013. The Current Situation Model for 4903 of the fiscal year 2013 can be seen in Figure 12.

5.1.1.2 Cost Analysis Model

The Cost Analysis Model will be used to investigate the effect of different batch sizes. There are limitations on how large and small a batch size can be and these limitations are related to the volume of the current mixer in production. The limitation of the mixer was given by the Coordinator Administrator. The maximum volume the mixer can handle is 3000 liters but there is a safety margin of 200 liters so the actual limitation is 2.800 liters. The minimum volume of the mixer used for Bong Dry Bouillon is 1.200 liters. The minimum volume is needed for the mixer to be able to mix the ingredients.[100] The new batch sizes were calculated by

$$Maximum\ batch\ size = \frac{Maximum\ volume\ (liter)}{\frac{weight\ of\ one\ SU\ (kilo)}{density\ (\frac{kilo}{liter})}} \tag{13}$$

$$Minimum\ batch\ size = \frac{Minimum\ volume\ (liter)}{\frac{weight\ of\ one\ SU\ (kilo)}{density\ (\frac{kilo}{liter})}} \tag{14}$$

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[100] Nilsson, Johan 2013-10-09

A scale between the maximum and the minimum batch size were calculated and dived in 10 steps scaled from smallest allowed batch size to the highest allowed batch size, see minimum SU and maximum SU in Table 5. The calculated batch sizes were used in the models to see which batch size for the different products resulted in the lowest total variable costs. The reason for the different number of sales units in the investigated batch sizes is that the products have different densities of the mixtures and different bucket sizes. Products 4900-4904 have a bucket size of 5kg and the other products 4906-4910 have a bucket size of 1,5kg.

Table 5: The maximum and minimum allowed batch sizes

Product	kilo/SU	batch weight (kilo)	Density (kilo/liter)	Minimum SU (1200liters)	Maximum SU (2800 liters)	Current batch size (SU)	10 step
4900	5,1	997	0,707	165	385	194	22
4901	5,1	1228	0,622	145	338	239	19
4902	5,1	1001	0,774	180	422	195	24
4903	5,1	1361	0,932	218	509	266	29
4904	5,1	1125	0,823	192	448	219	26
4906	1,5	1125	0,823	646	1507	736	86
4907	1,5	1004	0,807	633	1478	657	85
4908	1,5	1334	1,043	819	1911	873	109
4909	1,5	1480	0,952	748	1745	969	100
4910	1,5	1391	0,819	643	1501	911	86

The Cost Analysis Model will run 1.000 simulations of each batch size evaluated and an average of each cost, profit, revenue and lost sales will be used as an analysis value. To be able to run 1.000 simulations and save the result from each run the tool called What-If-Analysis was used in Excel. To be able to use this tool a version of Excel 2010 or newer is needed.

5.1.1.2.1 Fitting an appropriate distribution

A simulation program named EasyFit 5.5 Professional was used to find an appropriate probability distribution function for the demands of the different products. Since the customers only can demand a positive amount of sales units, the distribution for demand should be non-negative.

Campbell Soup Nordic has campaigns with their wholesalers Martin/Servera, MENIGO, M OLSSON CL and Svensk Cater. The demands for the different products were divided into different categories. The different categories of demand were "All data", "Data without campaigns", "Campaigns with Martin/Servera", "Campaigns with MENIGO", "Campaigns with M OLSSON CL" and "Campaigns with Svensk Cater". Some of the products had campaigns with different wholesalers at the same time which makes it difficult to sort out the different wholesalers demand. In this case another category of demand was used and it was based on coincident campaigns demand data from Martin/Servera and MENIGO. However, to be able to gather enough data to estimate good gamma distribution parameters for the Cost Analysis Model only a combination of campaigns of Martin/Servera and MENIGO was possible.

With the different categories of demand data, histograms were structured with the simulation program EasyFit 5.5 Professional. With EasyFit 5.5 Professional different distribution functions could be adjusted to the histograms and the non-negative gamma distribution had the best overall fit. Therefore the gamma distribution was chosen as the distribution used for simulating the different demands during the different campaigns and during non-campaign weeks.

There are two types of gamma distributions and they are (α, β)-distribution and (α, β, γ)-distribution. To determine which type of gamma distribution that had the best fit to the demand in the simulation program, three different Goodness of Fit tests were used. They automatically ranked the best distribution. The different Goodness of Fit-tests were Kolmogorov Smirnov, Anderson Darling and Chi-Squared.

The following tables and figures are results from the simulation program. These tables and figures are based on demand data when product 4901 had no campaigns. The first table below is the two types of gamma distributions ranked in the different Goodness of Fit tests. The first gamma distribution is the (α, β)-distribution and number two is the (α, β, γ)-distribution. In the table below all tests have ranked the (α, β)-distribution as the best fit for the demand when product 4901 had no campaigns.

Table 6: The result of which gamma distribution that has best ranking

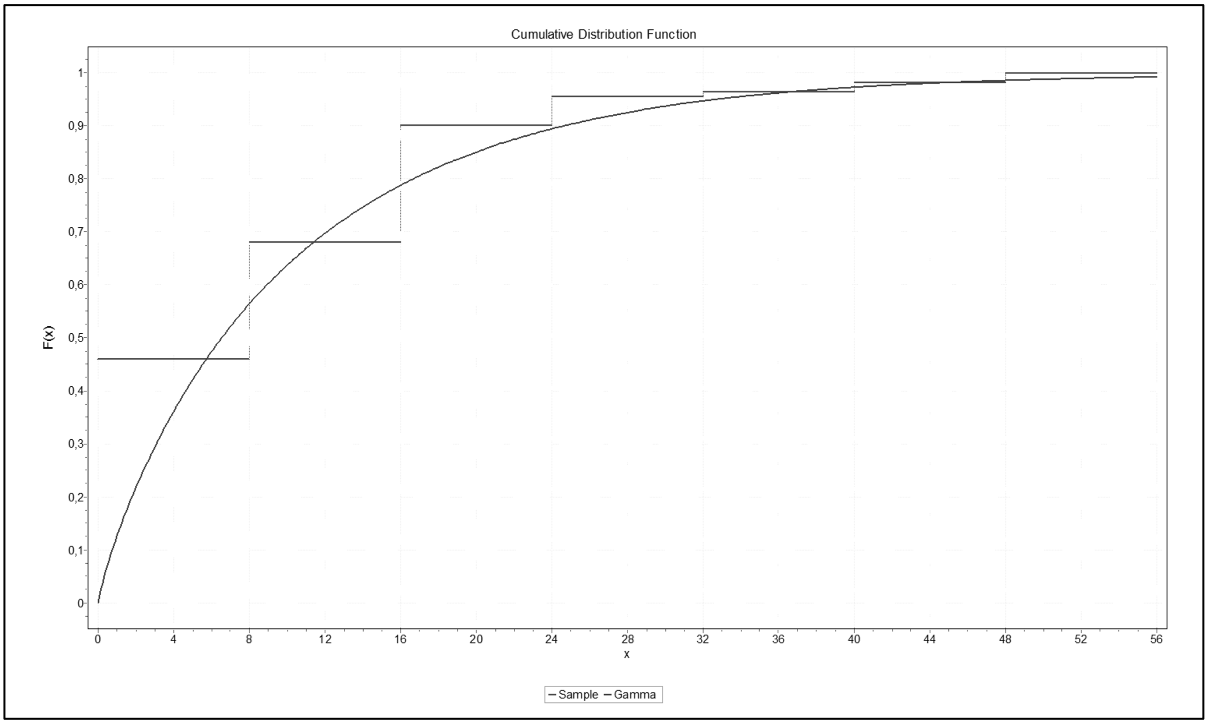
#	**Distribution**	**Kolmogorov Smirnov**		**Anderson Darling**		**Chi-Squared**	
		Statistic	Rank	Statistic	Rank	Statistic	Rank
1	Gamma	0,28319	1	23,01	1	37,273	1
2	Gamma	0,29163	2	48,133	2	62,96	2

In the table below the different gamma distribution parameters are recommended. It is important to recognize that the parameter γ is equal to zero and therefore not added in the table in the (α, β, γ)-distribution, numbered as 2. See Appendix 3 for all of the parameters for the different products and their campaigns.

Table 7: The parameters that is recommended for each distribution

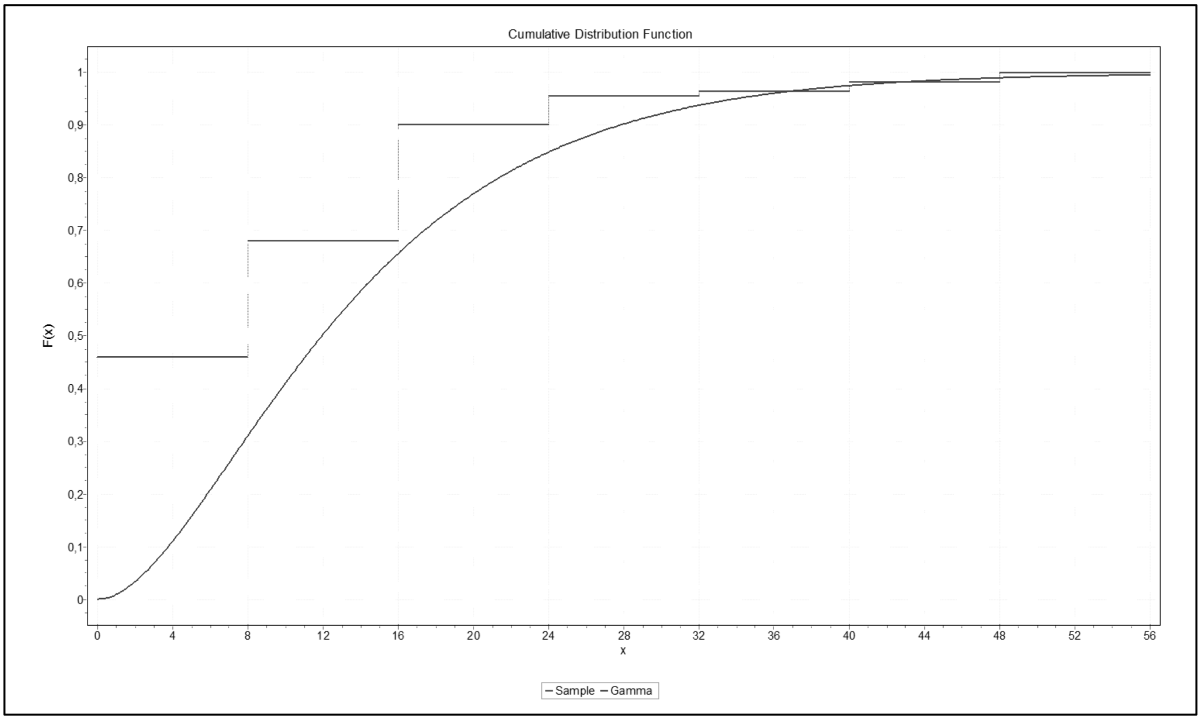
#	**Distribution**	**Parameters**
1	Gamma	α=0,83515 β=12,218
2	Gamma	α=1,9851 β=7,1708

Graph 11, below shows the cumulative distribution function and how well the (α, β)- distribution fits to the demand.



Graph 11: The Cumulative Distribution Function of the (α, β)-distributon

Graph 12, below shows the cumulative distribution function and how well the (α, β, γ)- distribution fits to the demand.



Graph 12: The Cumulative Distribution Function of the (α, β, γ)-distribution

When the cumulative distribution functions are compered it is clear that the (α, β)- distribution has the best fit for the demand and this is confirmed by the Goodness of Fit where the (α, β)- distribution had the best ranking, see Table 6.

5.1.1.3 The inventory for the models

The inventory of finished products have a continuously review and this means that Campbell Soup Nordic has control of their inventory and know exactly when products are moved in and out of the warehouse. They have a safety time of two weeks at their warehouse which means that they need to have enough of products available to cover the forecasted demand for two weeks. The SAP-system automatically warns if they reach the safety time and plan a production of the product. If a customer places an order, it is registered into SAP. The ordered products automatically will be marked as booked and will not be available for another customer. See Figure 11.

The inventory will decrease when there are sales to Sweden and Finland but will increase when there have been a production.

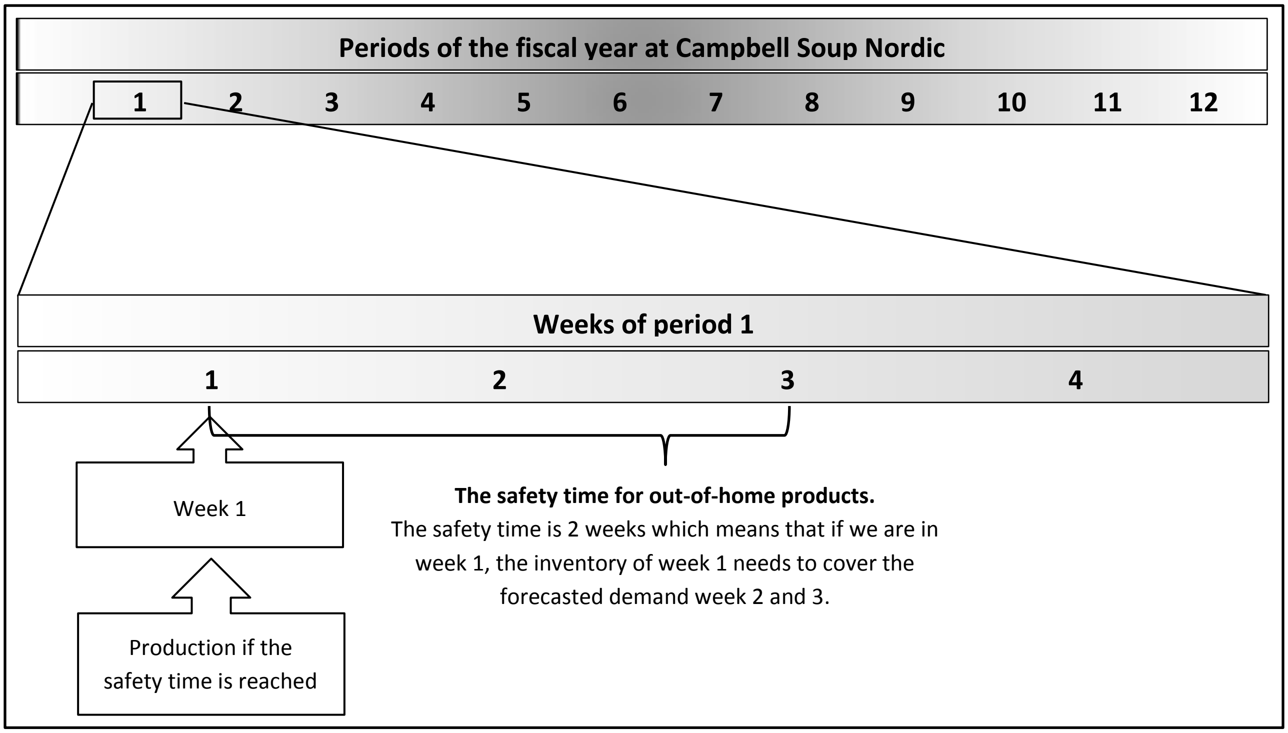


Figure 11: When the production occurs for an out-of-home product

5.1.1.4 The total profit of a year

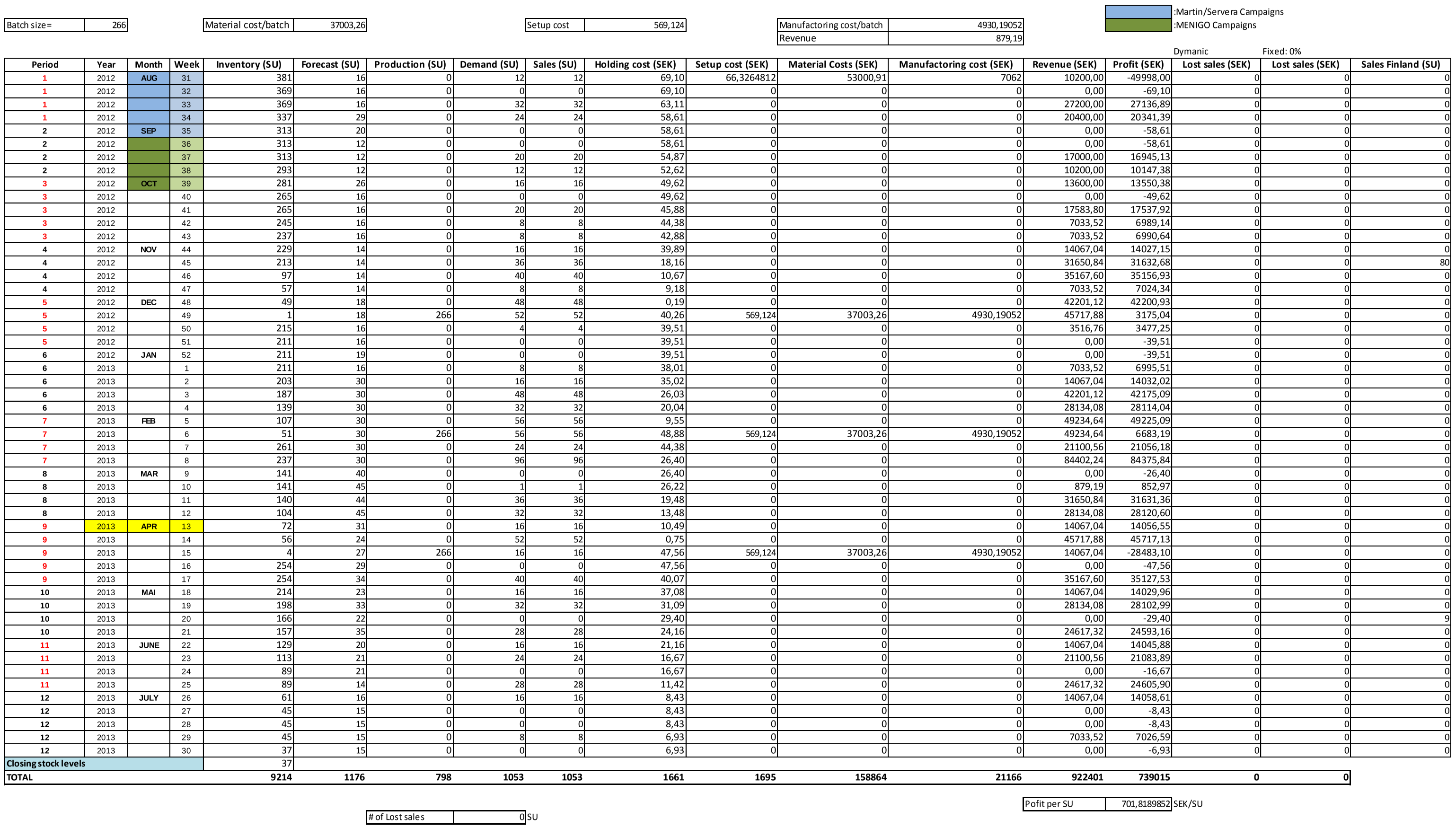
The profit of the year depends on the company´s revenue and its costs during the year. The different cost used in the study were holding cost, setup cost, material cost and manufacturing cost.

$$Profit = Revenue - Holding\ cost - Setup\ cost - Material\ cost - Manufacturing\ cost$$

This cost will be more thoroughly described in the part of implementation in Excel.

5.1.2 Implementation in Excel

The following section describes how the models were implemented in Microsoft Excel. The figure below shows the graphic look of the Current Situation Model and the Cost Analysis Model. They almost have the same construction with some small differences. These differences will be explained for each column in the model.



Batch size=	266
Material cost/batch	37003,26
Setup cost	569,124
Manufactoring cost/batch	4930,19052
Revenue	879,19

🟦 :Martin/Servera Campaigns

🟩 :MENIGO Campaigns

															Dymanic	Fixed: 0%	
Period	**Year**	**Month**	**Week**	**Inventory (SU)**	**Forecast (SU)**	**Production (SU)**	**Demand (SU)**	**Sales (SU)**	**Holding cost (SEK)**	**Setup cost (SEK)**	**Material Costs (SEK)**	**Manufactoring cost (SEK)**	**Revenue (SEK)**	**Profit (SEK)**	**Lost sales (SEK)**	**Lost sales (SEK)**	**Sales Finland (SU)**
1	2012	AUG	31	381	16	0	12	12	69,10	66,3264812	53000,91	7062	10200,00	-49998,00	0	0	0
1	2012		32	369	16	0	0	0	69,10	0	0	0	0,00	-69,10	0	0	0
1	2012		33	369	16	0	32	32	63,11	0	0	0	27200,00	27136,89	0	0	0
1	2012		34	337	29	0	24	24	58,61	0	0	0	20400,00	20341,39	0	0	0
2	2012	SEP	35	313	20	0	0	0	58,61	0	0	0	0,00	-58,61	0	0	0
2	2012		36	313	12	0	0	0	58,61	0	0	0	0,00	-58,61	0	0	0
2	2012		37	313	12	0	20	20	54,87	0	0	0	17000,00	16945,13	0	0	0
2	2012		38	293	12	0	12	12	52,62	0	0	0	10200,00	10147,38	0	0	0
3	2012	OCT	39	281	26	0	16	16	49,62	0	0	0	13600,00	13550,38	0	0	0
3	2012		40	265	16	0	0	0	49,62	0	0	0	0,00	-49,62	0	0	0
3	2012		41	265	16	0	20	20	45,88	0	0	0	17583,80	17537,92	0	0	0
3	2012		42	245	16	0	8	8	44,38	0	0	0	7033,52	6989,14	0	0	0
3	2012		43	237	16	0	8	8	42,88	0	0	0	7033,52	6990,64	0	0	0
4	2012	NOV	44	229	14	0	16	16	39,89	0	0	0	14067,04	14027,15	0	0	0
4	2012		45	213	14	0	36	36	18,16	0	0	0	31650,84	31632,68	0	0	80
4	2012		46	97	14	0	40	40	10,67	0	0	0	35167,60	35156,93	0	0	0
4	2012		47	57	14	0	8	8	9,18	0	0	0	7033,52	7024,34	0	0	0
5	2012	DEC	48	49	18	0	48	48	0,19	0	0	0	42201,12	42200,93	0	0	0
5	2012		49	1	18	266	52	52	40,26	569,124	37003,26	4930,19052	45717,88	3175,04	0	0	0
5	2012		50	215	16	0	4	4	39,51	0	0	0	3516,76	3477,25	0	0	0
5	2012		51	211	16	0	0	0	39,51	0	0	0	0,00	-39,51	0	0	0
6	2012	JAN	52	211	19	0	0	0	39,51	0	0	0	0,00	-39,51	0	0	0
6	2013		1	211	16	0	8	8	38,01	0	0	0	7033,52	6995,51	0	0	0
6	2013		2	203	30	0	16	16	35,02	0	0	0	14067,04	14032,02	0	0	0
6	2013		3	187	30	0	48	48	26,03	0	0	0	42201,12	42175,09	0	0	0
6	2013		4	139	30	0	32	32	20,04	0	0	0	28134,08	28114,04	0	0	0
7	2013	FEB	5	107	30	0	56	56	9,55	0	0	0	49234,64	49225,09	0	0	0
7	2013		6	51	30	266	56	56	48,88	569,124	37003,26	4930,19052	49234,64	6683,19	0	0	0
7	2013		7	261	30	0	24	24	44,38	0	0	0	21100,56	21056,18	0	0	0
7	2013		8	237	30	0	96	96	26,40	0	0	0	84402,24	84375,84	0	0	0
8	2013	MAR	9	141	40	0	0	0	26,40	0	0	0	0,00	-26,40	0	0	0
8	2013		10	141	45	0	1	1	26,22	0	0	0	879,19	852,97	0	0	0
8	2013		11	140	44	0	36	36	19,48	0	0	0	31650,84	31631,36	0	0	0
8	2013		12	104	45	0	32	32	13,48	0	0	0	28134,08	28120,60	0	0	0
9	2013	APR	13	72	31	0	16	16	10,49	0	0	0	14067,04	14056,55	0	0	0
9	2013		14	56	24	0	52	52	0,75	0	0	0	45717,88	45717,13	0	0	0
9	2013		15	4	27	266	16	16	47,56	569,124	37003,26	4930,19052	14067,04	-28483,10	0	0	0
9	2013		16	254	29	0	0	0	47,56	0	0	0	0,00	-47,56	0	0	0
9	2013		17	254	34	0	40	40	40,07	0	0	0	35167,60	35127,53	0	0	0
10	2013	MAI	18	214	23	0	16	16	37,08	0	0	0	14067,04	14029,96	0	0	0
10	2013		19	198	33	0	32	32	31,09	0	0	0	28134,08	28102,99	0	0	0
10	2013		20	166	22	0	0	0	29,40	0	0	0	0,00	-29,40	0	0	9
10	2013		21	157	35	0	28	28	24,16	0	0	0	24617,32	24593,16	0	0	0
11	2013	JUNE	22	129	20	0	16	16	21,16	0	0	0	14067,04	14045,88	0	0	0
11	2013		23	113	21	0	24	24	16,67	0	0	0	21100,56	21083,89	0	0	0
11	2013		24	89	21	0	0	0	16,67	0	0	0	0,00	-16,67	0	0	0
11	2013		25	89	14	0	28	28	11,42	0	0	0	24617,32	24605,90	0	0	0
12	2013	JULY	26	61	16	0	16	16	8,43	0	0	0	14067,04	14058,61	0	0	0
12	2013		27	45	15	0	0	0	8,43	0	0	0	0,00	-8,43	0	0	0
12	2013		28	45	15	0	0	0	8,43	0	0	0	0,00	-8,43	0	0	0
12	2013		29	45	15	0	8	8	6,93	0	0	0	7033,52	7026,59	0	0	0
12	2013		30	37	15	0	0	0	6,93	0	0	0	0,00	-6,93	0	0	0
Closing stock levels				37													
TOTAL				**9214**	**1176**	**798**	**1053**	**1053**	**1661**	**1695**	**158864**	**21166**	**922401**	**739015**	**0**	**0**	

Pofit per SU	701,8189852	SEK/SU
# of Lost sales	0	SU

Figure 12: The Current Situation Model for product 4903, fiscal year 2013

5.1.2.1 The columns commonalities and differences in the Models

5.1.2.1.1 Period, year, month and week

The models have the same weeks, months and periods for each fiscal year. In the column for months and weeks some of the cells are colored. The colors show that the specific product has a campaign during the weeks colored. Different colors are used for campaigns with different wholesalers of out-of-home products. Each campaign has two different shades of one color. The brighter shade represent when Campbell Soup Nordic has their discount weeks for the wholesalers and the darker shade shows when the wholesalers has their campaign weeks.[101] It is important to be aware of when Campbell Soup Nordic has their discounts week since it will affect the demand and revenue of their products during those weeks. The campaigns occur in fixed weeks. Often the same campaigns are recurrent during the same weeks. The wholesaler prices changes for the different campaigns and years.

The Easter occurs week 13 in the fiscal year 2013 and is colored yellow. This holiday is a high season for many of Campbell Soup Nordic´s products and therefore they highlight this holiday to pay extra attention since the demand may increase for this week.[102]

The fiscal year begins in week 31 and ends in week 30 the upcoming year. The fiscal year consists of 12 periods and each period is four or five weeks. There are always two periods of four weeks that are followed up by a five week period.[103]

	Period t	**Period t+1**	**Period t+2**	**Period t+3**	
…	4 weeks	4 weeks	5 weeks	4 weeks	**…**

Figure 13: Campbell Soup Nordic's period classifications

5.1.2.2 Calculate the initial inventory

The Current Situation Model´s initial inventory is based on historical inventory values while the initial inventories in the Cost Analysis Model´s starts at zero. This means that the Cost Analysis Model´s always starts with a production in the first week. The reason for this approach is that the Current Situation Model should reflect the historical costs by using historical data and the Cost Analysis Model starts with an empty inventory which should not be tied to a specific historical value. The inventory level for each week in the model is the number of sales units (SU) in the beginning of the week. The inventory in the models is calculated as follows

$$Inventory_t = Inventory_{t-1} + Production_{t-1} - Sales_{t-1} - Sales\ Finland_{t-1} \tag{15}$$

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[101] Frisk, Agneta 2013-10-07

[102] Johansson, Josefine 2013-09-17

[103] Rosdahl, Henrik 2013-09-18

Where,

$Inventory_{t-1}$ = inventory level during the previous week
$Production_{t-1}$ = number of sales units produced in the previous week
$Sales_{t-1}$ = number of sales units sold to the Swedish market in the previous week
$Sales\ Finland_{t-1}$ = nbr of sales units sold to the Finnish market in the previous week

This formula (15) is used for all weeks with an exception for the first week where there is a fixed start value in the inventories for both models as mentioned above. The inventory consists of both products that will be sold to the Swedish market and the Finnish market. Since there was no inventory data available for only the Swedish products, the Finnish sales had to be subtracted from the inventory since the products studied are for the Swedish market only.

5.1.2.3 Forecasts

The forecasts, in the Current Situation Model and the Cost Analysis Model, are based on historical forecasts that were entered manually in SAP.

5.1.2.4 Production

Campbell Soup Nordic produces when the inventory reaches the quantity level that is covered by the safety time. Both models use the same formula (16) in Excel.

$$Production_t = IF(Inventory_t < (Forecast_t + Forecast_{t+1}); \\ IF((Forecast_t + Forecast_{t+1}) > Batch\ size; 2 \cdot Batch\ size; Batch\ size); 0) \qquad (16)$$

t = a period time of one week in the Models

The safety time for the out-of-home products, cover ten forecast days, which corresponds to two weeks.[104] Campbell Soup Nordic produces if the inventory cannot cover ten forecast days, and if the forecast is greater than one batch size, they produce two batches. The total production of sales units of a year was calculated as

$$Total\ production = \sum_{t=1}^{52} Production_t \qquad (17)$$

Since there are 52 weeks in a year, the total production is the summation of all the production weeks' of a year.

5.1.2.5 Demand

The demand in the Current Situation Model was based on historical data whereas the demand in the Cost Analysis Model was based on gamma distribution.

In the Cost Analysis Model the inverse of the gamma distribution was used to get the demand of sales units and not the probability if there was a demand.

$$demand_t = gamma.inv(random(), \alpha, \beta) \qquad (18)$$

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[104] Rosdahl, Henrik 2013-09-18

The gamma distribution parameters are based on the result from the simulation program EasyFit 5.5 Professional. The parameters change during the year when Campbell Soup Nordic has campaigns with different wholesalers and when they have no campaigns at all.

5.1.2.6 Sales

In the Current Situation Model the historical data of sales was used and in the Cost Analysis Model the following formula was used;

$$Sales_t = IF((Inventory_t + Production_t) > Demand_t; Demand_t; (Inventory_t + Production_t)) \quad (19)$$

The formula explains the following: if the demand is covered by the inventory and the production of that week, the sales will meet the demand. If the inventory and the production of the week cannot meet the demand, the sales will be equivalent to the sum of what existed in inventory and what was produced during the week. Campbell Soup Nordic has a very flexible production and can easily change their production plan if necessary and therefore they can sell products that are produced the same week. The only limitation the production manager sees is the situation where no raw material is available[105] and thus production is not possible. In the model it is assumed that there is always raw material available for the production.

The total sold sales units of the year was calculated as

$$Total\ sales = \sum_{t=1}^{52} Sales_t \quad (20)$$

5.1.2.7 Holding costs

The holding cost is calculated by the following formula for both Current Situation Model and Cost Analysis Model:

$$Holding\ cost_t = \frac{Discount\ rate}{52} \cdot Material\ cost\ per\ SU \cdot Inventory\ level_{t+1} \quad (21)$$

$t =$ a period time of one week in the models
$Discount\ rate = 7\%$
$Inventory\ level_{t+1} =$ the outgoing inventory level for week t

The holding cost is calculated for each week and is based on the outgoing inventory level that is equal to the Inventory level$_{t+1}$. Campbell Soup Nordic´s discount rate of 7%[106] is dived over the 52 weeks in a year. Material cost is the cost that affects the inventory value. Material cost considers the ingredients, labels, buckets and lids for the products. These material costs are given by the recipes in SAP for each product.

The holding cost should also include the costs for handling the inventory and additional workers in the warehouses if they are necessary. Since the variable cost of different batch sizes was evaluated the

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[105] Lundh, Stefan 2013-09-23
[106] Sturk, Pontus 2013-09-27

changes of costs depending on volume had to be investigated. The costs for the warehouse are fixed and are not included in the analysis since they do not change with volume. Campbell Soup Nordic owns their warehouse hence the cost for running it is constant. For the Finnish products it is different since a third part logistics company is used for storing the inventory in Finland but since this study only includes Swedish products this is not relevant. It should also be mentioned that there are no alternative ways to use the storage so no lost revenue is lost if the storage is used. A conclusion is that the warehouse costs do not have a great impact on the variable costs.

The cost of capital is the cost that differs. The warehouse is large and has additional storage for added inventory. Further handlings by warehouse workers are considered to be negligible for the bouillons. If the inventory gets higher due to lager batch sizes this would result in more work during the production by transporting the pallets to the dedicated place but the same transportation would be needed if the batches would be smaller. Producing fewer times would also make it easier to store the produced bouillons at the same place. Less double handling would also be needed since a first in and first out policy is used. The inventory would be put in a specific place and picked and since it would have the same expire date no extra handling would be needed. The products produced at line 102 are slow movers compared with the products produced at other production lines therefor they are not picked as often as other products so they can be placed at a less convenient storage place.

The risks for damages of the products in the inventory have been very low historically and for many products there are none. After a consultation with the Supply Chain Manager at Campbell Soup Nordic it was decided that the best assumption would be to assume that there are no risks for damages for the Dry Bong Bouillon products.[107] Another assumption would only lead to unjust cost penalties that do not exist in reality. Other risks e.g. theft or fire are estimated to have a very low probability and therefore they will not either charge the holding cost[108]. It is common to include the insurance costs in the inventory costs but the total cost for insurance is a lump sum payment which the authors investigated. It is not obvious how much of this sum each sales unit produced consist of. Therefore it is difficult to divide the costs of the lump sum since it includes all insurance costs for the warehouse, the production, the offices and the equipment. For this cost to be interesting it would be necessary to be able to pinpoint the insurance cost that changes with the inventory level. It was said that the person in charge of this had left his employment at the company and therefor it was impossible to investigate further.[109]

The total holding cost of a year was calculated as

$$Total\ holding\ cost = \sum_{t=1}^{52} Holding\ cost_t \qquad (22)$$

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[107] Rosdahl, Henrik 2013-11-18

[108] Ibid

[109] Rantzer, Maria 2013-11-29

5.1.2.8 Setup Cost

The setup cost is the cost of adjusting production to be able to produce a new product. The cost includes the setup cost for the mixing machine and the setup cost for line 102. The setup cost for the mixing machine is charged by three machine operators. The setup cost for line 102 is charged by three or five employees where two are mechanics and three are machine operators. The setup time at line 102 can vary. It is sometimes only necessary to have three machine operators to make the setup. This is possible when the production have planned to have similar products after each other e.g. the products have the same bucket size. But, when there are bigger changes in the setup, e.g. when there will be a change of the bucket size, they also need two mechanics to help the three operators with the changes. In this case the setup cost will increase with the hourly wages for the mechanics.[110] Currently the two mechanics are not included in the production costs and are charged to another cost center. The authors thought that they should be considered in the production cost also hence the mechanics are included in a scenario in the sensitivity analysis.

The setup cost for a product is calculated as:

$$Setup\ cost = \frac{Setup\ time\ in\ minutes_{mixing\ machine}}{60} \cdot Setup\ cost\ in\ hour\ per\ operator \cdot nbr\ of\ operators\ at\ the\ mixing\ machine + \frac{Setup\ time\ in\ minutes_{line\ 102}}{60} \cdot Setup\ cost\ in\ hour\ per\ operator \cdot nbr\ of\ operators\ at\ line\ 102 \quad (23)$$

The setup cost only occurs when there is a production of the product and in both models the setup cost are formulated as:

$$Setup\ cost_t = IF(Production_t = 0; 0; Setup\ cost) \quad (24)$$

The formula above states (24) that if there is a production in the week for the product, there will be a setup cost, else there will be none. This formula is used for every week for both models with an exception for the first week, week 31, for the Current Situation Model. Since the Current Situation Model has an initial inventory from the previous year these setup costs has to be charged to the total cost. Otherwise the profit would get too high since sales units with no costs could be sold which results in a higher profit per sales unit then it should. This means that the first week in the Current Situation Model will be charged on the setup cost that is based on the initial inventory level.

$$Setup\ cost_{week\ 31} = inventory\ level_{week\ 31} \cdot \frac{Setup\ cost}{Batch\ size} \quad (25)$$

The total setup cost of a year was calculated as

$$Total\ setup\ cost = \sum_{t=1}^{52} Setup\ cost_t - \frac{Setup\ cost}{Batch\ size} \cdot Outgoing\ inventory\ level \quad (26)$$

Where,

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[110] Nilsson, Johan 2013-12-17

$$Outgoing\ inventory\ level = Inventory_{week30} + Production_{week30} - Sales_{week30} - Sales\ Finland_{week30} \quad (27)$$

As for the same reason that the total setup cost will be charged for the initial inventory the first week, it will also be uncharged for the outgoing inventory.

5.1.2.8.1 Order cost

The contracts are handled by purchasers on a higher European level involving all the different companies included in Campbell Soup. There are different constraints that have to be taken into considered when ordering. There is a minimum order size of the different materials and it can be of both volume and cost. This means that the purchaser has to puzzle when ordering and in many cases order more than necessary. This made it difficult to estimate the differences in cost depending on the volume.[111] It was unmanageable for the authors to estimate how much the investigated products burdens the total time spent on ordering. Given the limited time for the study it was not possible to follow the purchasers around making valid estimations. Therefore the supply was estimated to be available for the production. An attempt on estimating the ordering costs was made but this only resulted in a static order cost per unit which did not differ on the size and therefore did not contribute to the optimal batch size analysis. However it is obvious that the material costs get lower with increased sizes but this is something the study will not address further.

5.1.2.9 Material Costs

The material costs are based on the recipes from SAP where the material cost include the ingredients cost, label cost, bucket cost and lid cost. Conclusively the cost for one SU is easy to calculate and thus the material cost for a batch is given by (28).

$$Material\ cost\ per\ batch = Material\ cost\ per\ SU \cdot number\ of\ SU\ in\ a\ batch \quad (28)$$

The material cost appears when it is a production in the Current Situation Model or the Cost Analysis Model. This function in the model has the same structure at the Setup cost and is formulated as:

$$Material\ cost_t = IF(Production_t = 0; 0; Material\ cost\ per\ batch) \quad (29)$$

The Current Situation Model also has an exception for the formula above and for the same reason as discussed in the Setup cost. The formula in the first week, week 31, in the Current Situation Model will be as follows

$$Material\ cost_{week\ 31} = Inventory\ level_{week\ 31} \cdot \frac{Material\ cost\ per\ batch}{Batch\ size} \quad (30)$$

The total material cost of a year was calculated as

$$Total\ material\ cost = \sum_{t=1}^{52} Material\ cost_t - \frac{Materail\ cost\ per\ batch}{Batch\ size} \cdot Outgoing\ inventory\ level \quad (31)$$

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[111] Ljungberg, Mona 2013-10-02

Where,

$$Outgoing\ inventory\ level = Inventory_{week30} + Production_{week30} - Sales_{week30} - Sales\ Finland_{week30} \quad (32)$$

The total material is charged by the initial inventory the first week and therefore it will also be uncharged for the outgoing inventory.

5.1.2.10 Manufacturing costs

The manufacturing cost is based on an equation given by the production administrator at Campbell Soup Nordic.[112]

$$Total\ Manufactoring\ Cost\ per\ batch = Mixing\ machine\ cost\ per\ hour \cdot mixing\ time\ in\ hour + 3\ machine\ operators \cdot Labor\ cost\ per\ hour \cdot \frac{total\ mixing\ time\ in\ minutes - setup\ time\ in\ minutes}{60} + Machine\ costs\ at\ Line\ 102\ per\ hour \cdot \frac{theoretical\ run\ time\ forLine\ 102\ in\ minutes}{60} + 3\ machine\ operators \cdot Labor\ cost\ per\ hour \cdot \frac{total\ running\ time\ for\ line\ 102\ in\ minutes}{60} \quad (33)$$

The total running time for line 102 in minutes is calculated as

$$Total\ running\ time\ for\ line\ 102\ in\ minutes = theoratical\ run\ time\ for\ Line\ 102\ in\ minutes + unexpected\ stops \quad (34)$$

The unexpected stops are estimated to be five minutes per production for the Dry Bong Bouillon products.

The theoretical run time for Line 102 in minutes is calculated as

$$Theoretical\ run\ time\ for\ Line\ 102\ in\ minutes = Number\ of SU\ in\ a\ batch \cdot Number\ of\ units\ in\ a\ SU \cdot v \quad (35)$$

Where,

$Number\ of\ units\ in\ a\ SU = 1\ \text{bucket/SU}$
$v = 5\ \text{buckets/ min or } 7\ \text{buckets/min}$

The production rate of Line 102 is either 5 buckets/min or 7 buckets/min, the reason for this is the volumes of the buckets. The buckets with a volume of 1.5 liters can be produced at a rate of 7 buckets/min and the larger 5.0 liters buckets can be produced at a rate of 5 buckets/min. The number of units in a sales unit is one bucket when the theoretical run time for Dry Bong Bouillon is calculated. In

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[112] Nilsson, Johan 2013-09-26

some of Campbell Soup Nordics products there are several units in a sales unit which is common for the retail products however as mentioned before this is not the case for the bouillons.[113]

In the Current Situation Model and Cost Analysis Model the following formula was used to calculate the manufacturing cost

$$Manufacturing\ cost_t = IF(Poduction_t = 0; 0; Total\ Manufacturing\ Cost\ per\ batch) \qquad (36)$$

The formula states the following: there will be a manufacturing cost in week t if there is production, else there will be no manufacturing cost that week.

This formula was used for all weeks in both models with an exception for the first week, week 31, in the Current Situation Model with the reason which is explained in the Setup cost mentioned earlier.

The formula for the manufacturing cost the first week in the Current Situation Model is the following

$$Manufacturing\ cost_{week\ 31} = Inventory\ level_{week\ 31} \cdot \frac{Total\ Manufacturing\ cost\ per\ batch}{Batch\ size} \qquad (37)$$

The total manufacturing cost of a year is calculated as

$$Total\ manufacturing\ cost = \sum_{t=1}^{52} Manufacturing\ cost_t - \frac{Total\ Manufacturing\ cost\ per\ batch}{Batch\ size} \cdot Outgoing\ inventory\ level \qquad (38)$$

Where,

$$Outgoing\ inventory\ level = Inventory_{week30} + Production_{week30} - Sales_{week30} - Sales\ Finland_{week30} \qquad (39)$$

The total manufacturing cost is charged for the initial inventory the first week and therefore it will also be uncharged for the outgoing inventory.

5.1.2.11 Revenue

The revenue of the products differs during the year. The reason for this is that Campbell Soup Nordic has different prices of their products depending on if they have campaigns or not. The prices may also differ between the campaigns. This means that the price in week t can differ from the earlier week and the next coming week. The prices are based on actual price-settings for their products given by the planning manager.[114]

The models revenues are calculated as following

$$Revenue_t = Sales_t \cdot Price_t \qquad (40)$$

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[113] Ibid

[114] Frisk, Agneta 2013-10-11

The total revenue of a year was calculated as

$$Total\ revenue = \sum_{t=1}^{52} Revenue_t \tag{41}$$

5.1.2.12 Profit

The profit of week t is calculated as following for both models

$$Profit_t = Revenue_t - Holding\ cost_t - Setup\ cost_t - Material\ cost_t - Manufacturing\ cost_t \tag{42}$$

The total revenue of a year was calculated as

$$Total\ profit = Total\ revenue - Total\ holding\ cost - Total\ setup\ cost - Total\ material\ cost - Total\ Manufacturing\ cost \tag{43}$$

The average profit of a sales unit was calculated as

$$Average\ profit\ per\ Sales\ Unit = \frac{Total\ profit}{Total\ sales} \tag{44}$$

5.1.2.13 Lost sales: Dynamic

The lost sales that are dynamic are the most interesting in the Cost Analysis Model. These lost sales will be compared to the fixed lost sales in the Current Situation Model.

$$Lost\ sales, dynamic_t = IF(Demand_t > Sales_t); (Demand_t - Sales_t) * Average\ profit\ per\ Sales\ Unit; 0) \tag{45}$$

There will be lost sales if the demand is larger than the sales and the lost sales will be the revenue of the number of sales units that could not be sold. If the demand is not greater than the sales there will be no lost sales.

The total lost sales of a year that where dynamic were calculated as

$$Total\ lost\ sales_{Dynamic} = \sum_{t=1}^{t=52} Lost\ sales, dynamic_t \tag{46}$$

5.1.2.14 Lost Sales: Fixed

The lost sales that are fixed are used for the Current Situation Model. The lost sales are calculated according to historical lost sales percentage[115] and these will be a validation value for the lost sales in the Cost Analysis Model that has dynamic lost sales.

$$Lost\ sales, fixed_t = Sales_t \cdot Average\ profit\ per\ Sales\ Unit \cdot Historical\ lost\ sales\ procentage \tag{47}$$

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[115] Frisk, Agneta 2013-10-09

The total lost sales of a year that where fixed was calculated as

$$Total\ lost\ sales_{Fixed} = \sum_{t=1}^{t=52} Lost\ sales, fixed_t \tag{48}$$

5.1.2.15 Sales Finland

Simply the summation of the Finnish and Swedish inventory can be extracted from SAP. Thus the sales to Finland for products sold both in Sweden and Finland had to be subtracted from the inventory to get the inventory for the Swedish products.

5.2 Analysis method

Firstly, the Cost Analysis Model was compared with the Current Situation Model. The aim with this is was to validate how well the gamma distribution of the demand fits the model in comparison with the real data.

Secondly a sensitivity analysis of the Cost Analysis Model was made and the aim of the investigation was to see how different batch sizes affected the costs associated to varying batch sizes. The costs that are affected by varying batch sizes are holding cost, setup cost, manufacturing cost and lost sales. In the sensitivity analysis it was also investigated how well the various batch sizes meet the key performance indicator, KPI Case Fill Rate. Campbell Soup Nordic has a goal of 99% in Case Fill Rate.[116] In the sensitivity analysis except for the scenario of different setup times the setup time was 18 min with 3 machine operators.

The Case Fill Rate is calculated as

$$Case\ Fill\ Rate = \frac{Total\ SU\ Ordered - SU\ not\ shipped}{Total\ SU\ Ordered} \cdot 100\% = \left(1 - \frac{Lost\ sales}{Demand}\right) \cdot 100\% \tag{49}$$

Sales units that are not shipped are equal to lost sales and total sales units ordered are equal to demand.

5.2.1 Sensitivity Analysis

The different scenarios analyzed in the Cost Analysis Model were determined with the objective to understand which impact different changes could have on the production costs, holding costs and ultimately the total cost. When analyzing the current situation it was concluded that the production costs were higher than the holding costs therefore it was more interesting to investigate production were the set-up time was 18 minutes and therefore resulted in the lowest setup cost. The 18 minutes were the fastest changeover of the line 102 from one bouillon that did not need extensive cleaning and had the same bucket size[117]. During production this is often the case, it is rarely when only one bouillon

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[116] Rosdahl, Henrik 2013-09-18

[117] Nilsson, Johan 2013-11-01

is produced alone. With the higher setup times the costs would result in bigger batches always being more profitable. In other words more production times during a year would be more costly than having the products stored.

Scenario 1: The first scenario was to analyze how well the production and inventory could handle unexpected sales during campaigns. It is often difficult to exactly forecast how the sales will turn out during a campaign. This analyze was made to see how well the company could coop with increased sales and still be able to deliver the right case fill rate and avoid lost sales. The demand was increased with 30%, 50% and 100% during the campaign periods. For example:

$$demand_t = gamma.inv(random(), \alpha, \beta) \cdot \mathbf{1,50}$$

Scenario 2: The second scenario was to analyze how an increased cost of capital would affect the holding costs. This analyze would make it more expensive to keep inventory. Rather large increases of the cost of capital were research. An interest rate of 7 percent was given by the finance department[118] as the current interest and the other rates can be seen in Table 8. During this scenario the discount rate was changed to different rates; 15%, 20% and 30%.

$$Holding\ cost_t = \frac{\boldsymbol{Discount\ rate}}{52} \cdot Material\ cost\ per\ SU \cdot Inventory\ level_{t+1}$$

Scenario 3: The third scenario was decreasing a machine operator at line 102 to evaluate the impact on the total cost. This scenario was assessed since it was mentioned that one of the workers working at the line during the production of the bouillons is used for putting on the lids on the buckets earlier was not needed. This production step was earlier done by a machine. However the machine could not do it in the right way so the lids loosened. Fixing the machine so that it can fasten the lids would therefore lead to an investment but lower variable cost.

$$Total\ Manufactoring\ Cost\ per\ batch$$

$$= Mixing\ machine\ cost\ per\ hour \cdot mixing\ time\ in\ hour + 3\ machine\ operators \cdot Labor\ cost\ per\ hour \cdot \frac{total\ mixing\ time\ in\ minutes - setup\ time\ in\ minutes}{60} + Machine\ costs\ at\ Line\ 102\ per\ hour \cdot \frac{theoretical\ run\ time\ forLine\ 102\ in\ minutes}{60} + \mathbf{2}\ machine\ operators \cdot Labor\ cost\ per\ hour \cdot \frac{total\ running\ time\ for\ line\ 102\ in\ minutes}{60}$$

Scenario 4: The fourth scenario was decreasing the machine costs that ultimately had a large impact on the total costs. The percentages used can be seen in Table 8. The costs for the mixing machine and the production line machines were given the finance department per hour. For example if the machine cost were reduced by 20%.

$$Total\ Manufactoring\ Cost\ per\ batch$$

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[118] Van den Cruijce, Frans 2013-11-28

$$= \mathit{Mixing\ machine\ cost\ per\ hour} \cdot \mathbf{0,8} \cdot \mathit{mixing\ time\ in\ hour} + 3\ \mathit{machine\ operators} \cdot \mathit{Labor\ cost\ per\ hour} \cdot \frac{\mathit{total\ mixing\ time\ in\ minutes} - \mathit{setup\ time\ in\ minutes}}{60} + \mathit{Machine\ costs\ at\ Line}\ 102\ \mathit{per\ hour} \cdot \mathbf{0,8}\ \cdot \frac{\mathit{theoretical\ run\ time\ forLine}\ 102\ \mathit{in\ minutes}}{60} + 3\ \mathit{machine\ operators} \cdot \mathit{Labor\ cost\ per\ hour} \cdot \frac{\mathit{total\ running\ time\ for\ line}\ 102\ \mathit{in\ minutes}}{60}$$

Scenario 5: The fifth scenario was increasing the material costs since this would make the holding costs higher and perhaps make it more profitable to have lower inventory. Higher material costs can occur if the competition for the raw materials gets higher or new contracts are negotiated. . For example if the material cost were increased by 10%.

$$\mathit{Holding\ cost}_t = \frac{\mathit{Discount\ rate}}{52} \cdot \mathit{Material\ cost\ per\ SU} \cdot \mathbf{1.10} \cdot \mathit{Inventory\ level}_{t+1}$$

Scenario 6: The sixth scenario is to evaluate how a decreased safety time would affect the costs but also the ability to keep the same case fill rate. The safety time is the expected sales for the amount of time the safety time covers. If the safety time is one week the minimum inventory should be the expected sales for one week. For example if the safety time is one week

$$\mathit{Production}_t = \mathit{IF}(\mathit{Inventory}_t < (\mathit{Forecast}_t); \mathit{IF}((\mathit{Forecast}_t) > \mathit{Batch\ size}; 2 \cdot \mathit{Batch\ size}; \mathit{Batch\ size}); 0)$$

or if the safety time is three weeks.

$$\mathit{Production}_t = \mathit{IF}(\mathit{Inventory}_t < (\mathit{Forecast}_t + \mathit{Forecast}_{t+1} + \mathit{Forecast}_{t+2}); \mathit{IF}((\mathit{Forecast}_t + \mathit{Forecast}_{t+1} + \mathit{Forecast}_{t+2}) > \mathit{Batch\ size}; 2 \cdot \mathit{Batch\ size}; \mathit{Batch\ size}); 0)$$

Scenario 7: The seventh scenario was to evaluate the impact of different setup times but also assess the impact of including the two mechanics that were needed for the setup time when the bucket size was changed or other bigger changes.

$$\begin{aligned}\mathit{Setup\ cost} = {} & \frac{\boldsymbol{Setup\ time\ in\ minutes}_{\boldsymbol{mixing\ machine}}}{60} \cdot \mathit{Setup\ cost\ in\ hour\ per\ operator} \\ & \cdot \mathit{nbr\ of\ operators\ at\ the\ mixing\ machine} + \frac{\boldsymbol{Setup\ time\ in\ minutes}_{\boldsymbol{line}\ \mathbf{102}}}{60} \\ & \cdot \mathit{Setup\ cost\ in\ hour\ per\ operator} \cdot \boldsymbol{nbr\ of\ operators\ at\ line}\ \mathbf{102}\end{aligned}$$

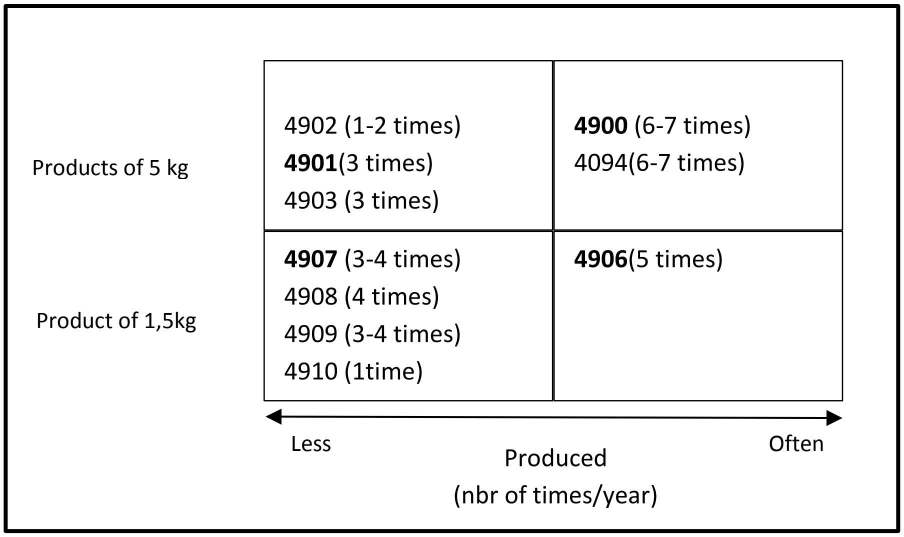
The different scenarios that were investigated are stated in the Table 8 below.

Table 8: Different scenarios that were investigated in the sensitivity analysis

Different Scenarios			
Unexpected increasing of sales during campaign	30%	50%	100%
Increasing of the cost of capital	15%	20%	30%
One less machine operator at Line 102	-	-	-
Decreasing of the machine costs	-20%	-30%	-50%
Increasing of the material costs	10%	20%	30%
Different safety time in the inventory of finished products	1 week	2 weeks	3 weeks
Different setup times	18 min, 3 labors + 0 mechanics	30 min, 3 labors + 2 mechanics	40 min, 3 labors + 2 mechanics

5.2.2 Products that were used in the sensitivity analysis

The products that were used in the sensitivity analysis were product 4900, product 4901, product 4906 and product 4907. The products were selected based on how often they were produced in a year. The reason of the selection was to investigate products with different turn overs. In the figure below the vertical axis shows the size of the product and the horizontal axis shows the number of times per year the product gets produced.



Products of 5 kg	4902 (1-2 times) **4901**(3 times) 4903 (3 times)	**4900** (6-7 times) 4094(6-7 times)
Product of 1,5kg	**4907** (3-4 times) 4908 (4 times) 4909 (3-4 times) 4910 (1time)	**4906**(5 times)

Figure 14: Matrix of the products

The reason for product 4910 not being investigated in the sensitivity analysis is that it has low sales, is only produced once in a year and the holding cost is very low. To produce this product more than once a year would not be interesting due to the high production cost. In the validation result of product 4902 it is stated that the Current Situation Model fits poorly and this means that the sensitivity analysis result would be misleading.

6 Results

This chapter shows the results from the sensitivity analysis of the different scenarios that were investigated and the result of the validation between the Current Situation Model and Cost Analysis Model. Of the ten products investigated, four of them were used in the sensitivity analysis. The products examined had different characteristics but reflects the remaining products.

6.1 Result of validation

The results of the Cost Analysis Model were based on an average of thousand simulations. The authors chose to do thousand simulation runs since it would give better credibility to the results.

The validation for product 4900 is presented in the Table 9 below. The results between the years in the Current Situation Model differed with approximately 15% to each other and this percentage was used to investigate how well the Cost Analysis Model fitted with the Current Situation Model for each year. The colored areas in the table show how well the Cost Analysis fitted with a margin of 15%. With this result it is stated that the gamma-distribution reflects the demand well and the result of the sensitivity analysis gives trustworthy results.

Table 9: The validation result for product 4900

4900; Batch Size 194 SU	Current Situation Model, setup time 18 min			ost Analysis Model, setup time 18 mi			Validation		
	F11	F12	F13	F11	F12	F13	F11	F12	F13
Holding cost (SEK/year)	2 930	2 855	3 215	2 707	3 033	2 996	0,92	1,06	0,93
Setup cost (SEK/year)	4 131	4 535	5 201	3 920	4 145	3 696	0,95	0,91	0,71
Material cost (SEK/year)	448 490	492 447	564 754	425 617	450 089	401 257	0,95	0,91	0,71
Manufacturing cost (SEK/year)	28 736	31 553	36 186	27 271	28 839	25 710	0,95	0,91	0,71
Revenue (SEK/year)	1 082 852	1 021 927	1 177 538	1 095 057	1 180 273	1 088 569	1,01	1,15	0,92
Profit (SEK/year)	598 564	490 536	568 182	635 543	694 167	654 910	1,06	1,42	1,15
Profit per SU (SEK/SU)	451	397	419	476	491	520	1,06	1,24	1,24
Total sold SU	1 328	1 236	1 355	1 336	1 413	1 260	1,01	1,14	0,93
Total demanded SU	1 365	1 239	1 387	1 371	1 445	1 274	1,00	1,17	0,92
Lost sales (SEK/year)	17 957	1 177	11 364	16 544	15 687	7 456	0,92	13,32	0,66
# lost sales (SU)	37	3	32	35	32	14	0,94	10,64	0,45
Total manufactured SU	1 164	1 358	1 940	1 426	1 496	1 358	1,22	1,10	0,70

The results of the validation for each product (4901-4910) are presented in the Table 10 to Table 18 below.

Table 10: The validation result for product 4901

4901; Batch Size 239 SU	urrent Situation Model, setup time 18 mi			Cost Analysis Model, setup time 18 min			Validation		
	F11	F12	F13	F11	F12	F13	F11	F12	F13
Holding cost (SEK/year)	3 562	3 761	3 380	3 035	3 038	2 989	0,85	0,81	0,88
Setup cost (SEK/year)	1 807	1 584	1 879	1 646	1 764	1 506	0,91	1,11	0,80
Material cost (SEK/year)	232 155	203 404	241 331	211 484	226 585	193 499	0,91	1,11	0,80
Manufacturing cost (SEK/year)	14 501	12 705	15 074	13 210	14 153	12 086	0,91	1,11	0,80
Revenue (SEK/year)	728 737	661 378	771 859	747 450	819 139	723 339	1,03	1,24	0,94
Profit (SEK/year)	476 712	439 925	510 195	518 075	573 599	513 259	1,09	1,30	1,01
Profit per SU (SEK/SU)	702	732	757	749	774	811	1,07	1,06	1,07
Total sold SU	679	601	674	691	741	633	1,02	1,23	0,94
Total demanded SU	679	601	728	696	747	636	1,03	1,24	0,87
Lost sales (SEK/year)	0	0	40 816	3 537	4 798	2 572	-	-	0,06
# lost sales (SU)	0	0	54	5	6	3	-	-	0,06
Total manufactured SU	717	478	717	800	855	752	1,12	1,79	1,05

Table 11: The validation result for product 4902

4902; Batch Size 195 SU	Current Situation Model, setup time 18 mi			Cost Analysis Model, setup time 18 min			Validation		
	F11	F12	F13	F11	F12	F13	F11	F12	F13
Holding cost (SEK/year)	3 049	2 230	1 869	2 222	1 854	1 848	0,73	0,83	0,99
Setup cost (SEK/year)	566	820	1 503	478	589	544	0,84	0,72	0,36
Material cost (SEK/year)	47 959	69 466	127 313	40 471	49 917	46 107	0,84	0,72	0,36
Manufacturing cost (SEK/year)	3 953	5 725	10 493	3 335	4 114	3 800	0,84	0,72	0,36
Revenue (SEK/year)	114 312	151 374	345 190	172 232	224 897	213 620	1,51	1,49	0,62
Profit (SEK/year)	58 785	73 132	204 013	125 726	168 422	161 321	2,14	2,30	0,79
Profit per SU (SEK/SU)	516	534	678	767	834	865	1,49	1,56	1,28
Total sold SU	114	137	301	164	202	187	1,44	1,47	0,62
Total demanded SU	114	137	301	165	203	187	1,44	1,48	0,62
Lost sales (SEK/year)	0	0	0	630	1 038	464	-	-	-
# lost sales (SU)	0	0	0	1	1	1	-	-	-
Total manufactured SU	0	195	585	209	308	268	-	1,58	0,46

Table 12: The validation result for product 4903

4903; Batch Size 266 SU	Current Situation Model, setup time 18 mi			ost Analysis Model, setup time 18 mi			Validation		
	F11	F12	F13	F11	F12	F13	F11	F12	F13
Holding cost (SEK/year)	1 725	1 865	1 661	1 657	1 442	1 641	0,96	0,77	0,99
Setup cost (SEK/year)	1 568	1 451	2 443	1 601	1 623	1 556	1,02	1,12	0,64
Material cost (SEK/year)	101 968	94 317	158 864	104 087	105 499	101 151	1,02	1,12	0,64
Manufacturing cost (SEK/year)	13 586	12 566	21 166	13 868	14 056	13 477	1,02	1,12	0,64
Revenue (SEK/year)	542 577	448 295	922 401	629 334	646 327	634 857	1,16	1,44	0,69
Profit (SEK/year)	423 730	338 097	738 267	508 121	523 706	517 032	1,20	1,55	0,70
Profit per SU (SEK/SU)	649	633	701	679	690	711	1,05	1,09	1,01
Total sold SU	653	534	1 053	748	758	727	1,15	1,42	0,69
Total demanded SU	653	534	1 053	759	774	733	1,16	1,45	0,70
Lost sales (SEK/year)	0	0	0	7 470	11 046	4 456	-	-	-
# lost sales (SU)	0	0	0	11	16	6	-	-	-
Total manufactured SU	532	266	798	882	884	873	1,66	3,32	1,09

Table 13: The validation result for product 4904

4904; Batch Size 219 SU	urrent Situation Model, setup time 18 mi			Cost Analysis Model, setup time 18 min			Validation		
	F11	F12	F13	F11	F12	F13	F11	F12	F13
Holding cost (SEK/year)	3 910	3 080	3 361	3 358	3 193	3 191	0,86	1,04	0,95
Setup cost (SEK/year)	4 519	3 747	4 038	4 239	4 172	3 674	0,94	1,11	0,91
Material cost (SEK/year)	537 873	446 011	480 652	504 491	496 567	437 273	0,94	1,11	0,91
Manufacturing cost (SEK/year)	34 117	28 290	30 487	31 999	31 497	27 736	0,94	1,11	0,91
Revenue (SEK/year)	880 167	850 143	1 174 371	845 100	886 031	1 068 295	0,96	1,04	0,91
Profit (SEK/year)	299 748	369 015	655 832	301 012	350 602	596 422	1,00	0,95	0,91
Profit per SU (SEK/SU)	172	256	422	185	218	422	1,07	0,85	1,00
Total sold SU	1 739	1 442	1 554	1 631	1 605	1 414	0,94	1,11	0,91
Total demanded SU	1 747	1 450	1 754	1 662	1 647	1 429	0,95	1,14	0,81
Lost sales (SEK/year)	2 997	3 690	78 700	5 843	9 223	6 343	1,95	2,50	0,08
# lost sales (SU)	8	8	200	31	42	15	3,92	5,20	0,08
Total manufactured SU	1 314	1 314	1 314	1 729	1 728	1 529	1,32	1,32	1,16

Table 14: The validation result for product 4906

4906; Batch Size 736 SU	Current Situation Model, setup time 18 min			Cost Analysis Model, setup time 18 min			Validation		
	F11	F12	F13	F11	F12	F13	F11	F12	F13
Holding cost (SEK/year)	3 410	3 272	3 277	3 291	3 161	2 962	0,97	0,97	0,90
Setup cost (SEK/year)	3 522	3 352	2 422	2 894	2 866	2 667	0,82	0,85	1,10
Material cost (SEK/year)	433 818	412 865	298 292	356 432	352 937	328 522	0,82	0,85	1,10
Manufacturing cost (SEK/year)	52 184	49 664	35 882	42 875	42 455	39 518	0,82	0,85	1,10
Revenue (SEK/year)	814 233	802 964	721 785	781 724	802 140	810 314	0,96	1,00	1,12
Profit (SEK/year)	321 298	333 811	381 913	376 232	400 721	436 644	1,17	1,20	1,14
Profit per SU (SEK/SU)	84	89	124	101	108	127	1,19	1,22	1,02
Total sold SU	3 820	3 752	3 072	3 742	3 706	3 449	0,98	0,99	1,12
Total demanded SU	3 894	3 752	3 072	3 778	3 726	3 488	0,97	0,99	1,14
Lost sales (SEK/year)	6 426	0	0	3 563	2 168	4 899	0,55	-	-
# lost sales (SU)	74	0	0	35	20	39	0,48	-	-
Total manufactured SU	3 680	4 416	2 944	4 084	4 099	3 794	1,11	0,93	1,29

Table 15: The validation result for product 4907

4907; Batch Size 657 SU	Current Situation Model, setup time 18 mi			Cost Analysis Model, setup time 18 min			Validation		
	F11	F12	F13	F11	F12	F13	F11	F12	F13
Holding cost (SEK/year)	2 421	2 352	2 547	2 756	2 526	2 409	1,14	1,07	0,95
Setup cost (SEK/year)	3 090	2 228	1 854	1 895	2 121	2 099	0,61	0,95	1,13
Material cost (SEK/year)	317 998	229 294	190 781	195 025	218 278	216 044	0,61	0,95	1,13
Manufacturing cost (SEK/year)	41 648	30 031	24 987	25 542	28 588	28 295	0,61	0,95	1,13
Revenue (SEK/year)	797 211	702 998	583 408	587 319	673 040	728 911	0,74	0,96	1,25
Profit (SEK/year)	432 054	439 094	363 240	362 101	421 527	480 063	0,84	0,96	1,32
Profit per SU (SEK/SU)	148	171	188	166	172	198	1,12	1,01	1,05
Total sold SU	2 925	2 572	1 934	2 188	2 448	2 423	0,75	0,95	1,25
Total demanded SU	2 925	2 572	1 934	2 207	2 467	2 462	0,75	0,96	1,27
Lost sales (SEK/year)	0	0	0	3 202	3 276	7 740	-	-	-
# lost sales (SU)	0	0	0	19	19	39	-	-	-
Total manufactured SU	3 285	2 628	1 314	2 486	2 803	2 734	0,76	1,07	2,08

Table 16: The validation result for product 4908

4908; Batch Size 873 SU	Current Situation Model, setup time 18 mi			Cost Analysis Model, setup time 18 mi			Validation		
	F11	F12	F13	F11	F12	F13	F11	F12	F13
Holding cost (SEK/year)	3 923	3 239	3 261	3 428	2 871	2 717	0,87	0,89	0,83
Setup cost (SEK/year)	2 886	2 031	1 743	1 999	2 052	2 004	0,69	1,01	1,15
Material cost (SEK/year)	340 613	239 745	205 738	235 875	242 152	236 564	0,69	1,01	1,15
Manufacturing cost (SEK/year)	49 228	34 650	29 735	34 090	34 997	34 190	0,69	1,01	1,15
Revenue (SEK/year)	998 767	862 650	742 196	815 645	869 344	923 962	0,82	1,01	1,24
Profit (SEK/year)	602 117	582 985	501 720	540 254	587 272	648 487	0,90	1,01	1,29
Profit per SU (SEK/SU)	159	187	204	176	187	211	1,11	1,00	1,04
Total sold SU	3 776	3 116	2 464	3 066	3 147	3 075	0,81	1,01	1,25
Total demanded SU	3 776	3 116	2 464	3 070	3 169	3 103	0,81	1,02	1,26
Lost sales (SEK/year)	0	0	0	779	4 073	5 890	-	-	-
# lost sales (SU)	0	0	0	4	22	28	-	-	-
Total manufactured SU	2 619	1 746	1 746	3 483	3 620	3 507	1,33	2,07	2,01

Table 17: The validation result for product 4909

4909; Batch Size 969 SU	Current Situation Model, setup time 18 min			Cost Analysis Model, setup time 18 min			Validation		
	F11	F12	F13	F11	F12	F13	F11	F12	F13
Holding cost (SEK/year)	1 502	1 472	1 497	1 731	1 481	1 445	1,15	1,01	0,97
Setup cost (SEK/year)	2 237	1 927	1 418	1 840	1 749	1 488	0,82	0,91	1,05
Material cost (SEK/year)	142 990	123 169	90 622	117 578	111 783	95 125	0,82	0,91	1,05
Manufacturing cost (SEK/year)	42 309	36 444	26 814	34 790	33 075	28 146	0,82	0,91	1,05
Revenue (SEK/year)	597 503	638 792	502 584	597 825	576 588	540 208	1,00	0,90	1,07
Profit (SEK/year)	408 465	475 780	382 234	441 887	428 501	414 003	1,08	0,90	1,08
Profit per SU (SEK/SU)	129	151	163	141	150	163	1,09	1,00	1,01
Total sold SU	3 158	3 157	2 352	3 132	2 854	2 534	0,99	0,90	1,08
Total demanded SU	3 158	3 157	2 352	3 148	2 870	2 543	1,00	0,91	1,08
Lost sales (SEK/year)	0	0	0	3 026	3 350	1 934	-	-	-
# lost sales (SU)	0	0	0	16	16	9	-	-	-
Total manufactured SU	2 907	2 907	1 938	3 594	3 469	2 983	1,24	1,19	1,54

Table 18: The validation result for product 4910

4910; Batch Size 911 SU	Current Situation Model, setup time 18 min			Cost Analysis Model, setup time 18 min			Validation		
	F11	F12	F13	F11	F12	F13	F11	F12	F13
Holding cost (SEK/year)	3 451	3 314	3 645	3 388	3 503	3 497	0,98	1,06	0,96
Setup cost (SEK/year)	487	552	629	601	535	536	1,24	0,97	0,85
Material cost (SEK/year)	77 534	87 985	100 227	95 815	85 226	85 352	1,24	0,97	0,85
Manufacturing cost (SEK/year)	8 651	9 817	11 183	10 691	9 510	9 524	1,24	0,97	0,85
Revenue (SEK/year)	267 606	312 980	356 287	332 934	303 167	303 410	1,24	0,97	0,85
Profit (SEK/year)	177 482	211 312	240 603	222 438	204 394	204 501	1,25	0,97	0,85
Profit per SU (SEK/SU)	228	239	239	231	239	238	1,01	1,00	1,00
Total sold SU	779	884	1 007	963	856	858	1,24	0,97	0,85
Total demanded SU	779	884	1 013	965	857	859	1,24	0,97	0,85
Lost sales (SEK/year)	0	0	2 406	631	185	254	-	-	0,11
# lost sales (SU)	0	0	6	3	1	1	-	-	0,18
Total manufactured SU	911	911	911	1 470	1 228	1 172	1,61	1,35	1,29

6.2 Result of Sensitivity Analysis

The results for the different scenarios of the sensitivity analysis are presented in the Table 21, Table 22 and Table 23 below. The first Table 19 shows which symbol that corresponds to the investigated products in the sensitivity analysis. See Appendix 5 for the results of the sensitivity analysis for the different scenarios.

Table 19: Symbol for each product in the sensitivity analysis

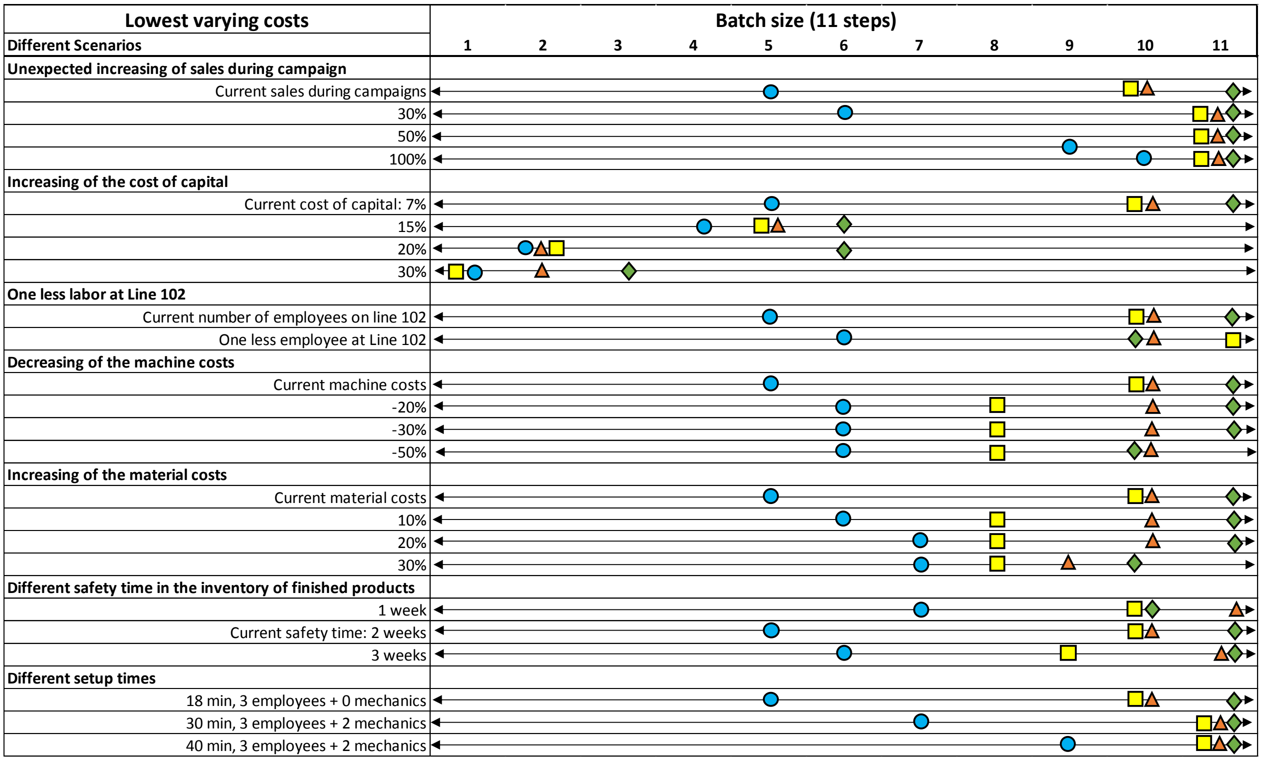
Product	Symbol
4900	◆
4901	▲
4906	■
4907	●

The Table 21 below shows which size each batch should have for each product if the varying cost is as low as possible without taking the Case Fill Rate into consideration. Each scenario has a suggestion on an optimal batch size. It is important to note that every product has a unique number of sales units since they have different volume constraints, see Table 20.

Table 20: The range of investigated batch sizes in sales units (SU)

Product	Batch size (SU)										
	Smal ←									→	Large
4900	165	187	209	231	253	275	297	319	341	363	385
4901	145	164	183	202	221	240	259	278	298	318	338
4906	646	732	818	904	990	1076	1162	1248	1334	1420	1507
4907	633	717	801	885	969	1053	1138	1223	1308	1393	1478

Table 21: Recommendation of batch size if the varying cost is as low as possible



The Table 22 below shows the two scenarios that affect the Case Fill Rate. The Case Fill Rate is affected when there is an unexpected increasing of sales that increase the lost sales. The Case Fill Rate is also affected by the production policy e.g. the safety time. Longer safety time gives higher Case Fill Rate.

Table 22: The scenarios that affect the Case Fill Rate

Fulfilled Case Fill Rate of 99%	**Batch size (11 steps)**											**Does not fulfill the criteria**
Different Scenarios	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	
Unexpected increasing of sales during campaign												
Current sales during campaigns	▲		■	◆				●				
30%		▲							◆		■	●
50%				▲								◆ ■ ●
100%												◆ ▲ ■ ●
Different safety time in the inventory of finished products												
1 week										●	▲	◆ ■
Current safety time: 2 weeks	▲		■	◆				●				
3 weeks	● ■ ▲ ◆											

The Table 23 below shows which size each batch should have for the investigated products if the gold standard case fill rate is achieved.

Table 23: Recommendation of batch size with a Case Fill Rate of 99% and lowest varying cost

Lowest varying costs and Case Fill Rate of 99%	**Batch size (11 steps)**											**Does not fulfill the criteria**
Different Scenarios	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	
Unexpected increasing of sales during campaign												
Current sales during campaigns								●		■ ▲	◆	
30%											■ ▲ ◆	●
50%											▲	◆ ■ ●
100%												◆ ▲ ■ ●
Increasing of the cost of capital												
Current cost of capital: 7%								●		■ ▲	◆	
15%					■ ▲			●		◆		
20%		▲	■			◆		●				
30%		▲	■	◆				●				
One less labor at Line 102												
Current number of employees on line 102								●		■ ▲	◆	
One less employee at Line 102								●		◆ ▲	■	
Decreasing of the machine costs												
Current machine costs								●		■ ▲	◆	
-20%								■ ●		▲	◆	
-30%								■ ●		▲	◆	
-50%								■ ●		◆ ▲		
Increasing of the material costs												
Current material costs								●		■ ▲	◆	
10%								■ ●		▲	◆	
20%								■ ●		▲	◆	
30%								■ ●	▲	◆		
Different safety time in the inventory of finished products												
1 week										●	▲	◆ ■
Current safety time: 2 weeks										■ ▲ ●	◆	
3 weeks						●			■	■	▲ ◆	
Different setup times												
18 min, 3 employees + 0 mechanics								●		■ ▲	◆	
30 min, 3 employees + 2 mechanics								●			■ ▲ ◆	
40 min, 3 employees + 2 mechanics									●		■ ▲ ◆	

6.3 Recommended batch size

The optimal batch sizes for the products investigated in the study are stated in Table 24 and Table 25 where the Case Fill Rate of 99% is fulfilled. These batch sizes are optimal during the optimal production conditions of a setup time of 18 minutes and no mechanics needed. This assumption works well when many dry bouillons can be produced following each other thus long setup times and the mechanics are avoided. Sometimes larger batch sizes than the current batch sizes results in increased inventory costs but decreased production costs and mostly importantly decreased total costs. However for a 4902 and 4910 this is not the case. See Appendix 4 for the results of the cost analysis.

Table 24: Recommended batch size with a setup time of 18 min and fulfilled Case Fill Rate of 99 %

4900		4901		4902		4903		4904	
Investigated Batch Size	Variable Costs	Investigated Batch Size	Variable Costs	Investigated Batch Size	Variable Costs	Investigated Batch Size	Variable Costs	Investigated Batch Size	Variable Costs
165	33961	145	18662	180	6261	218	17791	192	35825
187	32661	164	17837	204	6211	247	16885	217	34459
209	31672	183	17432	228	6327	276	16593	242	33693
231	30860	202	17001	252	6564	305	16304	267	32936
253	30299	221	16680	276	6829	334	16153	292	32424
275	29585	240	16494	300	7165	363	15756	318	32038
297	29213	259	16251	324	7487	392	15901	344	31727
319	28948	278	16153	348	7820	421	15774	370	31317
341	28684	298	16111	372	8185	450	15835	396	31317
363	28532	318	15833	397	8543	479	15936	422	31143
385	28499	338	16058	422	8927	509	15776	448	30936
Current batch size		Current batch size		Current batch size		Current batch size		Current batch size	
194	32402	239	16582	195	6192	266	16674	219	34601

Table 25: Recommended batch size with a setup time of 18 min and fulfilled Case Fill Rate of 99 %

4906		4907		4908		4909		4910	
Investigated Batch Size	Variable Costs	Investigated Batch Size	Variable Costs	Investigated Batch Size	Variable Costs	Investigated Batch Size	Variable Costs	Investigated Batch Size	Variable Costs
646	45812	633	32727	819	39320	748	32333	643	13430
732	44904	717	32550	928	38756	847	31715	728	13445
818	44658	801	32056	1037	38501	946	31336	813	13400
904	43890	885	31753	1146	38208	1045	30915	899	13551
990	43838	969	31357	1255	37983	1145	30729	985	13834
1076	44126	1053	31478	1364	37845	1245	30339	1071	14214
1162	43428	1138	31438	1473	37938	1345	30417	1157	14730
1248	43266	1223	31430	1582	38013	1445	30178	1243	15164
1334	43214	1308	31769	1691	38467	1545	30191	1329	15711
1420	43120	1393	31615	1801	38700	1645	30270	1415	16232
1507	43246	1478	31790	1911	38843	1745	30317	1501	16805
Current batch size		Current batch size		Current batch size		Current batch size		Current batch size	
736	45148	657	32804	873	38911	969	31080	911	13557

The table below shows the recommended batch size and its varying costs. The table also shows possible savings in the varying cost and number of pallets needed for the new recommended batch size.

Table 26: Optimal batch size for optimal production conditions

Product	Current batch size (SU)	Current Varying costs (SEK)	Recommended batch size (SU)	Recommended batch Varying costs (SEK)	Savings (SEK/year)	Nbr of pallets
4900	194	32402	385	28499	3902	5,35
4901	239	16582	318	15833	748	4,42
4902	195	6192	195	6192	0	2,83
4903	266	16674	363	15756	918	5,04
4904	219	34601	448	30936	3664	6,22
4906	736	45148	1420	43120	2028	8,88
4907	657	32804	1223	31430	1374	7,64
4908	873	38911	1364	37845	1066	8,53
4909	969	31080	1445	30178	901	9,03
4910	911	13557	813	13400	157	5,08

To make storage easier some of the batch sizes can be altered to fit on whole pallets for these batch sizes the cost do not increase more than 50kr. A higher cost is considered to be higher than the handling costs for the additional sales units since the storage place has not been considered to be a limitation. However since it might simplify the handling it has been considered. Note that Campbell Soup Nordic's current batch sizes are not adjusted for whole pallets. Batch sizes that are fill full pallets will lead to a better space utilization and easier handling.

Table 27: Optimal batch sizes for optimal production conditions and full pallets

Product	Current batch size (SU)	Recommended batch size (SU)	Nbr of pallets
4900	194	360	5
4901	239	318	4,42
4902	195	216	3
4903	266	360	5
4904	219	448	6,22
4906	736	1440	9
4907	657	1223	7,64
4908	873	1364	8,53
4909	969	1440	9
4910	911	800	5

The optimal batch sizes for the products during a not optimal production situation are stated in Table 28. During this production condition a longer setup time of 30 minutes is needed and two mechanics are necessary to change the production from small bucket sizes to larger or vice versa. During these conditions larger batch sizes often results in increased inventory costs but decreased production costs and mostly importantly decreased total costs.

Table 28: Optimal batch sizes for a setup time of 30min and two mechanics

Product	Current batch size (SU)	Current Varying costs (SEK)	Recommended batch size (SU)	Recommended batch Varying costs (SEK)	Savings (SEK/year)	Nbr of pallets
4900	194	37101	385	30963	6137	5,35
4901	239	18444	338	17288	1155	4,69
4902	195	6862	195	6862	0	2,71
4903	266	18966	479	16959	2007	6,65
4904	219	39340	448	33311	6029	6,22
4906	736	48458	1507	44777	3681	9,42
4907	657	35700	1223	33099	2601	7,64
4908	873	41822	1582	39420	2402	9,89
4909	969	33124	1745	31374	1750	10,91
4910	911	14258	813	14199	59	5,08

The batch sizes are altered to fit on whole pallets for these batch sizes as well with the same conditions as before. As can be seen in Table 29 it is not as profitable as before modify to full pallets.

Table 29: Optimal batch sizes for full pallets with a setup time of 30min and two mechanics

Product	Current batch size (SU)	Recommended batch size (SU)	Nbr of pallets
4900	194	385	5,35
4901	239	338	4,69
4902	195	195	2,71
4903	266	504	7
4904	219	448	6,22
4906	736	1507	9,42
4907	657	1223	7,64
4908	873	1600	10
4909	969	1745	10,91
4910	911	800	5

7 Conclusions

This chapter will remind the readers of the purpose and objective of this master thesis. The chapter will then describe the conclusions of the results. The chapter will finally give Campbell Soup Nordic recommendations on how they should continue with further studies and suggestions on how they can improve their daily business at the company.

7.1 The purpose and objective of the master thesis

The capital tied in inventories is believed to be too high and therefore Campbell Soup Nordic wants to investigate if they can lower their inventory levels. By finding a tool they would like to calculate more optimal inventory levels and also investigate production planning principles such as batch sizes and how many times a product should be produced per year.

The purpose of the study is to find a long term suggestion on feasible batch sizes and safety stocks. The study includes products that are slow mover products, medium mover products and fast mover products. The study will result in recommendations on batch sizes that lower the capital tied also taking the customer service level into consideration and the total costs.

The objective is to find a suggestion on how to lower the inventory levels and capitals tied without increasing the total cost or lower the customer service level measured in case fill rate.

7.2 Conclusion of the result

7.2.1 Conclusion of the result of the validation

Almost all of the products correspond well to the Cost Analysis Model with an accuracy of at least 85 %**,** see Table 9 to Table 18. This is good since the sales between the years differed around 15 % and the demand data and the gamma distribution were estimated by using historical data from three years back. It should be noted that product 4902 fits poorly to the Cost Analysis Model. A reason for this is, that the results for the different years of the Current Situation Model´s, differentiates more than 15% from year to year. The gamma-distribution based on three years of data might not be an optimal distribution for product 4902 since the conditions for this product has changed too much. A distribution which considers slow mover products with a low demand would perhaps fit better for 4902. However, the results of the validation for the rest of the products show that the sensitivity analysis is trustworthy and that the Cost Analysis Models corresponds well to the Current Cost Analysis Models.

It should be mentioned that the lost sales differ a lot for some products in their Cost Analysis Model and Current Situation Model. Campbell Soup Nordic collaborates with their customers by continuously communicating with them thus avoiding lost sales. However, in our Cost Analysis Model that kind of collaboration cannot be taken into consideration. The Cost Analysis Model instead shows the “worst case” scenario if Campbell Soup Nordic has no communication with their customers. This means that Campbell Soup Nordic has to keep in mind that the lost sales in our models do not reflect the actual lost sales, as these are lower due to the collaboration with the customers. However the lost sales given in the model will reflect the occasions when Campbell Soup Nordic will not be able to deliver to their customers. This will result in Campbell Soup Nordic having a dialogue with their customers where they will ask them to delay their orders. If Campbell Soup Nordic wants to avoid having to delay the orders and negative goodwill, they should use the batch sizes determined in the analysis considering lost sales.

7.2.2 Conclusion of the result of the sensitivity analysis

All of the products examined, except 4902 and 4910, should have larger batch sizes than they have for the time being according to the result given by the analysis. 4902 is a slow mover product with low demand and its optimal batch size is unchanged. The optimal batch size, which also is the current bath size for this product, corresponds to the total sale~~s~~ of one year. The current batch size of 4910 is larger than the total sale~~s~~ of one year and should therefore be reduced. The batch sizes have been scaled in a 10 stage scale, from the minimum volume in the mixing machine to the maximum volume for all the products. The scale differs for the different products, as the products have different densities. Depending on the scale, the products should have a small batch size, a medium batch size or a large batch size. The products 4900, 4901, 4904, 4906 and 4909 should have large batch sizes while 4907, 4907 and 4908 should have medium batch sizes see Table 24and Table 25 in the result. Finally 4902 and 4910 should have small batch sizes.

During the sensitivity analysis, the varying costs were examined for different scenarios. The varying costs include the holding cost, manufacturing cost~~s~~ and setup cost~~s~~. The optimal batch sizes are quite stable for the different sensitivity analysis scenarios. For all the investigated scenarios, except for increasing cost of capital and increasing setup cost, the same indications are given for what batch sizes should be used for the different products. The sensitivity analysis scenario covered:

- Unexpected sales during campaigns
- Decreasing of the cost of capital
- Decreasing one machine operator at line 102
- Decreasing machine costs for the mixing machine and production line 102
- Increasing the safety time
- Decreasing the safety time
- Increasing setup times and taking the mechanics into consideration

It has to be mentioned that the different rates for cost of capital investigated in the sensitivity analysis are rather high the intention was for getting changed batch sizes. By only changing the capital cost slightly, by one or two percent will not have any major effect on the results. The probability that the cost of capital would increase as much as in the sensitivity analysis is very low and should therefore not be the major factor for deciding what size the optimal batch size should be.

The setup cost is more critical for the product 4907 compared to the other investigated products. It is essential for Campbell Soup Nordic to know that medium mover products are more sensitive to high setup costs and with increasing setup times, it is optimal to increase the batch sizes.

In the last sensitivity analysis the mechanics were included in the costs, which the authors think is a good idea. However they are not included today. Since the mechanics are needed for the different setup changes they are needed for different products more or less. It should be investigated how much the mechanics are needed to know which products that are more costly. Smaller batch sizes demand more attention and therefore are more costly to produce.

In many cases, which have been mentioned before, the manufacturing costs and setup costs are higher than the cost for storing the products during a long time. The authors think one reason is the long shelf lives of the products. The products can be stored for 1.5 years, which result in very low costs for obsolete products. The products investigated also have stable design and probably will not change more than every second year or so. The cost of capital is 7 percent which also is a reason for the low storage cost.

The sensitivity analysis shows that medium batch sizes to large batch sizes are preferred in order to lower the lost sales. The products are most sensitive for unexpected sales during campaigns. This is reasonable, since lost sales is connected to unfulfilled request of demand .With a higher unexpected demand it is more difficult to fulfill the request which may lead to larger lost sales. With larger batch sizes it is more probable to have enough sales units stored, to be able to cover the demand.

Larger batch sizes will results in higher probability for Campbell Soup Nordic having the products available. Currently the company has a gold standard case fill rate of 99%. For this reason it can be a good idea to have larger batch sizes to increase the case fill rate. As for the sensitivity analysis for lost sales, the sensitivity analysis for fulfilling the case fill rate is most sensitive for unexpected sales.

7.2.3 Recommended batch sizes

The Bong Dry Bouillon products are traditional standard and "functional products" and these products normally have low margins, hence it is important to lower the total cost[119]. Some products investigated only had a low cost difference between the total costs with the optimal batch sizes in comparison to the current batch sizes but in some cases substantial savings could be made. If Campbell Soup Nordic continues to investigate what batch sizes they should have for their remaining products with the Costs Analysis Model described in this study, Campbell Soup Nordic could make large total savings. Then, as an old saying tells: small streams make great rivers.

7.2.4 Profitability for smaller batch sizes

To make it profitable with smaller batch sizes and lower inventory, manufacturing costs and setup costs have to be reduced. The machine costs should also be examined. Ways or investments for making the setup~~s~~ easier, the production faster, increasing the machine utilization and reduce the labor should be investigated. The differences in cost are significant and can be seen in Graph 13, Graph 14 and Graph 15. The vertical axis shows the varying cost which includes the holding cost, setup cost and manufacturing cost in SEK. The horizontal axis shows the different batch sizes investigated. The graphs show the optimal production condition for

- a setup time of 18minuts
- a setup time of 18minutes and machine costs reduced with 50%
- finally a setup time of 18 minutes and a cost of capital of 20%

Only the changed cost of capital makes a clear difference for the batch sizes. It should be reminded that the current cost of capital is 7%. To be able to make it worth lowering the inventory costs, the line manufacturing (cost line) cost should be closer to the line holding cost.

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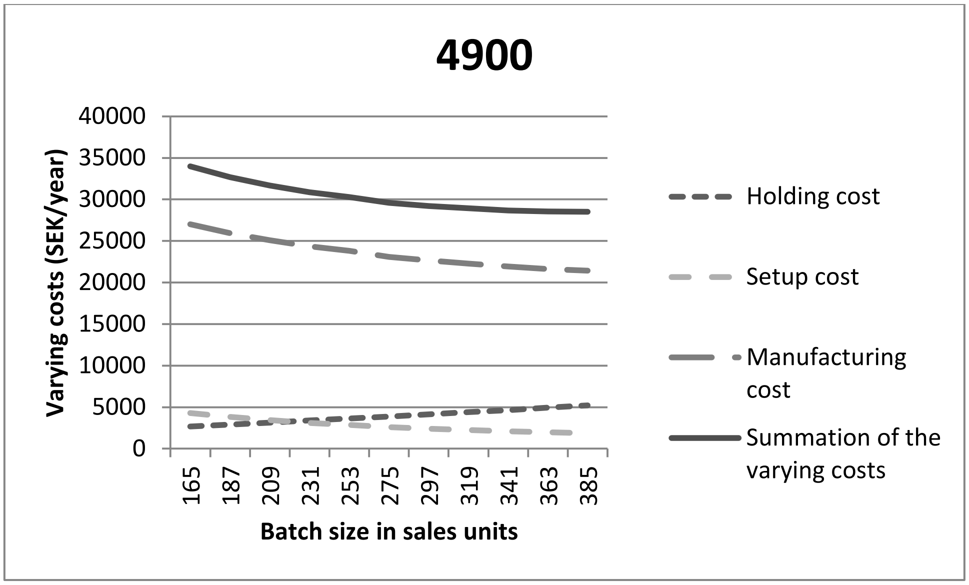
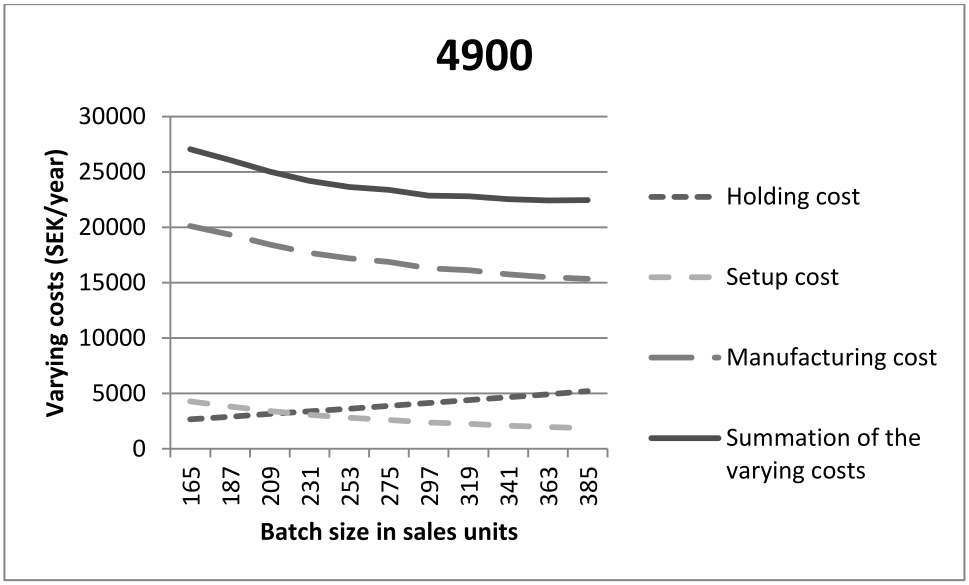
[119] Fisher, Marshall L. *What is the right supply chain for your product?.* Harvard Business Review, Harvard University, 1997

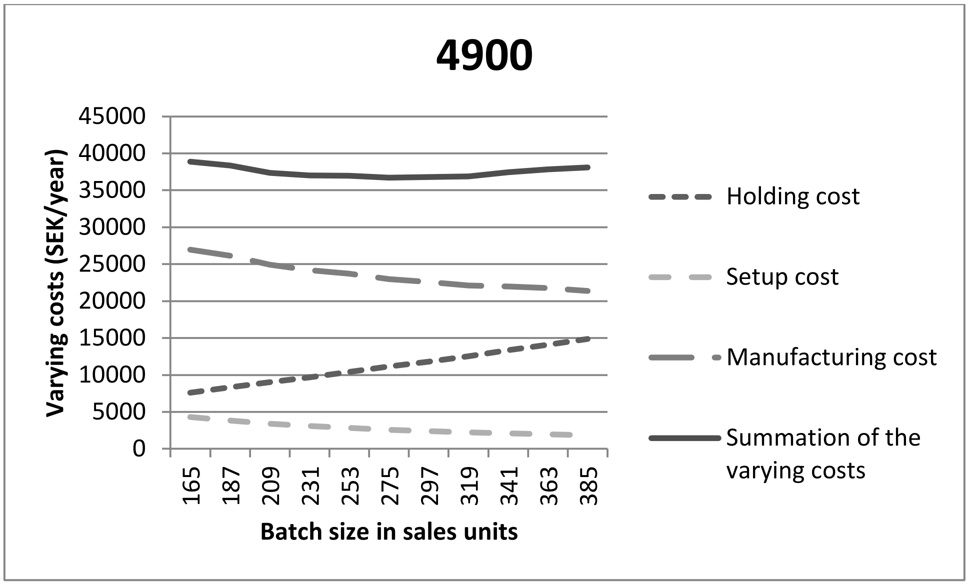
In the case of a setup time of 18 minutes the recommended batch sizes can lead to savings of around 5 percent of the total cost of the products examined. While in the case of a setup time of 30minutes considering the cost of mechanics can lead to saving around 9 percent of the total cost for the investigated products.



Graph 13: The varying costs for different batch sizes with optimal production conditions



Graph 14: The varying costs for different batch sizes with 50% of the current machine costs



Graph 15: The varying costs of different batch sizes with a cost of capital of 20% of the current material cost

7.3 The correlation of the result and the purpose and objective of the master thesis

The holding cost is low in comparison to the setup cost and manufacturing cost. The holding cost is rather low since Campbell Soup Nordic owns their facilities and the risks of storing the products are estimated to be extremely low. Instead of trying to lower the inventory levels for all products and hence lowering the capital tied, it is more interesting to investigate when the total cost for the products are the lowest. The final recommendation fulfills the gold standard of a case fill rate of 99%. The slow mover products should be produced ones a year since their manufacturing costs are higher than the holding cost. The medium and fast mover products can be produced more often since their manufacturing costs are lower per sales units than the slow mover products.

7.4 Final recommendations for further studies at Campbell Soup Nordic

7.4.1 Upgrade Microsoft Excel

We recommend Campbell Soup Nordic to invest in the upgraded version of the software Microsoft Excel, since they currently have a too old version of this software. Their current version of Microsoft Excel cannot handle the simulations in the Cost Analysis Model and an upgrade of the software is necessary if Campbell Soup Nordic would like to continue the investigations for their other products with the methods presented in this master thesis.

7.4.2 Use a simulation program

We recommend the company to use a simulation software such as Easy Fit Professional 5.5, which was used in this master thesis to determinate a suitable distribution function for the demand for their other products. It is a very good software tool for analyzing how well the supply chain can coop with fluctuating demand. The total sales simulated in the Cost Analysis Model for one year can also be used for estimating the expected sales during one year for the budget planning and long term production planning.

7.4.3 Analyze bought sales data

Campbell Soup Nordic acquires sales data but according to an employee at the sales department, they barely have time to analyze it. The sales data is very important information for making the forecasts and should be highly prioritized. For the authors it seems like this information sometimes fall between the cracks in the organization. Campbell Soup Nordic should come up with an action plan of how they should organize this task to analyze the sales data and use it in the sales forecasts.

7.4.4 Determine order costs

Today Campbell Soup Nordic does not have any good tool to determine order costs. This is a cost that could not be taken into consideration in the Current Situation Model or the Cost Analysis Model since there was no data for these costs available. When Campbell Soup Nordic has determined the order cost they could add this information into the models and then the models will give an even better estimation of actual costs.

7.4.5 Determine insurance cost per sales unit

Today Campbell Soup Nordic has an insurance cost that covers facilities, equipment and material. However it would be interesting for Campbell Soup Nordic to know the insurance cost per sales unit or the insurance cost difference depending on specified volumes stored. This insurance cost would affect the holding cost. The insurance cost could not be taken into consideration in the Current Situation Model or the Cost Analysis Model since the total insurance cost is treated as a fixed cost and not as a cost that is linked to the number of sales unit.

7.4.6 Investigate the purchasing of Raw Material

The raw material inventory is controlled by SAP. When SAP suggests a production plan for products, it takes the inventory of raw material into consideration. If there is not enough of raw material in the inventory, SAP will send a message to the purchasers and warn them that they need to place an order. Campbell Soup Nordic can do a model similar to the Current Situation Model and the Cost Analysis model but using a different approach. Instead of looking from the finished products perspective they could look at it from the raw material perspective. They can then analyze how much raw material they should order and how often. Today the contracts are set up and signed by the purchasers on the European level and Campbell Soup Nordic cannot affect the selection of suppliers or volumes. They should therefore investigate how much money they could save, if they could control what supplier they would like to work with and order the volumes they need. If this kind of investigation is made by Campbell Soup Nordic, they can determine if the current purchasing contracts are the best or not.

7.5 Recommendation for the Daily operations at Campbell Soup Nordic

7.5.1 Take responsibility for learning SAP

SAP has many functions that the employees do not use and these can be very helpful for running the business at Campbell Soup Nordic. Every employee should be given time to investigate the possibilities of SAP in their area and explore new tools that could develop the business in a more time effective manner. If employees took more responsibility in this area they would discover functions like ABC-analysis and the different forecasting methods, which can be used in an earlier stage. The authors asked the employees if they had made these kinds of analysis and got the response that this was not possible with the current system. However, when discussing with the IT manager, it became clear that these functions already exists in SAP. However, nobody had asked for the functionality. Since the IT manager does not know all the theories, all business operations or what functions the different employees at Campbell Soup Nordic need, it is important for the employees to ask the IT manager what features exists. This might initially be time consuming, but in the long run Campbell Soup Nordic will gain benefits if all employees have knowledge about SAP and are using the full potential of SAP.

7.5.2 Work with ABC-analysis

Currently Campbell Soup Nordic does not work with ABC-analysis (Antecedent-Behavior-Consequence) which could be a big advantage. If used, Campbell Soup Nordic would know what products that have a significant impact on overall inventory cost. They have access to this functionality in SAP but do not use it, which could be beneficial to use in a long term perspective.

7.5.3 Collaborate with the distributors

Campbell Soup Nordic would like to use VMI (vendor managed inventory) with their wholesalers, but they are not interesting in that kind of collaboration. The wholesalers want to have full control of their own business. VMI would be a very good tool to handle the Bullwhip Effect. The Bullwhip Effect occurs in some grade in each stage in the supply chain. Campbell Soup Nordic should keep a dialogue about the benefits of VMI with their wholesalers and not give up the idea of having VMI introduced. VMI is win-win collaboration for all stages in the supply chain. By using VMI, unnecessarily high inventories can be avoided in each stage of the supply chain.

Recently Campbell Soup Nordic was thinking of collaborating with one of their suppliers of packing material. Campbell Soup Nordic stores the material in their warehouse, but the supplier still owns it. In this way, they have a visible inventory for the supplier and can communicate in good time when they need to order new material. If this collaboration is successful it can be a good example to bring up when they are negotiating with the wholesalers about VMI.

It should be noted that Campbell Soup Nordic faces many sources of the Bullwhip effect as price fluctuations, order batching, demand signal processing and rationing game. However, the biggest reason for their large inventory is their low holding cost in comparison with the setup cost and manufacturing cost.

7.5.4 Reduce workload for the Plant & Logistics Controller

During our time at Campbell Soup Nordic we noticed that the workload of the Plant & Logistics Controller Nordic is very high. The Plant & Logistics Controller plays a key role in the organization and, it seems like all employees heavily relies on this position. This position is currently staffed by a consultant. However, a consultant will not be there in a long term perspective. Campbell Soup Nordic should take some action for staffing this position in-house so the person having it can focus on improvements instead of learning the organization. It is important the Plant & Logistics Controller stay long term and knowledge not goes to waste.

7.5.5 Structured meetings

During our interviews with employees at Campbell Soup Nordic we noticed that many of them wanted more structured meetings with clear meeting protocols, so everyone knows what is expected of them. This also makes it easier to follow up actions at the next meeting. By having more structured meetings they would avoid tasks fall through the cracks. The meetings could also be more time affective if everyone were prepared before the meeting~~s~~. We recommend that Campbell Soup Nordic creates a standard template for meeting protocols.

7.6 Final conclusion of the study

We recommend Campbell Soup Nordic to continue with this study since it has proven that savings can be made by small changes of the batch size. Since they have low holding costs they should probably make their batch sizes larger to save production costs and setup costs. Something that could be beneficial would also be to try to benchmark with literature our other companies in the industry to see if other improvements can be made. It is very popular for companies to try to lower inventory and in this case it could be interesting for other companies to do a study like this as well since this study shows the opposite of the trend and what the management of Campbell Soup Nordic initially believed.

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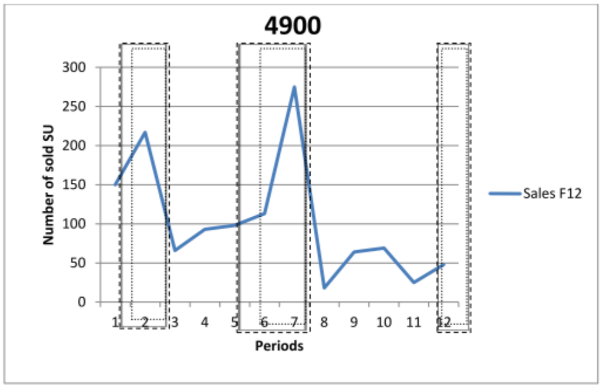
Other

Campbell Soup Nordics internal information in SAP

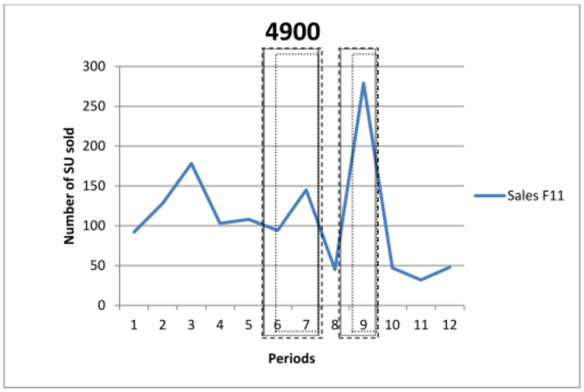
Appendix 1

When different campaigns occur for the investigated products, in the fiscal years 2011, 2012 and 2013.

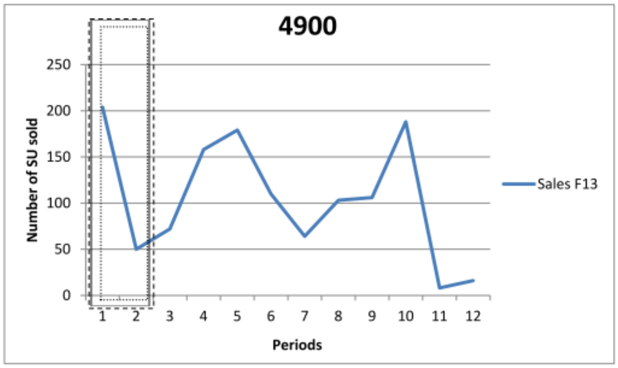
Campaigns for product 4900



Graph 16: The campaigns of the fiscal year 2011 for product 4900

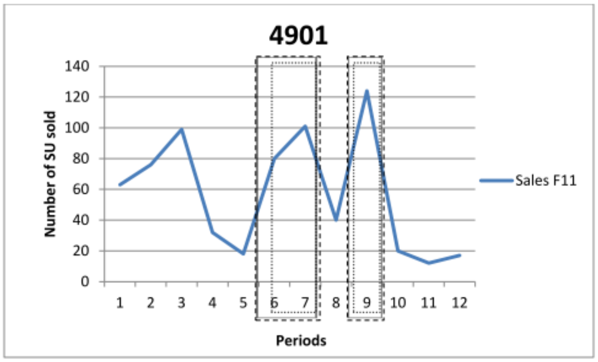


Graph 17: The campaigns of the fiscal year 2012 for product 4900

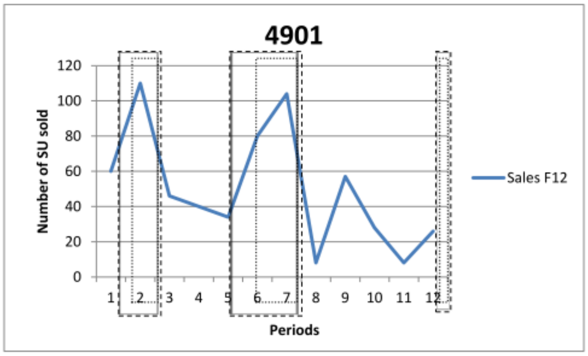


Graph 18: The campaigns of the fiscal year 2013 for product 4900

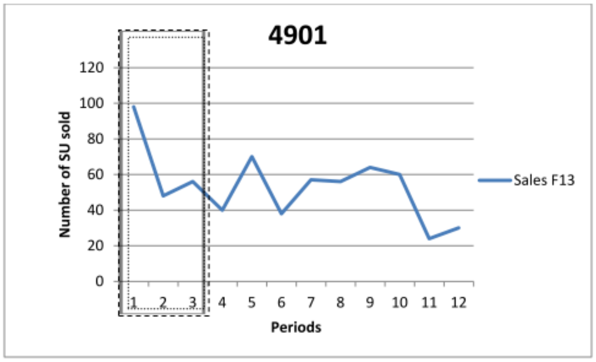
Campaigns for product 4901



Graph 19: The campaigns of the fiscal year 2011 for product 4901

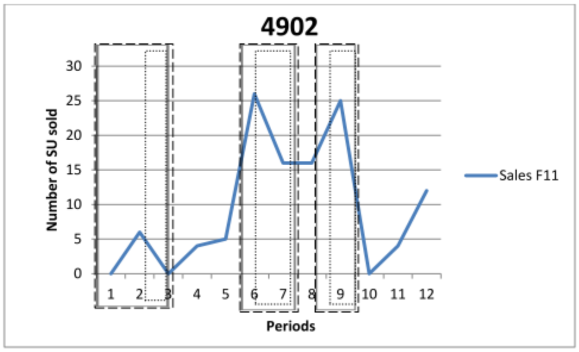


Graph 20: The campaigns of the fiscal year 2012 for product 4901

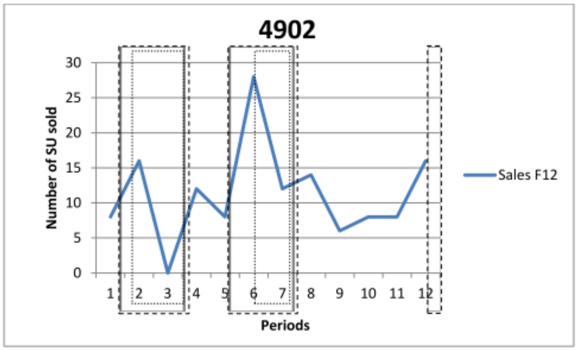


Graph 21: The campaigns of the fiscal year 2013 for product 4901

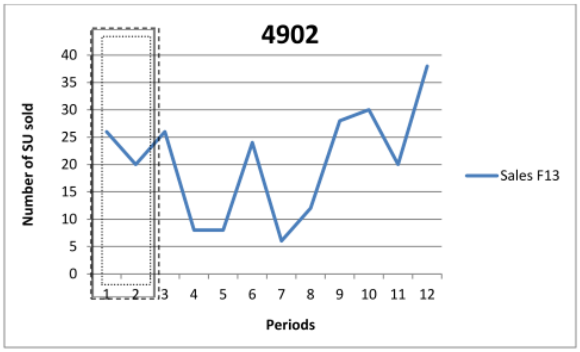
Campaigns for product 4902



Graph 22: The campaigns of the fiscal year 2011 for product 4902

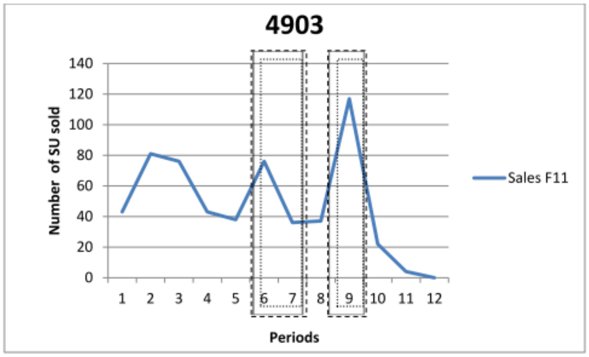


Graph 23: The campaigns of the fiscal year 2012 for product 4902

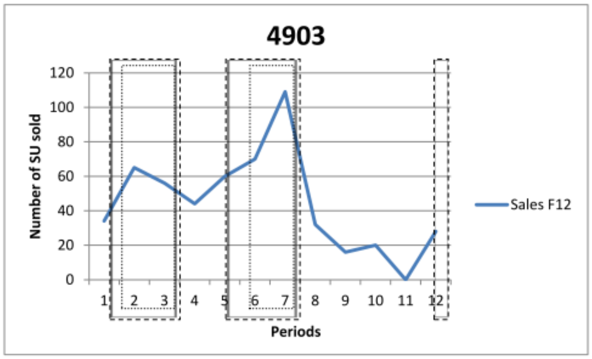


Graph 24: The campaigns of the fiscal year 2013 for product 4902

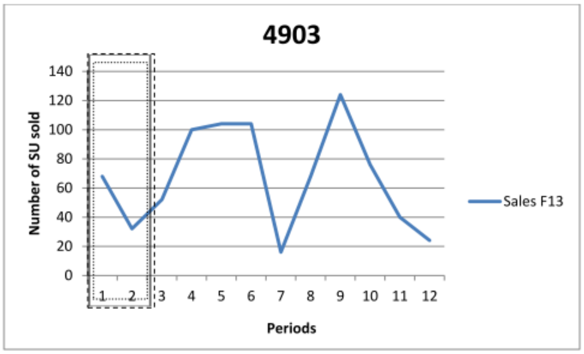
Campaigns for product 4903



Graph 25: The campaigns of the fiscal year 2011 for product 4903

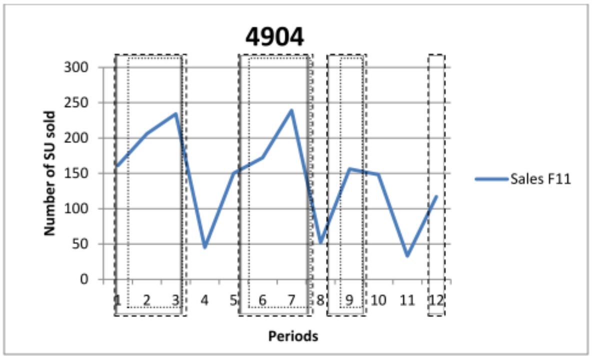


Graph 26: The campaigns of the fiscal year 2012 for product 4903

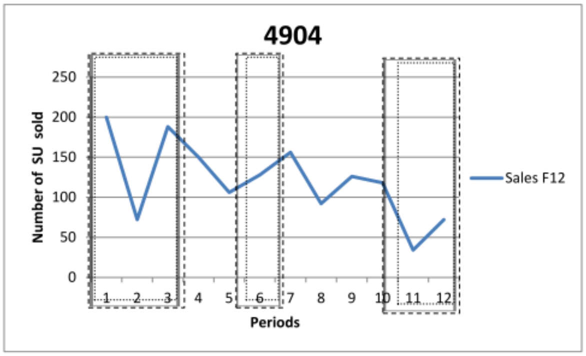


Graph 27: The campaigns of the fiscal year 2013 for product 4903

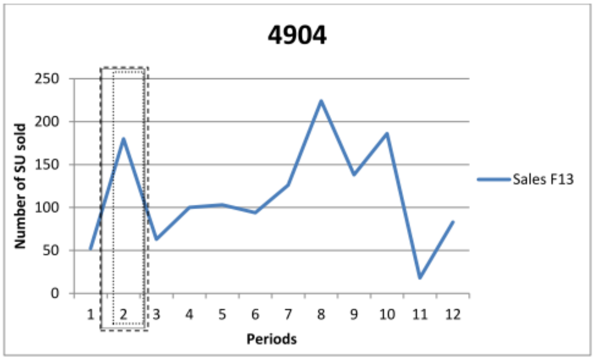
Campaigns for product 4904



Graph 28: The campaigns of the fiscal year 2011 for product 4904

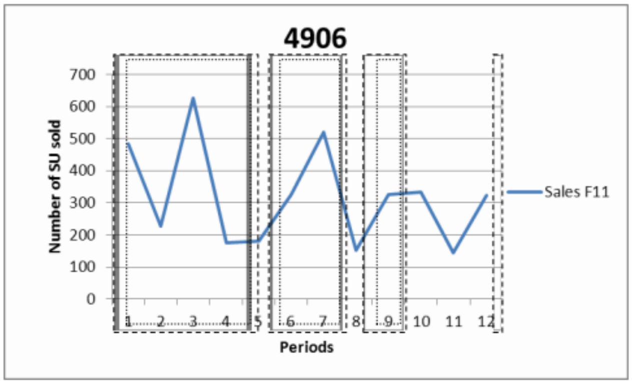


Graph 29: The campaigns of the fiscal year 2012 for product 4904

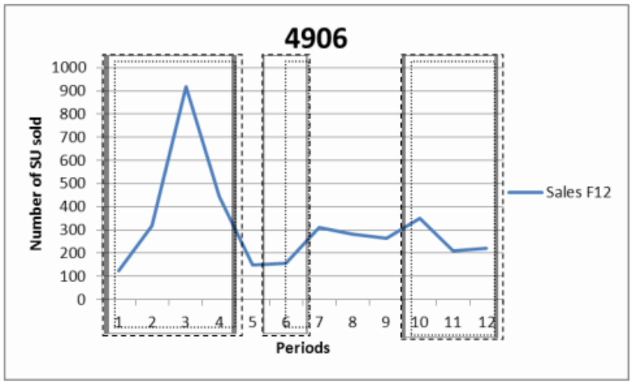


Graph 30: The campaigns of the fiscal year 2013 for product 4904

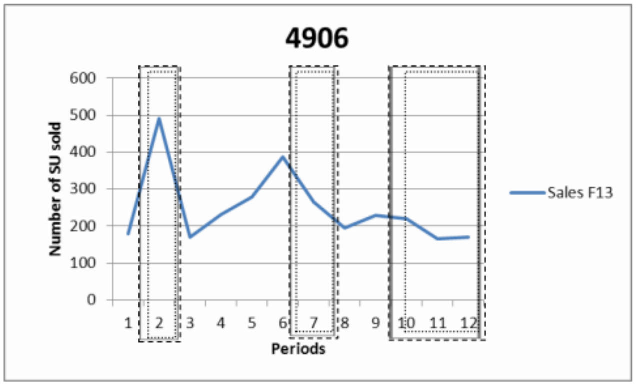
Campaigns for product 4906



Graph 31: The campaigns of the fiscal year 2011 for product 4906

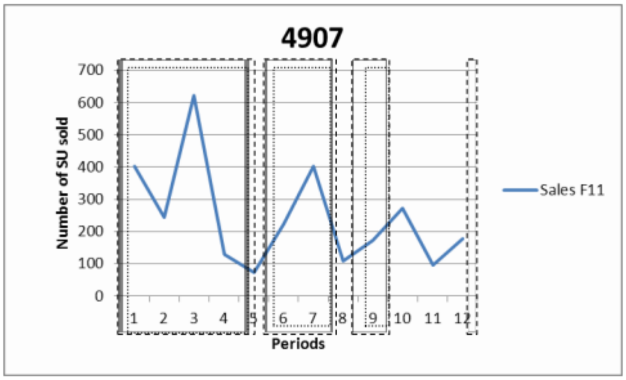


Graph 32: The campaigns of the fiscal year 2012 for product 4906

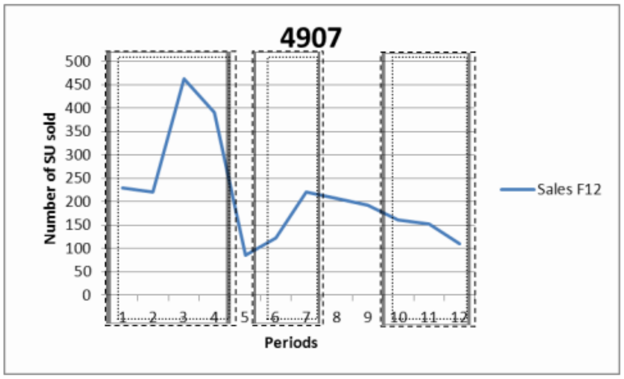


Graph 33: The campaigns of the fiscal year 2013 for product 4906

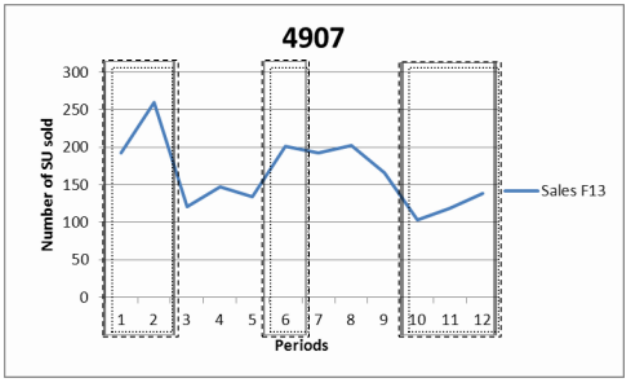
Campaigns for product 4907



Graph 34: The campaigns of the fiscal year 2011 for product 4907

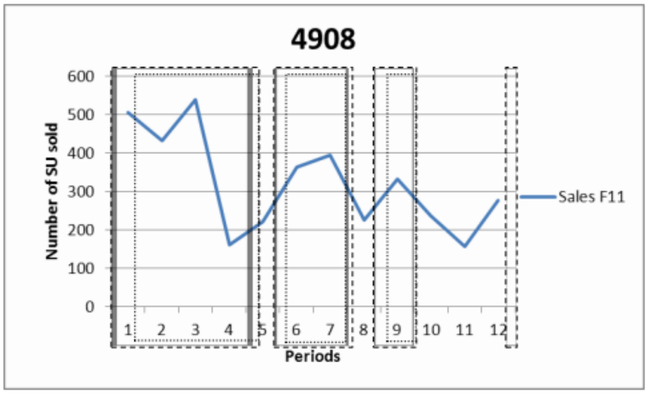


Graph 35: The campaigns of the fiscal year 2012 for product 4907

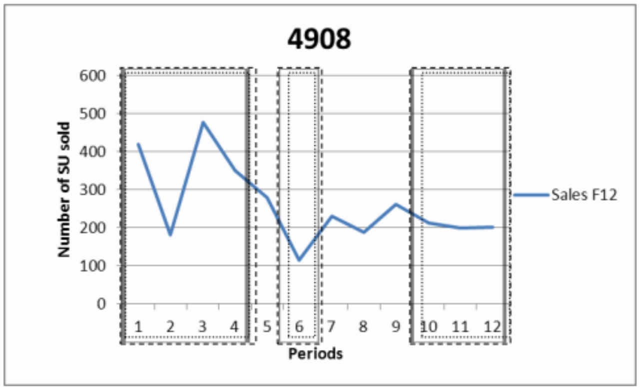


Graph 36: The campaigns of the fiscal year 2013 for product 4907

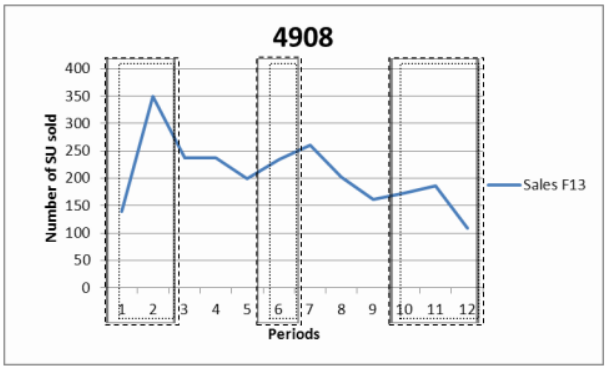
Campaigns for product 4908



Graph 37: The campaigns of the fiscal year 2011 for product 4908

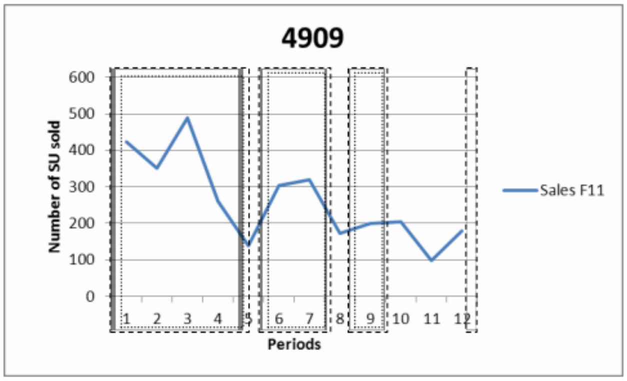


Graph 38: The campaigns of the fiscal year 2012 for product 4908

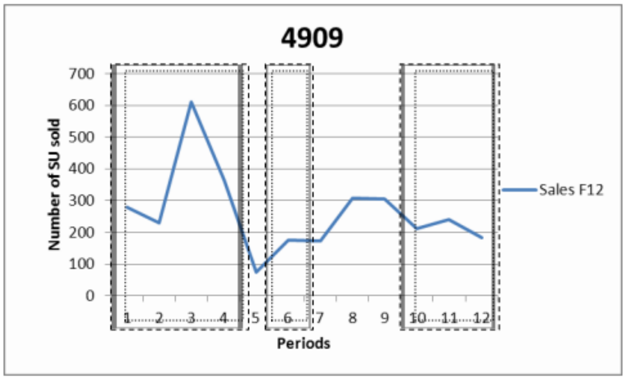


Graph 39: The campaigns of the fiscal year 2013 for product 4908

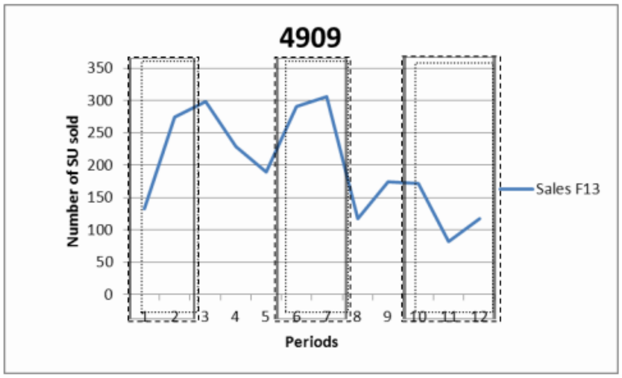
Campaigns for product 4909



Graph 40: The campaigns of the fiscal year 2011 for product 4909 for product 4909

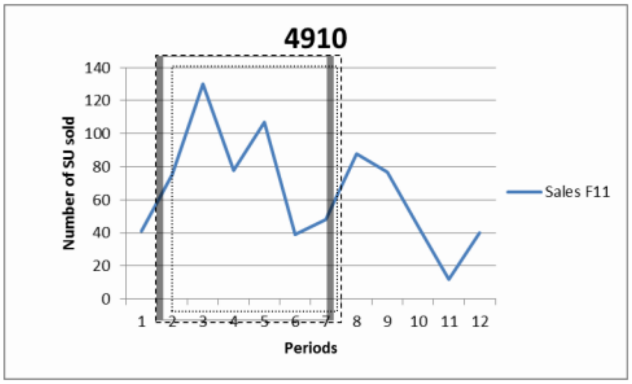


Graph 41: The campaigns of the fiscal year 2012

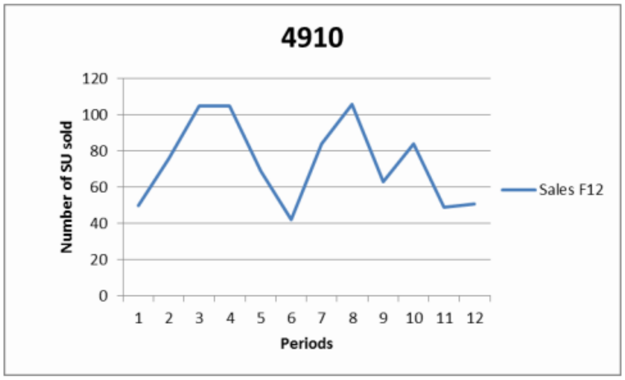


Graph 42: The campaigns of the fiscal year 2013 for product 4909

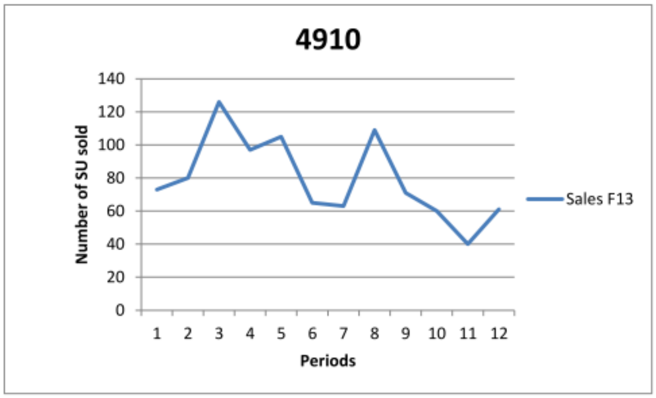
Campaigns for product 4909



Graph 43: The campaigns of the fiscal year 2011 for product 4910



Graph 44: No campaigns of the fiscal year 2011 for product 4910



Graph 45: No campaigns of the fiscal year 2013 for product 4910

Appendix 2

The lost sales of the investigated products for the fiscal years 2011 and 2012

Table 30: The lost sales for the fiscal year 2011

Fiscal year 2011				
Material	**Demand**	**Sales**	**Lost sales**	**Unit**
4900	1365	1328	37	SU
	100%	97%	3%	
4901	679	679	0	SU
	100%	100%	0%	
4902	114	114	0	SU
	100%	100%	0%	
4903	653	653	0	SU
	100%	100%	0%	
4904	1747	1738	9	SU
	100%	99%	1%	
4906	3894	3820	74	SU
	100%	98%	2%	
4907	2925	2925	0	SU
	100%	100%	0%	
4908	3776	0	3776	SU
	100%	100%	0%	
4909	3158	3158	0	SU
	100%	100%	0%	
4910	779	779	0	SU
	100%	100%	0%	

Table 31: The lost sales for the fiscal year 2012

Fiscal year 2012				
Material	**Demand**	**Sales**	**Lost sales**	**Unit**
4900	1239	1236	3	SU
	100%	99,76%	0,24%	
4901	601	601	0	SU
	100%	100%	0%	
4902	137	137	0	SU
	100%	100%	0%	
4903	534	534	0	SU
	100%	100%	0%	
4904	1450	1442	8	SU
	100%	99%	1%	
4906	3752	3752	0	SU
	100%	100%	0%	
4907	2572	2572	0	SU
	100%	100%	0%	
4908	3116	3116	0	SU
	100%	100%	0%	
4909	3157	3157	0	SU
	100%	100%	0%	
4910	884	884	0	SU
	100%	100%	0%	

Appendix 3

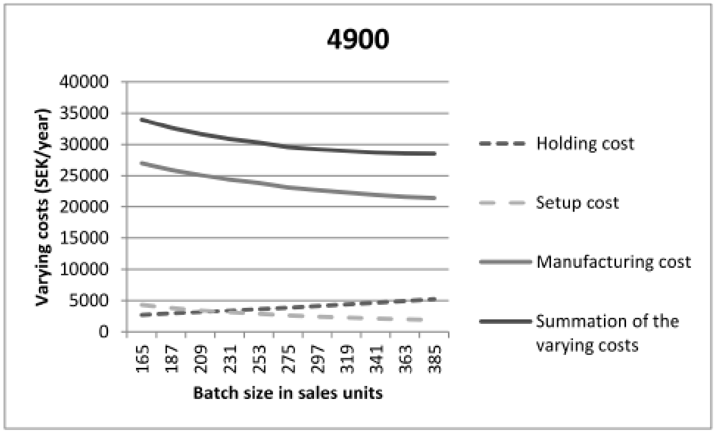
The demand parameters, used for the investigated products, in the gammadistributions.

Table 32: The parameters of the different gamma-distributions of the demands

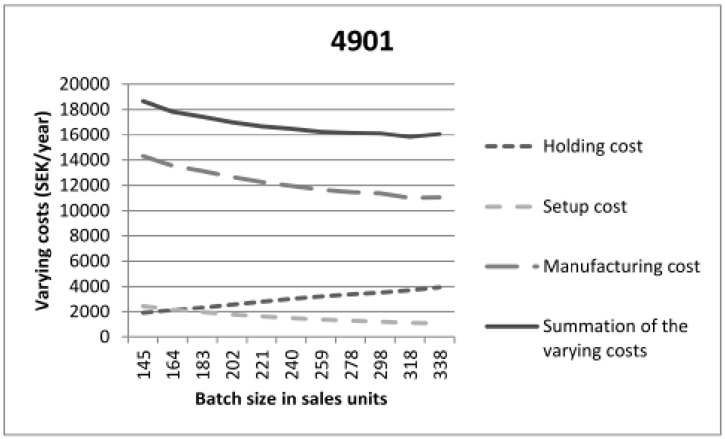
Product	Category	α-value	β-value	γ −value
4900	No campaigns	0,94877	22,386	0
	Campaigns with Martin/Servera	1,4395	27,431	0
4901	No campaigns	0,83515	12,218	0
	Campaigns with Martin/Servera	1,9614	10,9	0
4902	No campaigns	0,55745	5,9972	0
	Campaigns with Martin/Servera	0,95323	5,0185	0
	Campaigns with M OLSSON CL	0,17787	3,0667	0
4903	No campaigns	0,53545	25,518	0
	Campaigns with Martin/Servera	1,5825	10,657	0
4904	No campaigns	1,4904	17,525	0
	Campaigns with Martin/Servera	0,56797	57,058	0
	Campaigns with MENIGO	1,8082	20,721	0
	Campaigns with Svensk Cater	6,4519	5,6263	0
	Campaigns with both Martin/Servera and MENIGO	0,8325	45,474	0
4906	No campaigns	0,8266	32,918	0
	Campaigns with Martin/Servera	1,2247	62,787	0
	Campaigns with MENIGO	1,757	37,7	0
	Campaings with M OLLSSON CL	0,7879	91,1	0
	Campaings with Svensk Cater	1,5732	68,271	0
	Campaigns with both Martin/Servera and MENIGO	1,7413	43,1	0
4907	No campaigns	1,1025	34,517	0
	Campaigns with Martin/Servera	0,86414	67,78	0
	Campaigns with MENIGO	1,3907	35,261	0
	Campaings with M OLLSSON CL	1,1732	22,446	0
	Campaings with Svensk Cater	0,72054	76,61	0
	Campaigns with both Martin/Servera and MENIGO	1,294	38,368	0
4908	No campaigns	3,7281	14,252	0
	Campaigns with Martin/Servera	1,118	60,914	0
	Campaigns with MENIGO	1,5135	40,326	0
	Campaings with M OLLSSON CL	1,7375	26,721	0
	Campaings with Svensk Cater	7,8342	9,3181	0
	Campaigns with both Martin/Servera and MENIGO	0,79774	77,344	0
4909	No campaigns	1,2691	36,49	0
	Campaigns with Martin/Servera	1,8648	27,33	0
	Campaigns with MENIGO	1,6194	31,897	0
	Campaings with M OLLSSON CL	1,035	83,953	0
	Campaings with Svensk Cater	0,97248	83,292	0
	Campaigns with both Martin/Servera and MENIGO	2,0742	29,611	0
4910	No campaigns	1,2846	12,853	0
	Campaigns with Martin/Servera	1,1476	20,217	0

Appendix 4

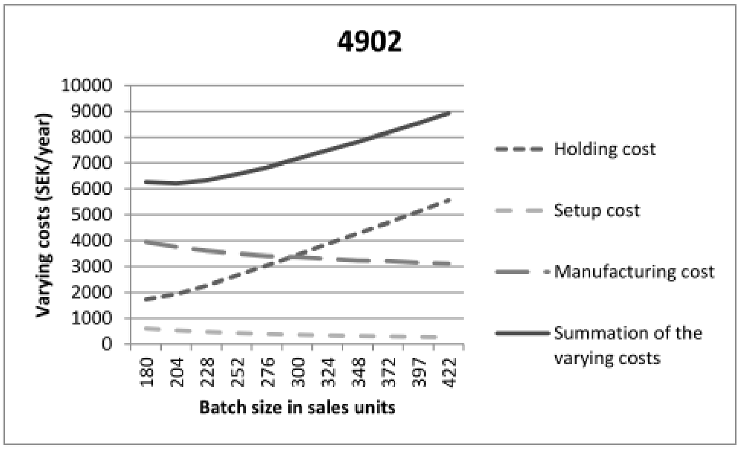
The result of the Cost Analysis Model for the different prodcuts when the setup time is 18 minutes. The graphs shows the holding costs, setup costs and manufacturing costs.



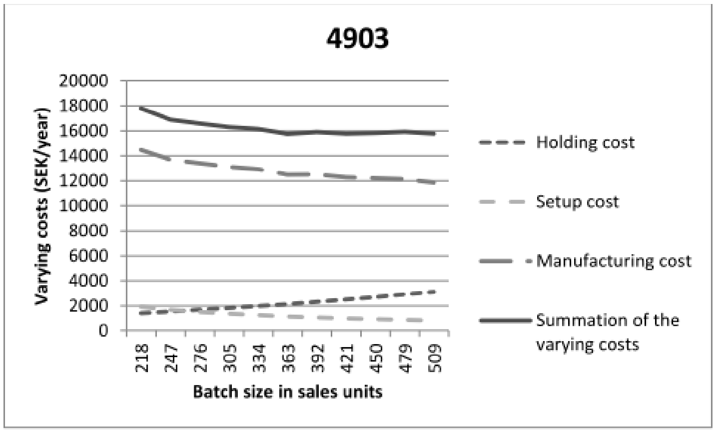
Graph 46: The varying cost for product 4900



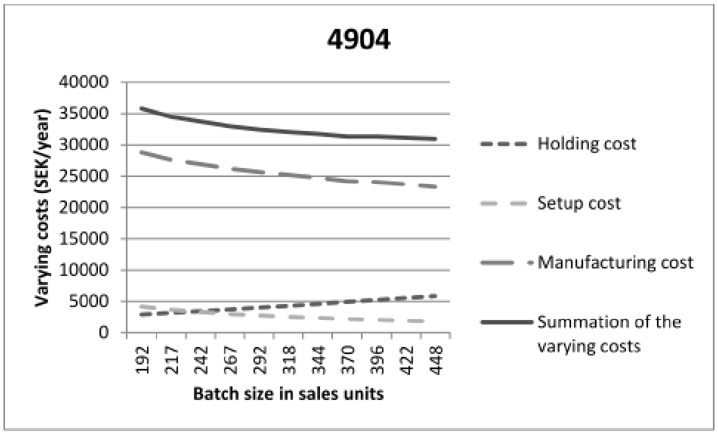
Graph 47: The varying cost for product 4901



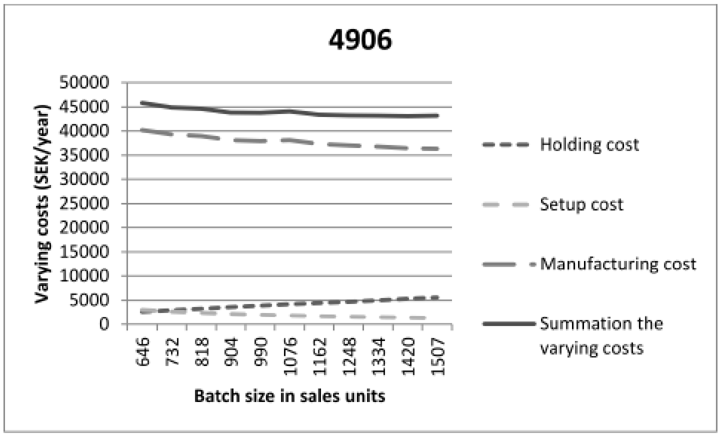
Graph 48: The varying cost for product 4902



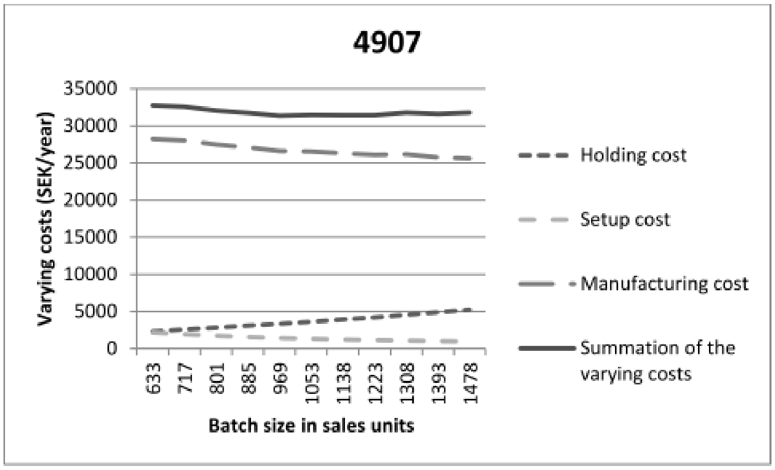
Graph 49: The varying cost for product 4903



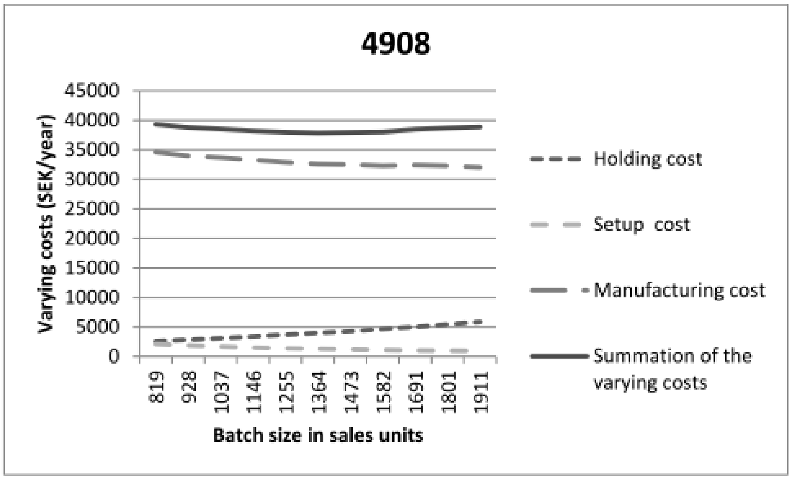
Graph 50: The varying cost for product 4904



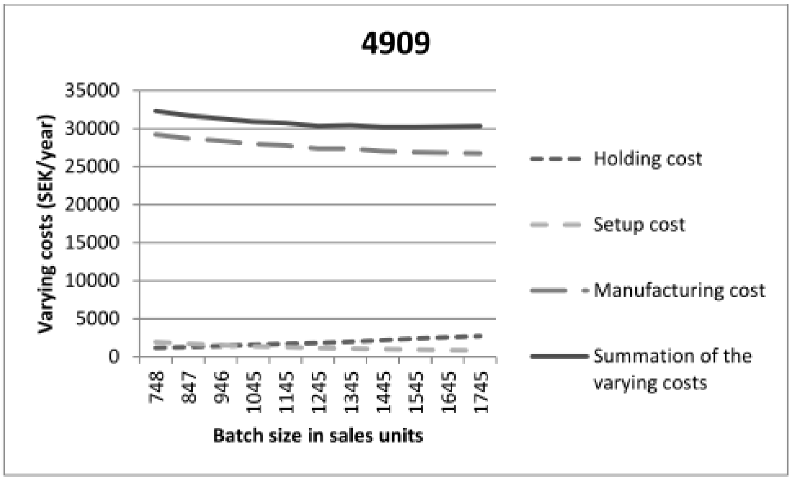
Graph 51: The varying cost for product 4906



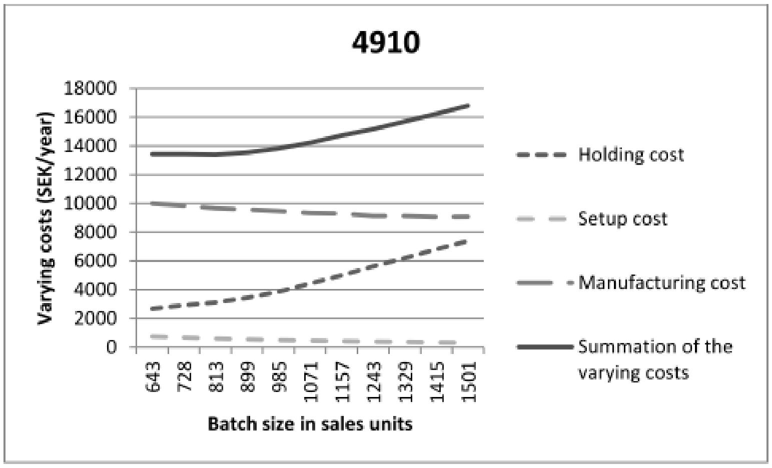
Graph 52: The varying cost for product 4907



Graph 53: The varying cost for product 4908



Graph 54: The varying cost for product 4909

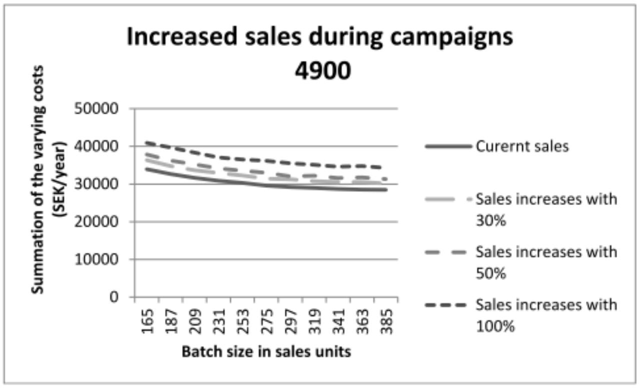


Graph 55: The varying cost for product 4910

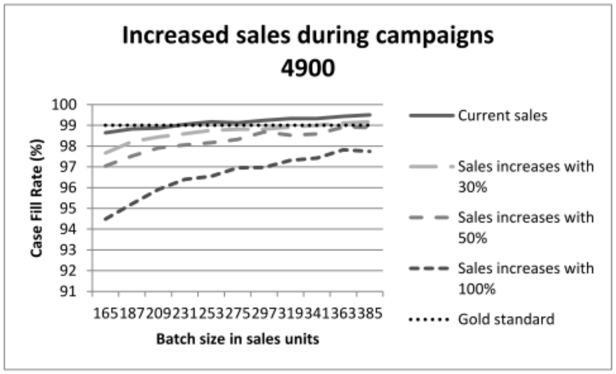
Appendix 5

The results of the different scenarios in the sensativity analysis for the investigated products 4900, 4901, 4906 and 4907.

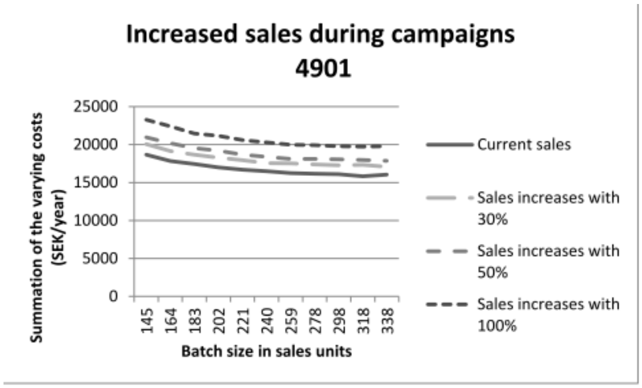
Unexpected increasing of sales during campaigns



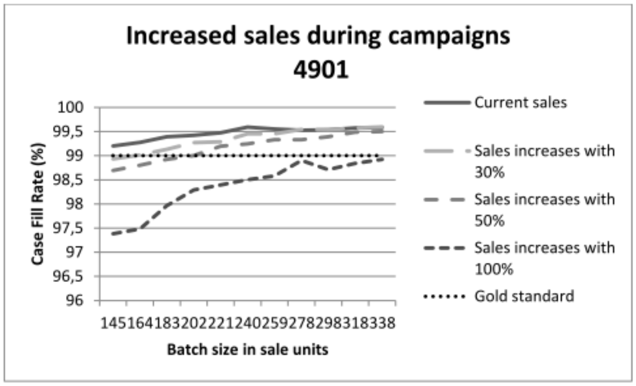
Graph 56: Varying costs for different batch sizes when there are unexpected sales during campaigns



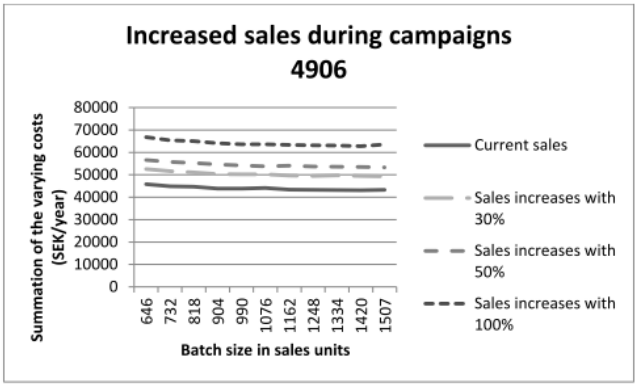
Graph 57: Case Fill Rates for different batch sizes when there are unexpected sales during campaigns

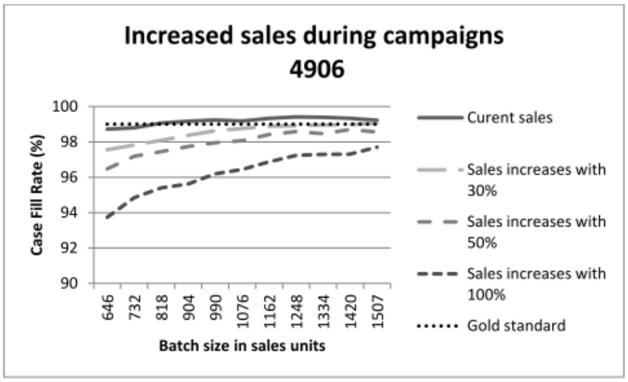


Graph 58: Varying costs for different batch sizes when there are unexpected sales during campaigns



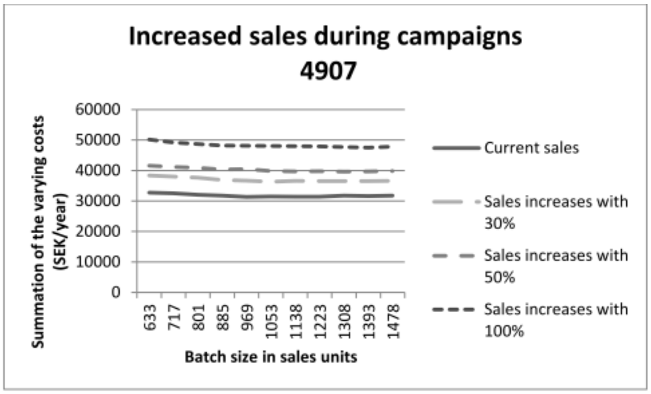
Graph 59: Case Fill Rates for different batch sizes when there are unexpected sales during campaigns

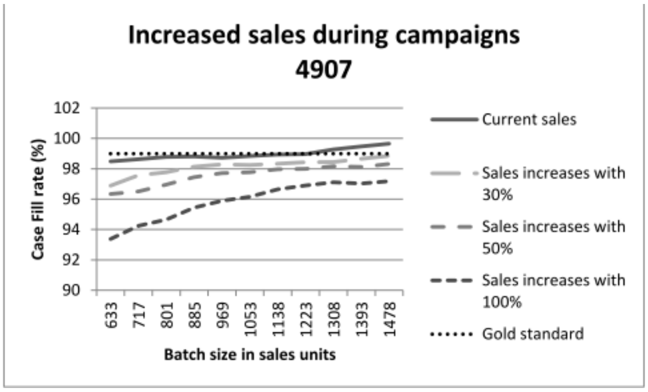




Graph 60: Varying costs for different batch sizes when there are unexpected sales during campaigns

Graph 61: Case Fill Rate for different batch sizes when there are unexpected sales during campaigns

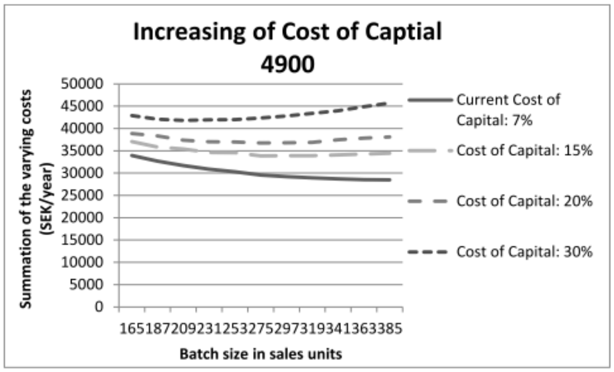


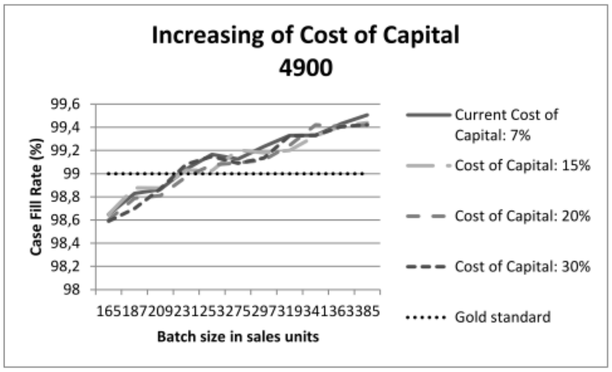


Graph 62: Varying costs for different batch sizes when there are unexpected sales during campaigns

Graph 63: Case Fill Rates for different batch sizes when there are unexpected sales during campaigns

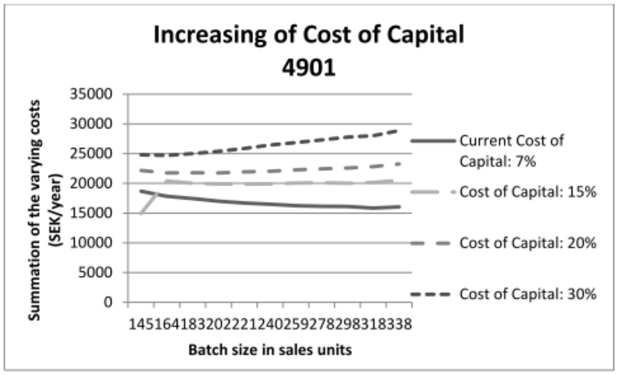
Increasing of the Cost of Capital



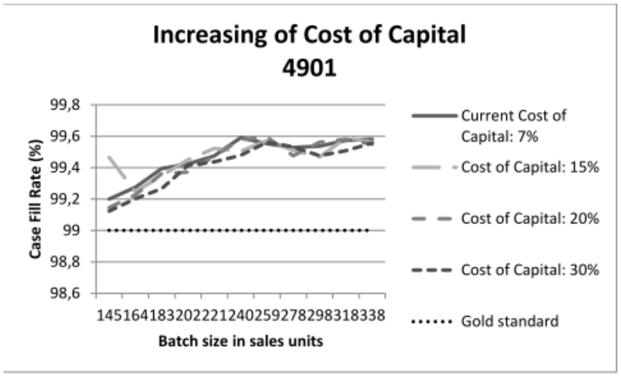


Graph 64: Varying costs for different batch sizes when the Cost of Capital increases

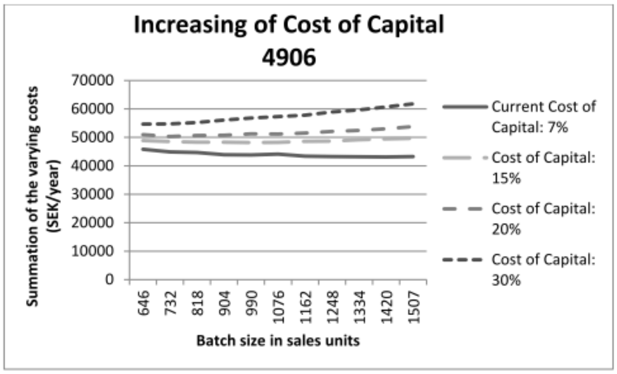
Graph 65: Case Fill Rates for different batch sizes when the Cost of Capital increases



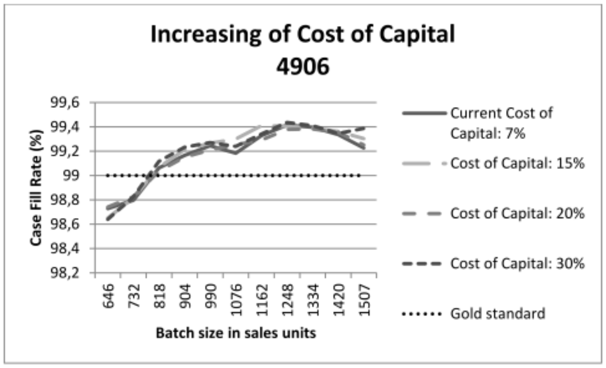
Graph 66: Varying costs for different batch sizes when the Cost of Capital increases



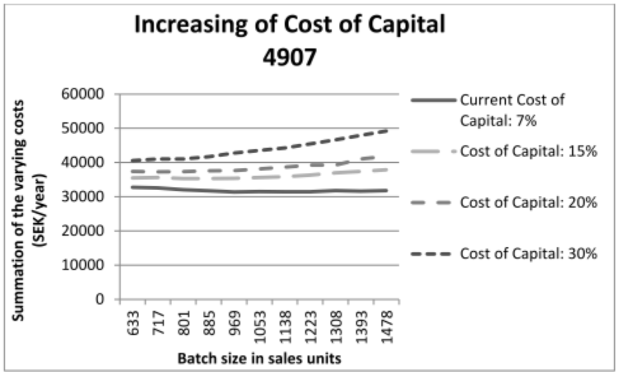
Graph 67: Case Fill Rates for different batch sizes when the Cost of Capital increases



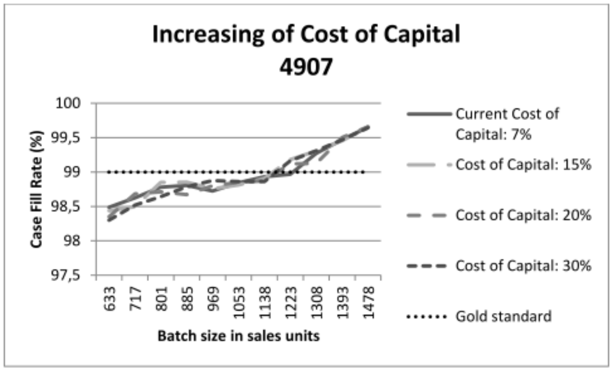
Graph 68: Varying costs for different batch sizes when the Cost of Capital increases



Graph 69: Case Fill Rates for different batch sizes when the Cost of Capital increases

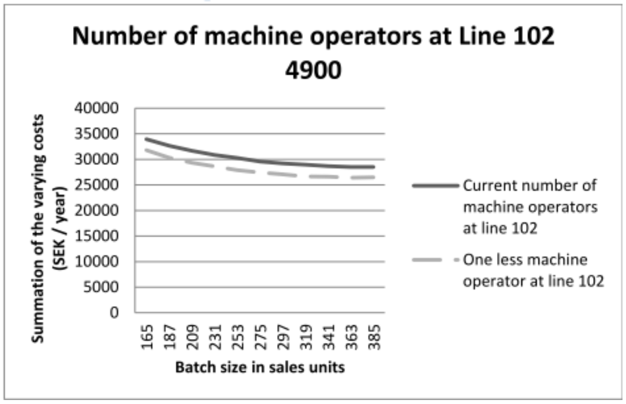


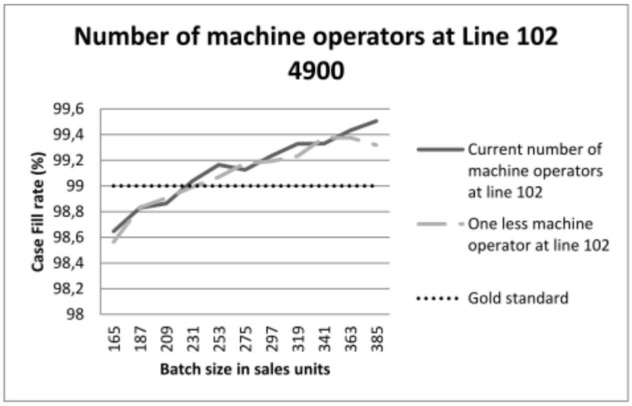
Graph 70: Varying costs for different batch sizes when the Cost of Capital increases



Graph 71: Case Fill Rates for different batch sizes when the Cost of Capital increases

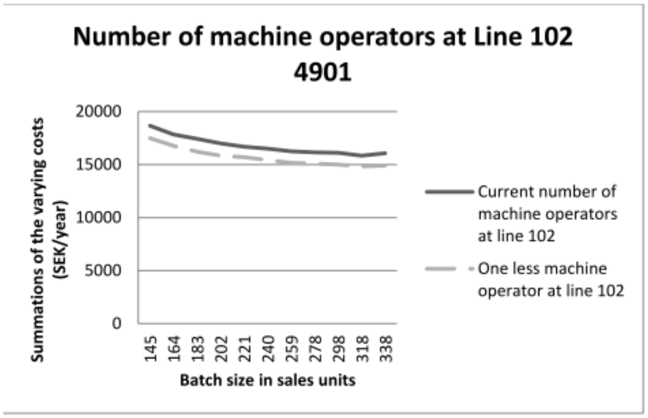
One less machine operator at line 102

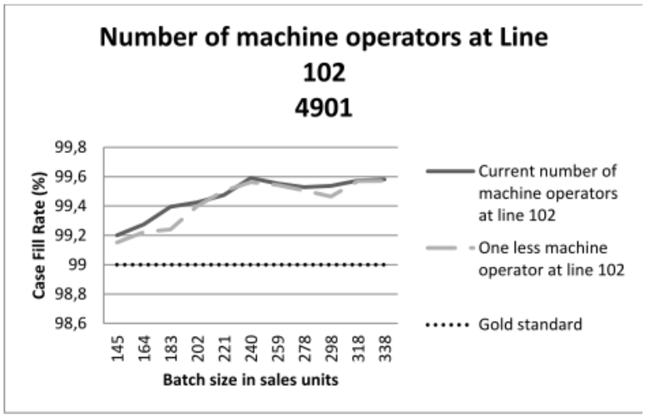




Graph 72: Varying costs for different batch sizes when there is one less machine operator at Line 102

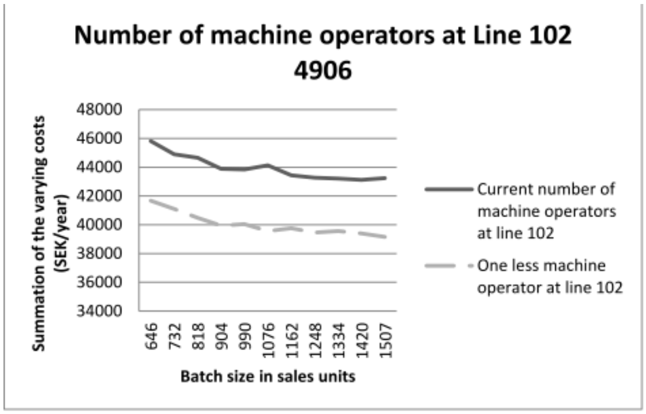
Graph 73: Case Fill Rates for different batch sizes when there is one less machine operator

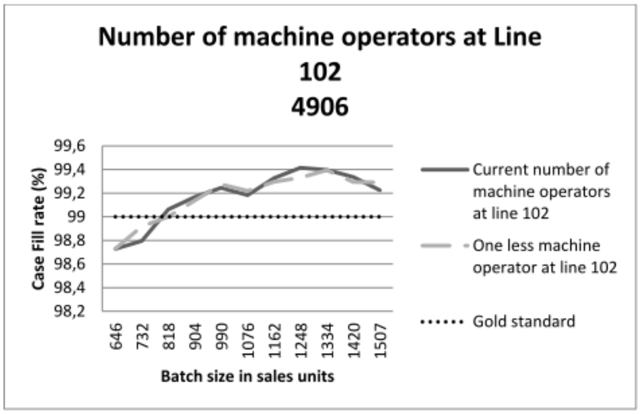




Graph 74: Varying costs for different batch sizes when there is one less machine operator

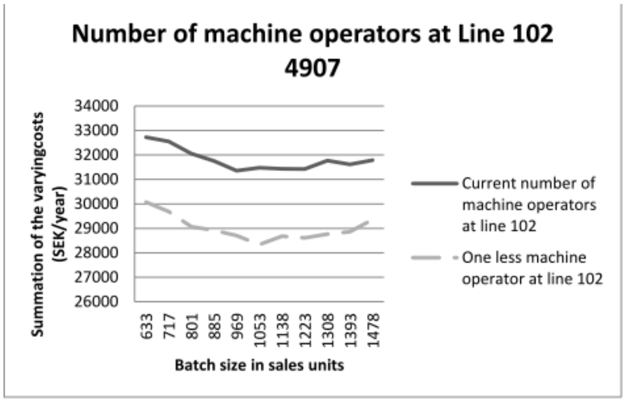
Graph 75: Case Fill Rates for different batch sizes when there is one less machine operator

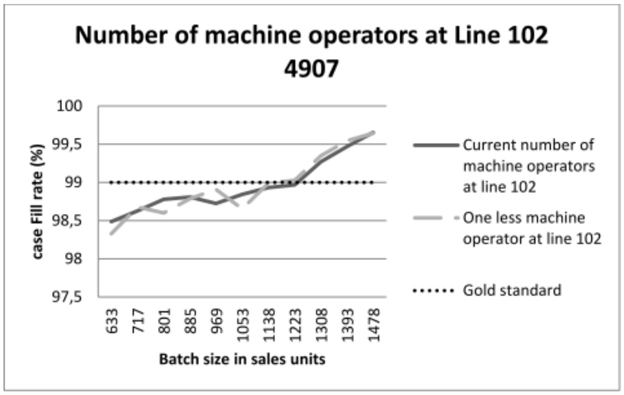




Graph 76: Varying costs for different batch sizes when there is one less machine operator

Graph 77: Case Fill Rates for different batch sizes when there is one less machine operator

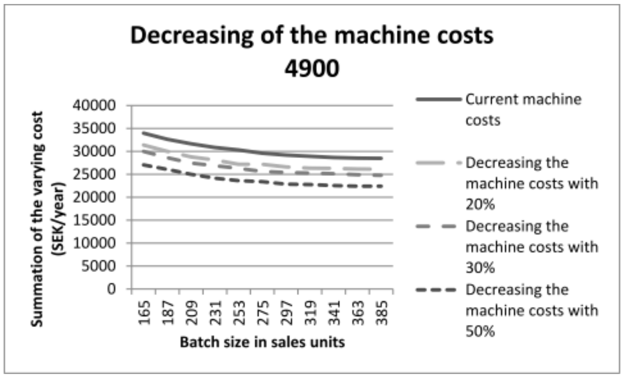


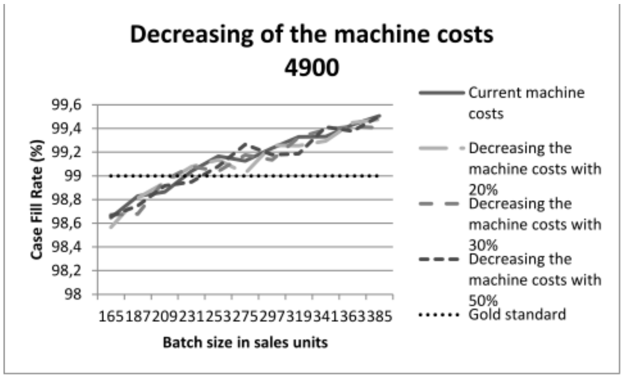


Graph 78: Varying costs for different batch sizes when there is one less machine operator

Graph 79: Case Fill Rates for different batch sizes when there is one less machine operator

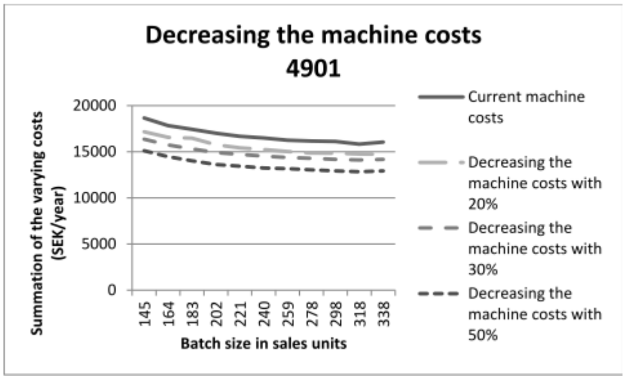
Decreasing of the machine costs

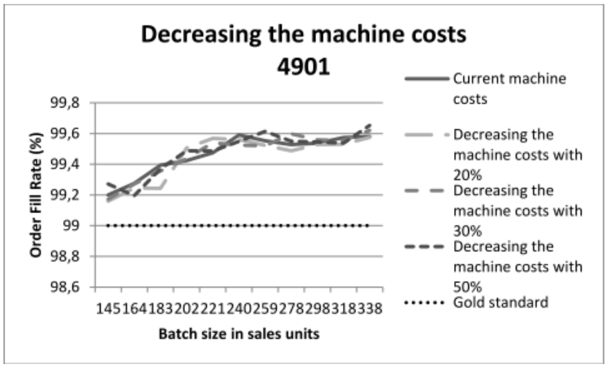




Graph 80: Varying costs for different batch sizes when the machine costs decreases

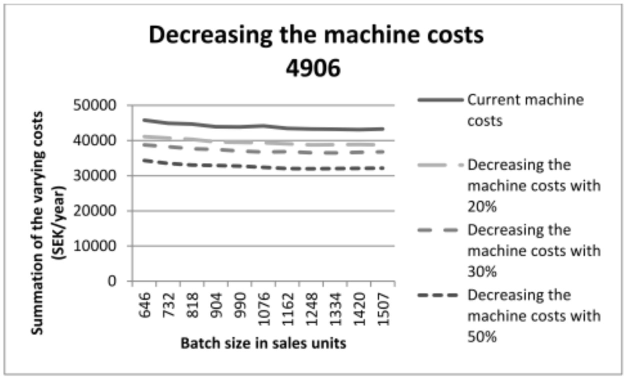
Graph 81: Case Fill Rates for different batch sizes when the machine costs decreases

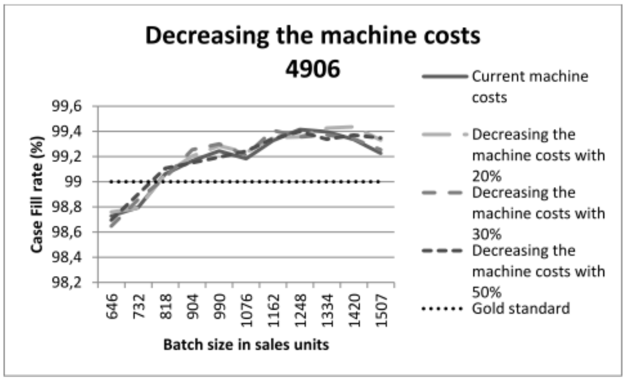




Graph 82: Varying costs for different batch sizes when the machine costs decreases

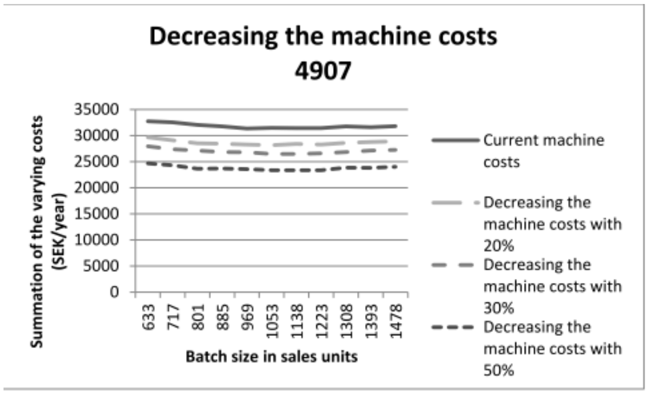
Graph 83: Case Fill Rates for different batch sizes when the machine costs decreases

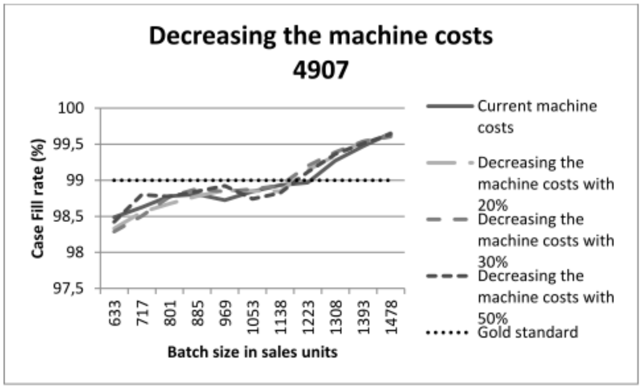




Graph 84: Varying costs for different batch sizes when the machine costs decreases

Graph 85: Case Fill Rates for different batch sizes when the machine costs decreases

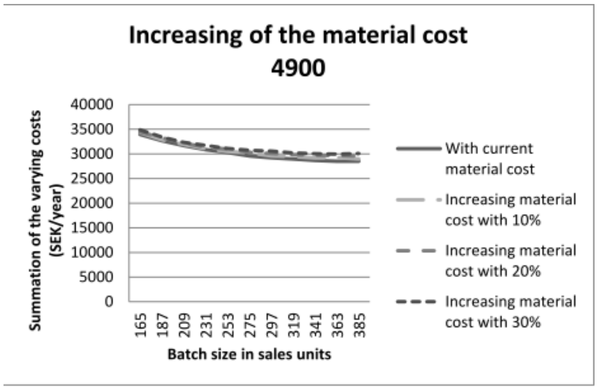


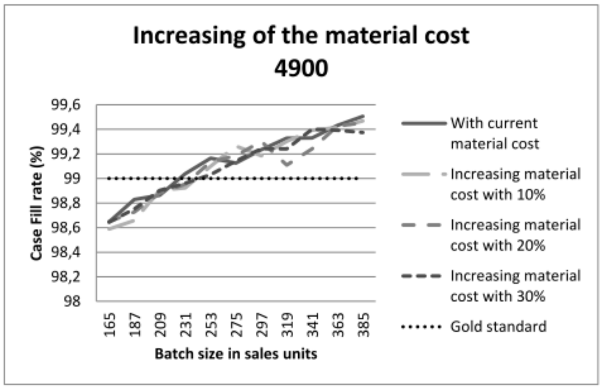


Graph 86: Varying costs for different batch sizes when the machine costs decreases

Graph 87: Case Fill Rates for different batch sizes when the machine costs decreases

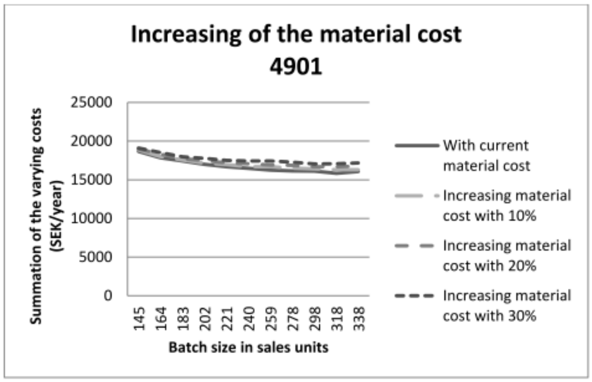
Increasing of the material costs

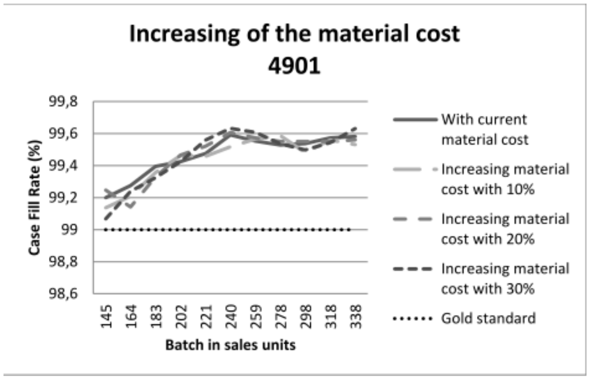




Graph 88: Varying costs for different batch sizes when the material costs increases

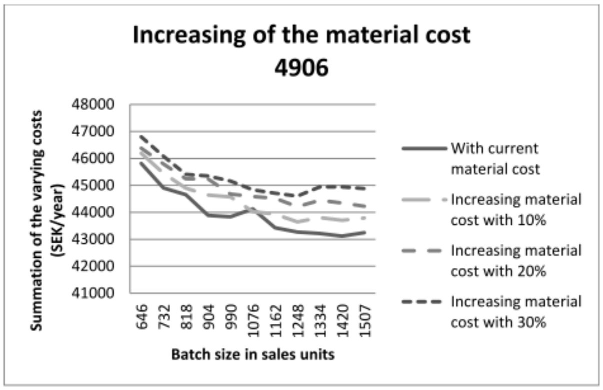
Graph 89: Case Fill Rates for different batch sizes when the material costs increases

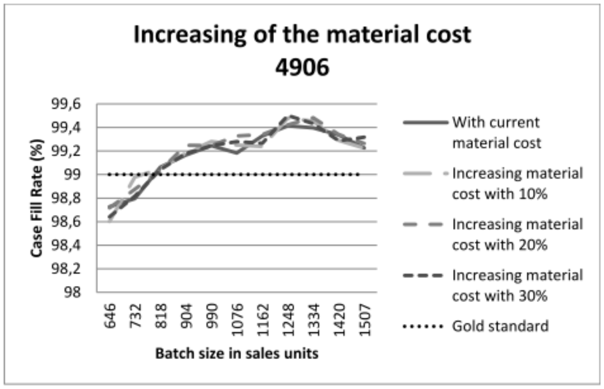




Graph 90: Varying costs for different batch sizes when the material costs increases

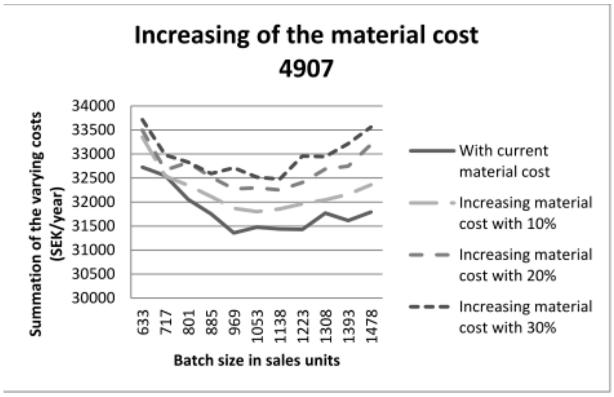
Graph 91: Case Fill Rates for different batch sizes when the material costs increases

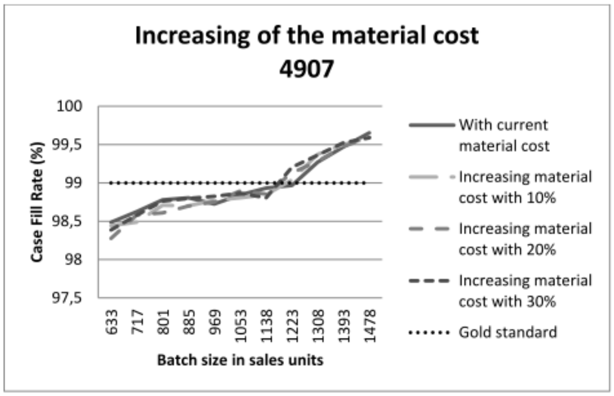




Graph 92: Varying costs for different batch sizes when the material costs increases

Graph 93: Case Fill Rates for different batch sizes when the material costs increases

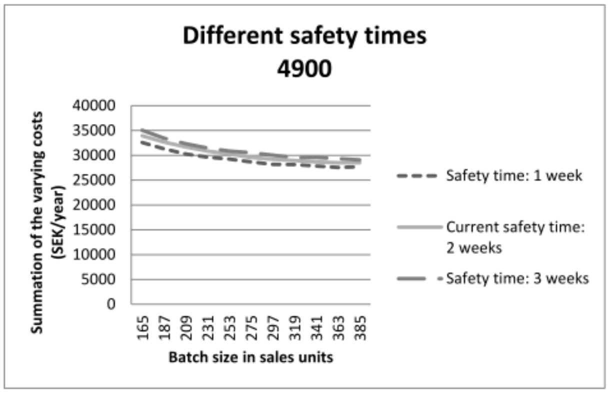




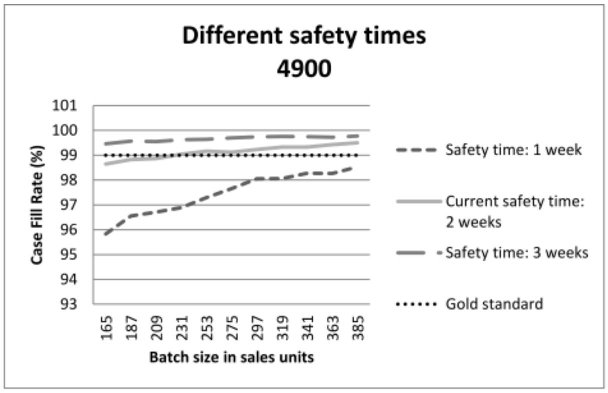
Graph 94: Varying costs for different batch sizes when the material costs increases

Graph 95: Case Fill Rate for different batch sizes when the material costs increases

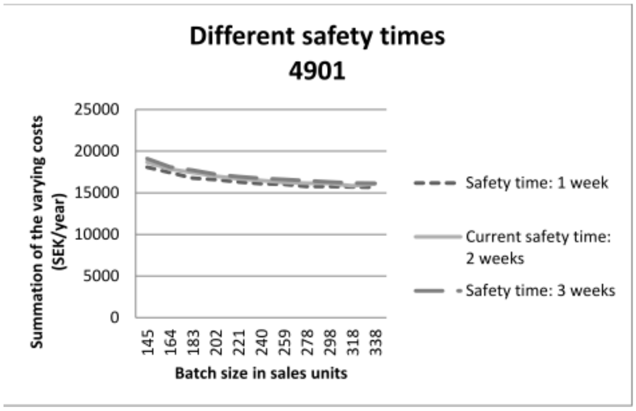
Different safety times for the inventory of finished products



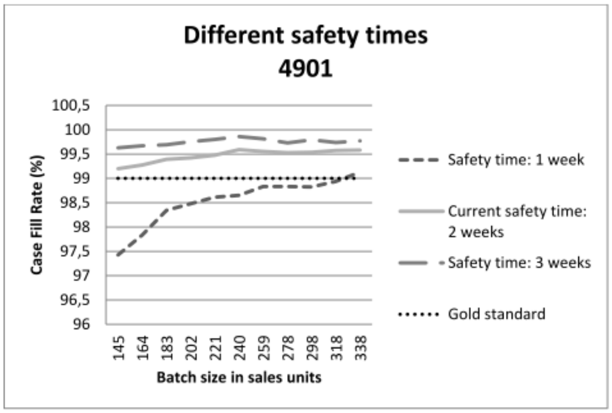
Graph 96: Varying costs for different batch sizes with different safety times



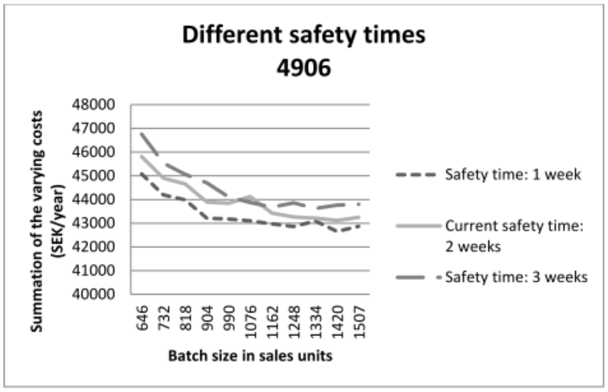
Graph 97: Case Fill Rates for different batch sizes with different safety times



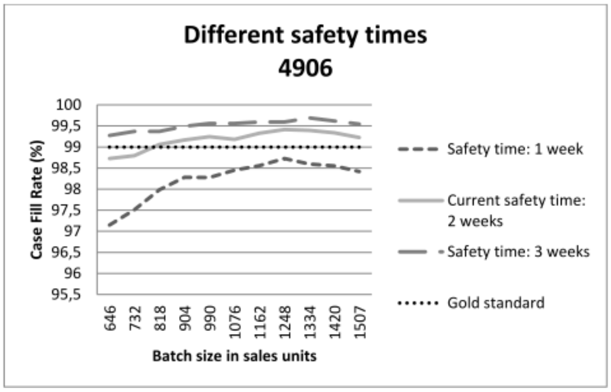
Graph 98: Varying costs for different batch sizes with different safety times



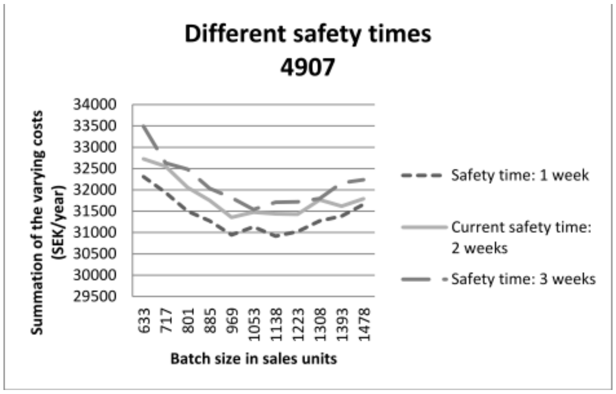
Graph 99: Case Fill Rates for different batch sizes with different safety times

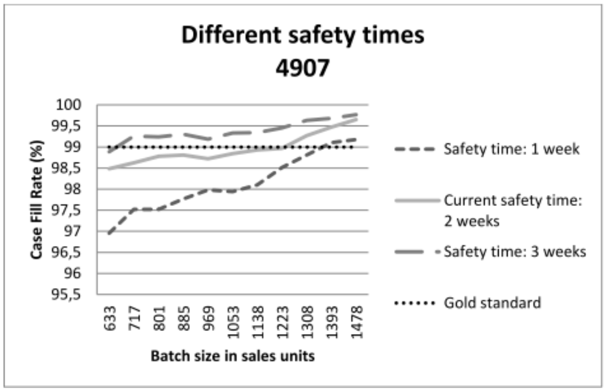


Graph 100: Varying costs for different batch sizes with different safety times



Graph 101: Case Fill Rates for different batch sizes with different safety times

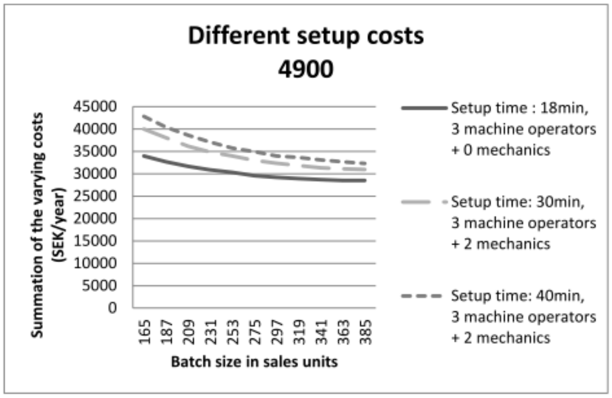


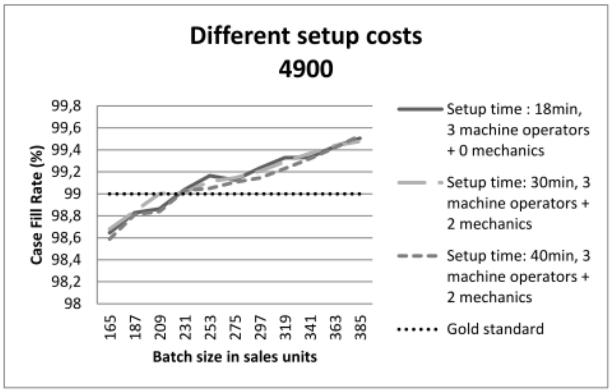


Graph 102: Varying costs for different batch sizes with different safety times

Graph 103: Case Fill Rates for different batch sizes with different safety times

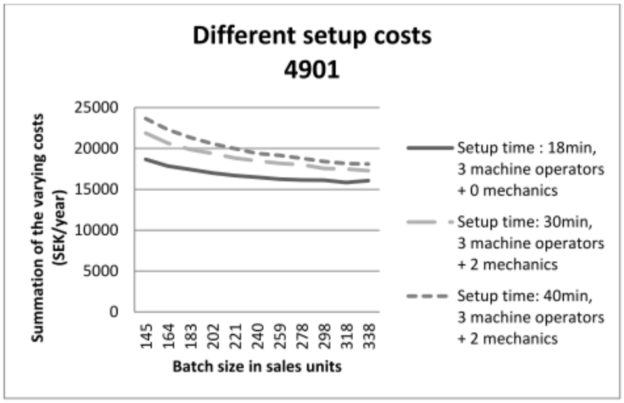
Different setup costs

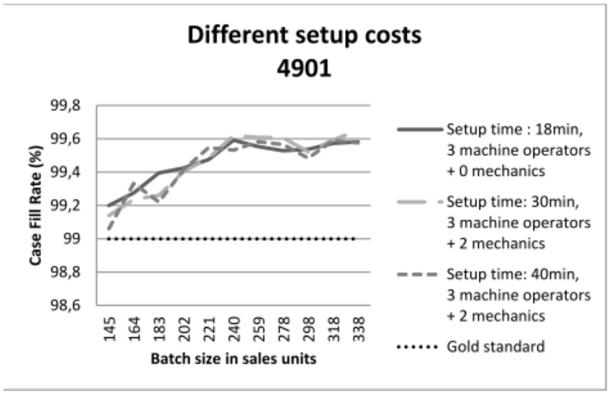




Graph 104: Varying costs for different batch sizes with different setup costs

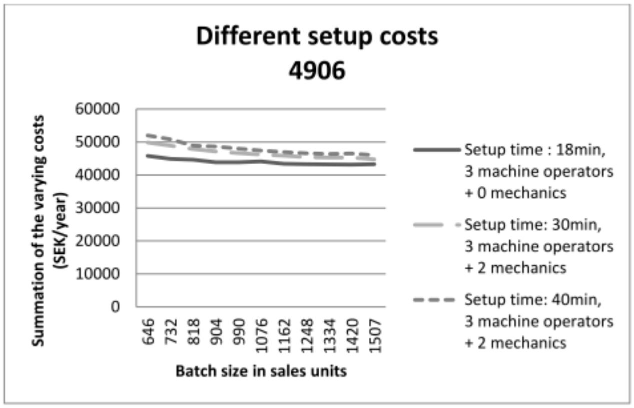
Graph 105: Case Fill Rates for different batch sizes with different setup costs



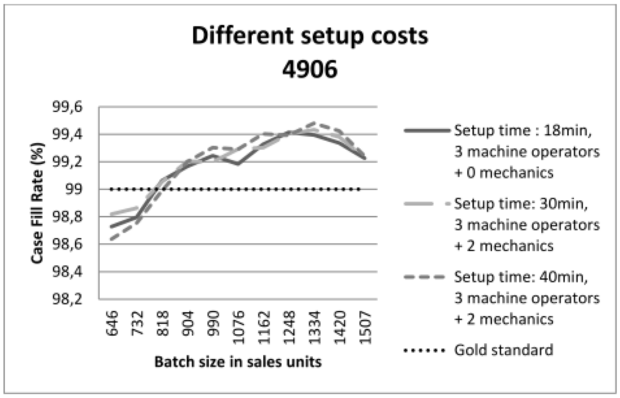


Graph 106: Varying costs for different batch sizes with different setup costs

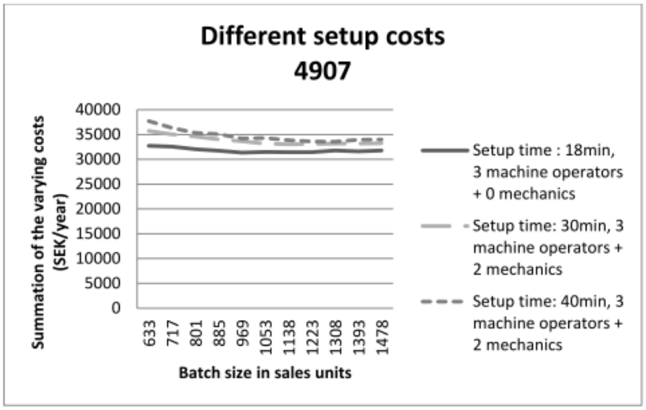
Graph 107: Case Fill Rate for different batch sizes with different setup costs



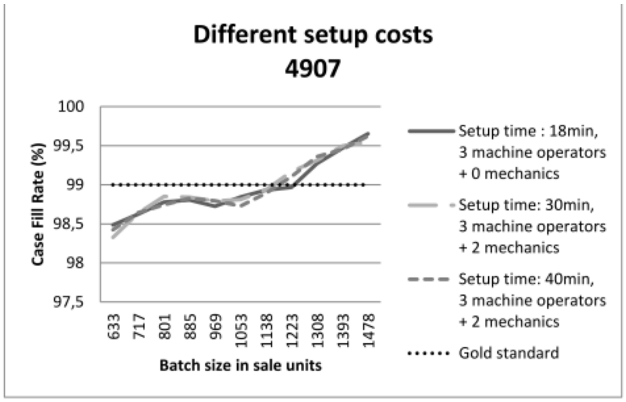
Graph 108: Varying costs for different batch sizes with different setup costs



Graph 109: Case Fill Rates for different batch sizes with different setup costs



Graph 110: Varying costs for different batch sizes with different setup costs



Graph 111: Case Fill Rates for different batch sizes with different setup costs