Inventory management in a customer landscape with diverse requirements on flexibility

A case study at Atria Sweden AB

Master Thesis in Production Management - MIOM01

Spring 2019

Authors:
Annika Fredriksson
Andreas Pettersson
Supervisors:
Johan Marklund, LTH
Kenneth Karlsson, Atria Sweden AB
Examinator:
Peter Berling, LTH

II

Acknowledgements

Abstract

Title
Inventory management in a customer landscape with diverse requirements on flexibility - A case study at Atria Sweden AB.

Course
Degree Project in Production Management – MIOM01.

Authors
Annika Fredriksson and Andreas Pettersson.

Supervisor
Johan Marklund.

Background and Research Question
Atria Sweden AB manufactures meat products towards both the Swedish and Danish markets. As a result of the different products and customer requirements, Atria applies different manufacturing strategies towards the different products. Atria has access to reliable forecasts and regular orders from the Swedish market, making it possible to manufacture these products towards stock. From the Danish market forecasts are currently unreliable and orders are not as frequent when compared to the Swedish market. Therefore, Danish products are manufactured based on customer orders and Atria wants to be flexible enough to satisfy customer demand and achieve targeted service levels. Atria has increased their efforts in information gathering by actively collecting demand data from customers when available to improve their demand forecast. Atria wants to investigate how their processes can be improved to increase overall flexibility to satisfy customer demand.

Methodology
The study has been conducted using an abductive research approach. Thus, both qualitative and quantitative data was collected to analyze the research question. Quantitative data was collected through the database at Atria, this data was complemented with qualitative data collected through semi-structured interviews.

Theoretical Framework
This study is based on established scientific literature in the area of inventory management.

V

Conclusion

This study has shown that flexibility and service levels can be improved for specific products by implementing an (R, Q) – policy. Additionally, the expected service level can be calculated assuming accurate knowledge of the demand. By calculating the fill rate of the gamma distributed demand, the service levels can be estimated.

Keywords

Inventory management, fill rate, gamma distribution, MTS, MTO, (R, Q) – policy, food industry, perishable goods, reorder points, process analysis.

Sammanfattning

Titel

Lagerstyrning i ett kundladskap med olika krav på flexibilitet – En fallstudie på Atria Sverige AB

Kurs

Examensarbete i produktionshantering– MIOM01

Författare

Annika Fredriksson och Andreas Pettersson

Handledare

Johan Marklund

Bakgrund och Syfte

Atria Sverige AB tillverkar köttprodukter till den svenska och danska marknaden. Atria tillämpar olika produktionsstrategier mot de olika produkterna då produkter och kunder sätter olika krav på tillverkningen. Atria har tillgång till pålitliga prognoser samtidigt som kundorder ankommer relativt frekvent från den svenska marknaden. Detta gör det möjligt för Atria att tillverka svenska produkter mot lager. Från den danska marknaden är prognoser relativt opålitliga och kundorder ankommer inte lika frekvent jämfört med den svenska marknaden. Därför tillverkar de danska produkterna direkt mot kundorder. Atria vill vara flexibla nog att kunna möta kundernas efterfrågan samt nå uppsatta servicemål. Arbeten har påbörjats för att förbättra prognoser genom att samla mer information från kunders efterfrågan där det finns möjligheter. Atria vill undersöka hur deras processer kan förbättras för att öka deras flexibilitet och möta kundernas efterfrågan.

Metodologi

Detta är en abduktiv studie där både kvalitativa och kvantitativa data har samlats och analyserats för att besvara studiens syfte. Kvantitativa data har samlats från Atrias databas, denna data har kompletterats med kvalitativa data som samlats från semi-strukturerade intervjuer.

Teoretisk bakgrund

Denna studie är baserad på etablerad vetenskaplig litteratur inom lagerhantering och lagerstyrning.

Slutsats

Denna studie har visat att flexibilitet och service kan förbättras för några av produkterna genom att implementera en (R, Q) – policy. Den uppnådda servicenivån kan även beräknas givet en god kunskap om efterfrågan. Genom att beräkna fyllnadsgraden för en gammafördelad efterfrågan kan servicenivåer uppskattas.

Nyckelord

Inventory management, fill rate, gamma distribution, MTS, MTO, (R, Q) – policy, food industry, perishable goods, reorder points, process analysis.

List of figures

List of tables

Table of contents

1. Introduction

This first chapter will introduce the background, problem description and purpose of this thesis as well as a discussion of the delimitations of this work.

1.1 Background

It is easy to be confused as a manufacturing manager these days, since they are overwhelmed by manufacturing tools and philosophies from books, web sites, courses and other sources. Many manufacturers often describe their own manufacturing philosophy with buzzwords such as MRP, JIT, TQM and BRP. The issue with this development is that these buzzwords attempt to sell a single solution that is meant for all situations. Therefore, they cannot account for what works in each situation, which can lead to less than optimal performance in manufacturing. One very valuable tool for manufacturing managers is the systems approach. By offering a holistic view of manufacturing processes and supporting a clear link between company policies and objectives, systems analysis is a logical foundation for problem solving in operations and production management (Hopp and Spearman, 2008).

Atria Oyj is a Finish food industry company, their market is divided into four areas which are: Atria Finland, Atria Sweden, Atria Denmark & Estonia, and Atria Russia. The main focus of this work is Atria Sweden, a food manufacturer with their core focus on meat products, cold cuts, convenience food, poultry products and vegetable & fresh delicatessen products. Of these products the cold cut category is manufactured for both the Swedish and the Danish markets with certain brands dedicated to each of the two markets. This is the solution for the factory located in Malmö where several brands of cold cut products are manufactured.

As a manufacturer of food products Atria has high customer requirements on their products regarding the shelf life and the service level of their manufactured goods. If Atria does not manage to reach the agreed to service levels, then they are penalized by their customer with costly fines.

1

1.2 Problem Description

Despite the proximity, Swedish and Danish markets are different in terms of customer requirements. Atria allows customers to make changes to order quantities close to the delivery date, the timeframe in which customers are allowed to change their orders depend on which market they belong to. Customers from the Swedish market orders products 1-2 days before actual delivery. Atria manages to handle the Swedish marked with a *make to stock* (MTS) policy since they have access to reliable demand forecasts from this market. Additionally, demand from the Swedish market is very frequent and shipments depart from the finished goods warehouse every day. In contrast, Danish customers' orders 7 working days before Atria delivers these orders. Atria is unable to handle the Danish market through an MTS policy since forecasts from this market are currently unreliable. In comparison to the Swedish market, the orders are not as frequent as well. Additionally, Atria is only allowed to use a maximum of 5 days of the finished goods shelf-life before customers receive their products. Therefore, the Danish market is handled through a *make to order* (MTO) policy or a combination of MTO and MTS. More precisely manufacturing aims to cover the forecasted week through stock but mostly they try to manufacture towards customer orders. Occasionally they can also receive orders that exceed the production capacity of the factory in Malmö. This can sometimes be difficult to communicate to the customers, and they are still expected to produce according to customers' expectations. One reason for the customers' lack of understanding may be that Atria's production in Denmark is very flexible and has a more responsive strategy to manufacturing. In Sweden, Atria's factories are more oriented towards efficient resource utilization.

Promotion horizon is another factor that differs between the countries, which complicates the production planning further. From their Swedish customers Atria is afforded a four weeks' notice while their Danish customers provide information regarding their promotions two weeks in advance. This unpredictability and required flexibility create a need for Atria to use a flexible working staff. The ones from the staff that are needed for the current week are

called upon a few days in advance. For the workers this means a lot of uncertainty as to how much they will work each month in the cutting department. Their wages are based on how many hours they work. A large pool of flexible workers introduces problems when workers suddenly turn in sick resulting in understaffing. Overstaffing can also occur if too many flexible workers are called at the same time to meet short term production needs. However, a flexible production is something that is needed when dealing with the Danish market. Therefore, the flexible workers are a valuable resource. The conflict that arises from supplying two different markets with different requirements on flexibility has so far put a lot of pressure on manufacturing. By studying the manufacturing and inventory management processes at Atria, it should be possible to discern how flexibility and performance can be improved for the Danish products specifically.

The information flow and the order decisions are depicted in Figure 1. Since order information must travel through several departments there may be information delays affecting the production planning.
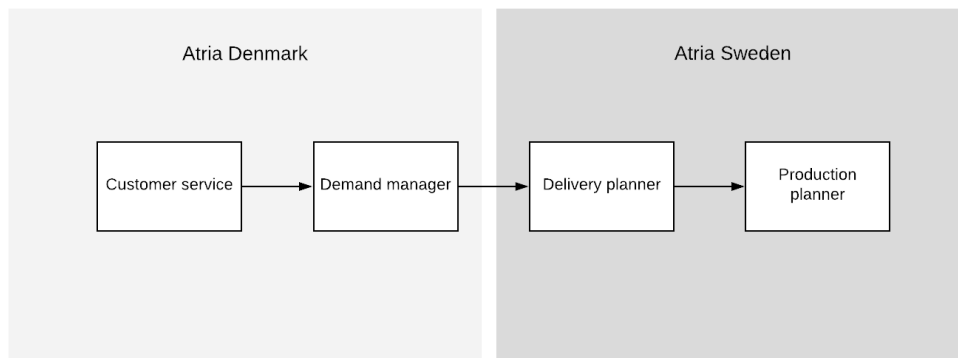
Figure 1: Flow of customer order information

1.3 Purpose

The purpose of this study is to investigate the current production planning and inventory management processes at Atria's factory in Malmö and suggest improvements. The goal is to better meet targeted service levels with as little inventory as possible.

3

1.4 Delimitations

Atria is a large company with manufacturing located in several European countries, the manufacturing strategies can vary between factories. Therefore, in order to reduce the complexity of this study, only the manufacturing in one country will be addressed.

Furthermore, Atria has several manufacturing facilities in Sweden, and at these facilities the products produced for the Danish market varies. The different facilities do not have a common production planning process. As this is the case, the scope of this study will be further narrowed to the production planning process in Malmö. More specifically, the study will focus on the production lines in the Malmö factory that are dedicated to produce for the Danish market.

2. Methodology

This study will be performed in two steps; Process Analysis and, Operations Research Modeling. The process analysis step is used to identify where improvements can be made for flexibility and operational performance. Then the operations research modeling approach is used to analyze the current performance and then improve these identified areas and provide a useful model for the company.

2.1 Research Approach

With the research question in mind a balanced approach, utilizing both qualitative and quantitative data methods have been selected. The goal of the qualitative approach is to "understand the phenomenon in its own terms" while the quantitative approach has the goal of "adding to the body of knowledge by constructing a formal theory that explains, predicts and controls the phenomenon in question". As the qualitative approach utilizes inductive reasoning by nature and the quantitative approach using deductive reasoning, the balanced approach combines both and is abductive in nature (Kotzab et al., 2005).

Mapping the production planning process will utilize qualitative methods to facilitate understanding of the processes. Quantitative methods will be used to develop a mathematical model that will act as a decision support tool.

2.2 Process Mapping

Process mapping allows for uncovering and capturing of knowledge from people and processes in organizations. It is a technique that is widely adapted for improvement and development in organizations (White and Cicmil, 2016). The production planning process will be mapped using interviews of involved managers (listed under recourses) and observations at Atria Malmö.

In order to map the production and planning process for the products in question, a record of the relevant activities must be identified. Data should be captured at the lowest level possible as this can be aggregated into activities and processes (Whicker et al., 2009). The output at this stage will be a map

detailing the activities in the production and planning processes that will serve to facilitate understanding of the internal processes at Atria.

The mapping process begins by physically walking through the process from beginning to end along with each process/activity owner. This is essential to gain firsthand understanding of the activities in the process and of the time and resources they require. Identifying changes in the product is also essential, especially in processes involving food. For instance, the measured units may change along the production process (e.g. from 1kg of cooked meat to a package of 100g). Once the process map has been drawn, additional interviews are required with the process owners and final adjustments must be made to ensure the validity of the process map (Whicker et al., 2009).

2.3 Operations research modeling approach

Secondly the methodology applied in this thesis project will be based on the six phases of the Operations research modeling approach described by Hillier and Lieberman (2010). Each phase will be elaborated on in this section.

1. Defining the problem and gathering data (including mapping of the current processes)
2. Formulating a mathematical model
3. Deriving solutions from the model
4. Testing the model
5. Preparing to apply the model
6. Implementation

However, the last two steps will not be carried out due to the nature of this study. It is not possible for the authors of this thesis to prepare for application nor to implement it at Atria. How these steps may be performed will still be discussed in this section so the information can be used by Atria.

2.3.1 Define the problem and gather data

By studying the system, a statement of the problem can be developed, including e.g. ascertaining the appropriate objectives, constraints, interrelationships and time limits. These objectives should be as specific as they can be while still encompassing the main goals and having a reasonable degree of consistency with the organization's decision makers. The study consists of a detailed technical analysis of the problem and then a report is made that identifies different alternative solutions under different assumptions and values. The solutions should not be suboptimal, meaning that they are best for only one component, they should be optimal for the overall organization. Then management evaluates the report and makes the final decision (Hillier and Lieberman, 2010).

One possible approach to avoid sub optimization is to use long-run profit maximization as the sole objective. However, profit-making organizations do not use this in actual practice, they tend to adopt the goal of satisfactory profits, combined with other objectives (Hillier and Lieberman, 2010).

There are five parties that are generally affected by a business firm located in a country, who needs to be understood:

1. The owners, who desire profits
2. The employees, who desire steady employment at reasonable wages
3. The customers, who desire a reliable product at a reasonable price
4. The suppliers, who desire integrity and a reasonable selling price for their goods
5. The government and nation, which desire payment of fair taxes and consideration of national interests

Considerable time will be spent trying to improve the precision of all the data needed to accurately understand the problem and provide the needed input for the mathematical model (Hillier and Lieberman, 2010). In this project the time is limited, therefore the hours will have to be properly distributed.

7

2.3.1.1 Data Gathering Methods

When data is gathered it is crucial to validate this in any project, even if you have a perfect model it will not produce a valid conclusion if the data used is invalid. Because of this, data is usually grouped as either primary or secondary data.

Primary and Secondary data

Primary data means that data has been collected with a specific hypothesis in mind. The validation of this data starts as it is recorded. As observations are recorded, they are classified as primary data. Secondary data in contrast means that data have not been collected with a specific hypothesis in mind. This data was recorded for other purposes and not specifically for the research project. Secondary data could have been originally collected for management purposes, administration, surveillance or control functions (Emanuelson and Egenvall, 2014).

In this study, data will be collected using several different approaches. In order to grasp the context and processes of the research subject, interviews will be conducted with the people involved in the processes in and surrounding the research subject. The data and information gathered through this method will be more qualitative in nature but inquires of quantitative data will also be made. The interview guide can be viewed in Appendix 1. Data will also be captured from the different information systems used by Atria, this raw data is purely quantitative. A third method of collecting data is also required in order to find quantitative data not yet measured by Atria, as well as qualitative information that may be overlooked by interviewees. In order to capture this data, observations and measurements are performed on site with access to the company processes.

Resources

In order to carry out this master thesis, an understanding of Atria's processes is needed, access to historical data regarding production planning, customer orders, KPI (service levels historically, scraps) are required. To gain access to this information, it will be necessary to contact staff in both the Swedish and

Danish organizations and discuss the manufacturing and surrounding processes with them.

The logistics manager at Atria Sweden has served as a contact person and supervisor for this thesis. He facilitated contacts with all the persons needed together with the HR manager. They scheduled timeslots for semi-structured interviews with the production manager, production planner and delivery planner on the Swedish side of the organization as well as the demand manager and customer service on the Danish side. Apart from access to these people and their information, no other resources were provided from Atria Sweden, but several study visits have been done.

2.3.2 Mathematical problem formulation

Once the problem is defined, a mathematical model can be constructed to analyze the problem. Mathematical models are advantageous to verbal descriptions of problems in that they describe the problem very concisely and the structure of the problem becomes more comprehensible. The mathematical model also makes cause-and-effect relationships more visible and could indicate where additional data is needed (Hillier and Lieberman, 2010).

The gathering of relevant data for the mathematical model can often be a difficult task. Often out of necessity, the values of some parameters are rough estimates. The reason for this could be the uncertainty or large variation of the real value. In order to take this into account in the mathematical analysis a sensitivity analysis can be performed. A sensitivity analysis shows what happens to the solution of the model if the parameters change. For real world problems it is preferable to seek solutions that are not sensitive to parameters that are uncertain or expected to vary. The mathematical model will first be developed in a very simple version and then successively refined until it adequately characterizes the real-world problem (Hillier and Lieberman, 2010).

2.3.3 A computer-based procedure that derives solutions

After a mathematical model has been formulated representing the problem, a computer-based procedure needs to be developed to derive solutions from said

model. The optimal solutions that are derived from this model are not necessarily optimal in the real world. This needs to be recognized since the mathematical model is by necessity an idealized representation of the real situation. Therefore, the practical implications and success of the model needs to be studied (Hillier and Lieberman, 2010).

Since satisfaction and optimization may be impossible to achieve simultaneously goals are established to fit levels of performance in different areas. If a solution that satisfies all set goals is found, then it is in many cases likely to be adopted (Hillier and Lieberman, 2010).

Considering that the optimal solution for the problem may be different from the real problem, a post optimality analysis will be performed. This analysis involves a what-if analysis, which addresses what would happen if some assumptions about the problem changed. A sensitivity analysis is also involved in this post optimality analysis. In a sensitivity analysis the most sensitive parameters are investigated in the discovered solution. A sensitive parameter is a value which if changed will also change the optimal solution. This also means that the sensitivity analysis will reveal what values need to be known rather than estimated (Hillier and Lieberman, 2010).

In the post optimality analysis, weaknesses in the solutions are used to suggest improvements in the model. This is done iteratively until improvements become too minor to warrant further analysis (Hillier and Lieberman, 2010).

2.3.4 Test and refine the model

The first iteration of the mathematical model will most likely contain some flaws. The reasons are that relevant factors and interrelationships are often missing and must be identified and incorporated into the model. Identification of flaws in the model is done primarily through testing of the model. The model is also checked for general issues and mistakes for instance that dimensions and units are used consistently without any discrepancies. This is part of the model validation process (Hillier and Lieberman, 2010).

The model will also be used in conjunction with historical data in a retrospective test. This test is used to measure the performance of the model had it been used previously. This means using the production planning model to construct solutions based on previous order data, analyzing the results and comparing these results to the historical results at Atria. One downside to retrospective testing is that the past does not necessarily represent the future. To mitigate this as much as possible, new and updated data will be used to test the model further with data that was unavailable during the construction of the model (Hillier and Lieberman, 2010).

2.3.5 Prepare for the application of the model

When the testing phase has been completed and an acceptable model has been developed, the next step is to install a well-documented system for applying the model as prescribed by management. The system will include the model, solution procedure and operating procedures for implementation and is usually computer-based. Furthermore, a large amount of computer programs often needs to be used and integrated. When another program is applied to the model, additional computer programs may trigger the implementation of the results automatically. However, in other cases an interactive computer-based system called "a decision support system" is installed to help managers use data and models to support their decision making as needed, instead of replacing it. This installed system can then be called upon whenever to provide a specific numerical solution (Hillier and Lieberman, 2010).

In great operation research studies, several months could be required to develop, test and install this system. This is for developing and implementing a process for maintaining the system throughout its future use. As conditions change, this process should modify the system and model accordingly (Hillier and Lieberman, 2010).

2.3.6 Implement

It is not until the model is fully implemented that the benefits of the study will be gained. It is important that the team who made the study participates in the

launch, to make sure that the model solutions are accurately translated and to rectify any flaws that are uncovered. However, the key to a successful implementation is the support of both top management and operating management. This support is more likely gained if management has been kept well informed and its active guidance has been encouraged throughout the study (Hillier and Lieberman, 2010).

This final stage of implementation involves several steps:

1. The management receives an explanation, from the ones who made the study, of the new system to be adopted and how it relates to operating realities.

2. Both parties share the responsibility for developing the procedures required to put this system into operation.

3. Operating management sees to that relevant training is given to the personnel involved, and the new course of action is initiated.

If these three steps are executed successfully, the new system could be used for years. During the period where the new system is used it is important to continue to obtain feedback on how well the system is working. When significant deviations from the original assumptions occur, the model should be revised and modified. At the end of the study, it is also appropriate for the team to document its methodology clearly and accurately enough so that the work is reproducible (Hillier and Lieberman, 2010).

3. Theoretical Framework

For this project, scientific literature in operations research, production management and inventory management are relevant. A literature study was conducted in which several scientific articles and other sources was investigated.

3.1 Operations research

Operations research is fundamentally concerned with the well-being and success of the entire organization. It is a science that uses quantitative techniques for decisions by determining the most efficient way to act under given circumstances (Eiselt and Sandblom, 2013). An operations research study is thus focused on finding optimal solutions that suit the entire organization rather than suboptimal solutions to satisfy parts of the organization. Therefore, objectives should be formulated to align the research with the organizational goals. Despite the possibility of these goals being inconvenient for parts of the organization (Hillier and Lieberman, 2019).

When applying an operations research model, there are four major concerns; feasibility, optimality, sensitivity and implement-ability. Essentially questioning if it is plausible, if it is the best solution, if the unknown happens - what then, and lastly if the acquired solution is possible to implement (Eiselt and Sandblom, 2013).

3.1.1 Research with Interviews

When conducting research with interviews, valuable tools include the open-ended question and semi-structured interview. And open-ended question is a question that does not dictate the form of the answer. This allow for the interviewed participant to answer the question however they want and often allows for rich and complex accounts to be put forward. A semi-structured interview is conversational in tone with relaxed encounters and using accessible and informal language. However, what distinguishes a semi-structured interview from a conversation is the interviewer guiding the conversation using an interview guide. A second key point of difference is the asymmetrical

relationship of an interview. During an interview the interviewee is primarily the one sharing information while the interviewer guides the discussion and listens to the responses (Magnusson and Marecek, 2015).

3.2 Production Scheduling

To show graphically the relationship between planned performance and actual performance for production control, a control chart can be made. The Gantt chart is recognized as the earliest and best known, it specifies the starting point of each job, who will do the job and how long it will take. This chart combined with information technology has enhanced all types of decision-making processes and has led to a decline of shop foremen to software systems and optimization algorithms for production scheduling (Herrmann, 2006)

Production scheduling has a decision-making systems perspective, it is a part of the complex flow of information and decision-making that forms the manufacturing planning and control system (Herrmann, 2006).

3.3 Advance order information

In most supply chains there are measures to counter the inherent uncertainties of demand. Safety stock continues to this day to be the most common measure against uncertainties. However, uncertainties in demand can directly be reduced by increasing the information shared through partners in the supply chain (Karaesmen, Buzacott and Dallery, 2002). The advances in information technology, combined with supply chain integration, have made advance-order information commonly available in a wide range of industries (Hariharan and Zipkin, 1995). Usually there is some form of information on future demand often through forecasts or through supply contracts. *Advance order information* refers to early commitment to orders from customers. This type of early information sharing enables companies to achieve better service performance and keeping lower inventories (Karaesmen, Buzacott and Dallery, 2002). There is a crucial question to this reservation principle, and that is when, in what time interval, items should be reserved for a certain customer. Early reservation suggests shorter delivery delays to the customer at the expense of a reservation

stock build-up, and potentially longer delays for other customers. A reservation made too early or too late means incorrect prioritization and extra costs for holding inventory and/or long delays (Marklund, 2006).

3.4 Customer order decoupling point

The customer order decoupling point or CODP, is the location in the supply chain where the value adding processes are based on forecasts upstream, and based on real customer orders downstream (Hoekstra, Romme and Argelo, 1992). This point often dictates whether to use flexible or efficient manufacturing strategies. Upstream from the CODP the manufacturing tends to be much more efficient, while downstream of the CODP the manufacturing usually applies flexible manufacturing techniques. It is suggested that companies that operate in an MTS manufacturing environment rely on forecasts. This is since most of their value adding processes are located upstream from the CODP. Since there is a reliance on forecasts in this environment, it is also beneficial to exchange forecasts with customers. In contrast, in an MTO manufacturing environment most of the value adding processes are located downstream from the CODP. Companies that manufacture in an MTO environment benefit from their suppliers by sharing forecasts and engaging in joint R&D (van Donk and van Doorne, 2015).

The CODP also coincides with the last major stock location in the goods flow. Deliveries to customers are generally made from this point (Hoekstra, Romme and Argelo, 1992).

3.5 Inventory Management

The role of inventory management is of increasingly large importance in the supply chains of modern organizations, as the tied-up capital in raw material, work in process and finished goods represents large improvement areas. Utilizing a scientific method for inventory control can mean competitive advantages for the organization (Axsäter, 2006).

Inventory has a large impact on the material flow time, thus the throughput in the supply chains of organizations. This means that inventory must be managed

15

with considerations to not increase costs too much while also not reducing the responsiveness in the supply chain (Chopra and Meindl, 2013). The placement of the inventory can also have significant effects on the supply chain performance and cost. A large centralized inventory of raw materials would provide lower costs but with reduced responsiveness as compared to an inventory of semi-finished or finished goods. Therefore, the placement of the inventory is essential to managing the right responsiveness and costs of the supply chain (Chopra and Meindl, 2013).

Then the goal of inventory management is to hold inventory cost down by determining when and how to order. These cost functions associated with the inventory systems includes replenishment cost, inventory carrying cost, and shortage cost (Ali et al., 2013).

Inventory level and inventory position are important concepts in inventory management. They have the following definitions.

$Inventory\ Level = stock\ on\ hand - backorders$

$Inventory\ Position = stock\ on\ hand + outstanding\ orders - backorders$

3.5.1 (R, Q) Inventory Policy

When using a (R, Q) policy an order is made as soon as the inventory position (IP) reaches a certain level, this level is referred to as R (reorder point). The order is meant to replenish the IP to a level above R and is of size Q (order quantity). The order may also be the smallest number of integers of Q in order to reach an IP that is larger than R.

Safety stock may also be implemented in an (R, Q) inventory policy, in this case the safety stock may be calculated using Eq 1.

$$SS = R - \mu'$$

The purpose of the safety stock is to protect against variations in demand during the lead time (Axsäter, 2006).

3.5.2 Service level

There are several definitions of service level in the scientific literature, and still more definitions if one would account for how different companies modify and adapt these service level measures. The service level definition used in this report will be that of "fill rate". Fill rate is defined as "the fraction of demand that can be met immediately from available stock for continuous or unit demand". This is equivalent to the probability of having a positive inventory level. Using Fill rate as a measure provides a good picture of the perceived actual service. One very common approach to calculating the fill rate of demand is by assuming the demand to be normally distributed and continuous (Axsäter, 2006). Normal distribution is used much in literature since it is easy to apply in practice and is well understood. However, the normal distribution is not without its flaws. One issue is that the distribution is restricted to always be symmetrical. This also contributes to the second downside of the normal distribution which is that it can take on negative values (Moors and Strijbosch, 2002). In contrast, the gamma distribution cannot take on negative values and its asymmetrical shape varies depending on the modulus value, k, it ranges from a monotonic decreasing function through unimodal distributions slanted to the right, to symmetric normal type distributions. The other parameter that controls the gamma distribution is the scale parameter, θ. The distribution is generally mathematically controllable in its inventory control applications (Burgin, 1975). The normal distribution is compared to a gamma distribution in Figure 2.
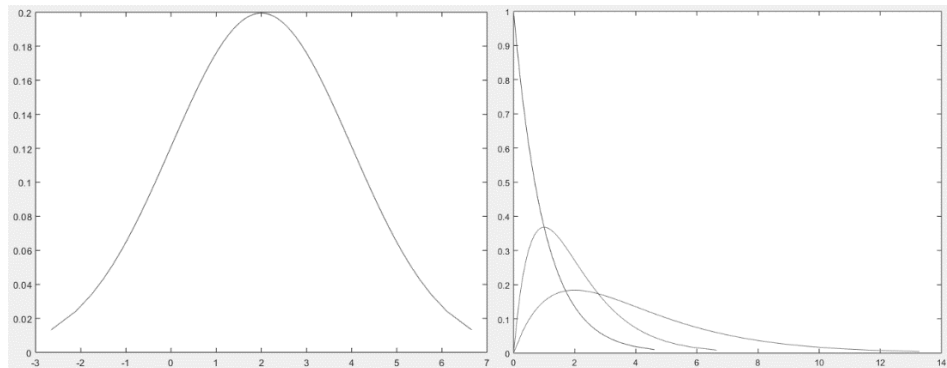
Figure 2: Normal distribution compared to Gamma distribution

The gamma distribution has the mean $k\theta$ and variance $k\theta^2$. If the mean and standard deviation of the lead time demand is given (μ', σ') then the corresponding parameters to the gamma distribution can be determined as the following (Axsäter, 2006).

$$k = (\mu'/\sigma')^2$$
$$\frac{1}{\theta} = \mu'/(\sigma')^2$$

3.5.3 Inventory Costs

3.5.3.1 Holding costs

The holding cost rate is often estimated as a percentage of the unit value. The holding cost is the summation of several types of costs that can be viewed as two components, capital cost and out-of-pocket holding cost. The capital cost refers to the cost of tying up capital and is related to the return on an alternative investment of this capital, it depends on the amount invested in inventory and the return that is to be expected from this investment. The out-of-pocket holding cost can be split into three parts; inventory service cost, storage space cost, and inventory risk cost. These costs could consist of material handling, storage, damage, obsolescence, insurance and taxes. If the organization owns the warehouse where inventory is stored then the storage costs are essentially

18

fixed since the storage area that is being paid for cannot be reduced if the amount of inventory is reduced (Axsäter, 2006 and Berling, 2005).

3.5.3.2 Order or Set-up Costs

This cost is associated with the replenishment activities and is not directly dependent of the number of units in the batch. The cost for a batch produced in house is often called set-up cost, it includes costs that are associated with preparing the resources for producing the order, such as scrap costs, calibration costs and downtime costs. If a batch is ordered from an outside supplier, it is often denoted ordering cost. These costs could be clerical work for preparing, releasing, monitoring and receiving the order, and the physical handling of goods and inspections (Berling, 2002). In other words, they are fixed costs that are obtained independently of the quantity that is ordered or produced (Pilar et al., 2017).

3.5.3.3 Shortage costs

While customers can sometimes agree to wait for outstanding orders and have the orders backlogged, the shortage of goods can have several costly consequences. Even if the sale is kept and backlogged there are administrative costs that occur. Late deliveries can also end up being discounted for the customers. The customer could also move on to different suppliers and the sale will then be lost. The shortage cost can also account for penalty fees from the customers as well as any goodwill that is lost for late deliveries. Instead of considering shortage costs many organizations choose to have service constraints, since the estimation of shortage costs is usually challenging (Axsäter, 2006 and Xu, 2017).

3.5.3.4 Additional costs

One inventory cost that is prevalent in the food industry where the inventory is perishable is the cost of wasted products as inventory is outdated. Generally, in order to achieve higher service levels, manufacturers can choose to increase their safety stocks. However, increasing the safety stock also leads to the expected amount of outdated inventory to rise (van Donselaar and Broekmeulen, 2012).

3.6 Postponement

Postponement is an operations strategy that aims to resolve issues that arises from operating in a mass customized market (Ismail and Sharifi 2006). By delaying value-adding activities throughout the supply chain, postponement tries to manage risks and uncertainties in the demand. There are four constructs of postponement that have been identified, shipment, manufacturing, ordering/purchasing and product design (Saghiri, 2011).

The food industry proceeds into a future full of speculations, pressures and tight margins where postponement could be a solution for possible innovation. However, the food industry will not be realizing the benefits of this strategy if they are not aware of the environmental consequences of implementing such a strategy. When viewing this strategy from an environmental perspective, it is generally not preferred for the food industry because it is perishable goods. However, there needs to be further investigation and development to provide a clear picture in this matter (Abukhader and Jonson, 2011).

4. Empirical Context

In this section, Atria Sweden AB will be presented along with the facts and information relevant to this study. The company description will include their supply chain, manufacturing processes, lead times and service level measurements.

4.1 Company profile

Atria Sweden AB is a food manufacturing company and it is a part of the Finish corporation Atria oyi**.** Atria Sweden AB manufactures food products for the Swedish, Danish and Finnish markets. The corporation was founded in 1903 in Finland and started to expand internationally in the 1990's. Atria Sweden AB was founded in 1997 in Sköllersta as the Atria corporation acquired the business from the Lithell family. Lithells is one of the brands being produced by Atria Sweden to this day. Since Atria started its business in Sweden, they also acquired the Sardus corporation and took ownership of their food brands as well. Today Atria Sweden AB has built a portfolio of well-known food brands which include: Lithells, Sybilla, Lönneberga, Pastejköket, Onsalakorv. Ridderheims, TZAY and Lagerbergs. Today Atria Sweden has 7 production facilities in Sweden and around 800 employees.

The types of products manufactured at Atria Sweden are sliced meat products, whole meat products, hamburgers, vegetarian meat options and non-meat products such as pea soup and rice pudding. Atria Sweden is also sourced by food brands not part of the Atria oyi corporation, to produce their food items. This study is focused on the manufacturing facility in Malmö and will specifically analyze the manufactured products destined for the Danish market, see Table 1.

Product Number	Product type - Atrias names	Product type - official names	Atria Service level requirements
307202	Hamburger rygg	A	98%
307203	Rullepölse	B	98%
307207	Spegepölse	C	98%
307208	Griljerad kyckling	D	98%
307211	Rökt rullepölse	E	98%
307217	Landskinke	F	98%
307218	Rostbiff	G	98%
307220	Röd pebbar kyckling	H	98%

4.2 Supply Chain

As this study will focus on products manufactured in Sweden for the Danish market, the supply chain will be described from Atria's suppliers of raw materials upstream to the end customers in Denmark downstream, see Figure 3.

Orders of raw materials are made directly from the production site in Malmö where the manufacturing is planned. Purchase plans for raw materials are determined two weeks in advance. The lead time for raw materials is usually 2-3 days.

All the different finished goods are derived from different raw materials with one exception. There is one type of raw material that is used to make two different products, but all the other raw materials are dedicated to its own product.

The orders for raw materials are made from the Malmö office is either for raw uncooked meat, or on two different semi-finished goods from Denmark. The uncooked meat is placed together in different bins in the raw materials warehouse, the semi-finished goods is placed on different racks in the semi-finished goods warehouse. Both the raw materials warehouse and semi-finished goods warehouse are located in the factory in Atria Malmö Fosie, see Figure 3 below.
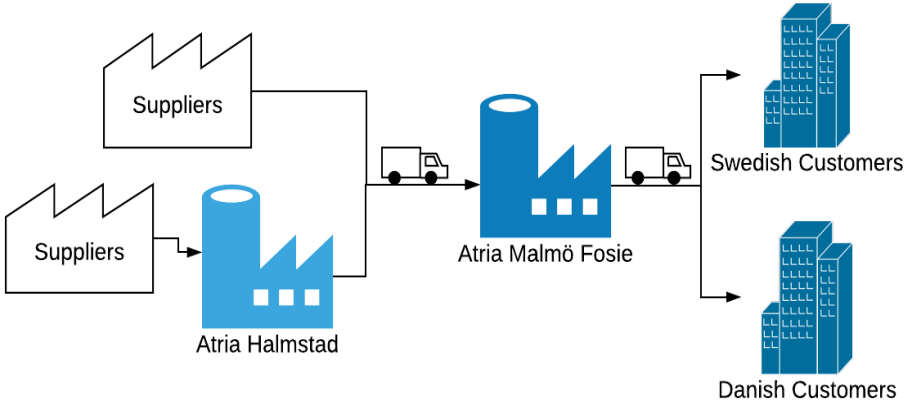

Figure 3: Supply chain structure

4.3 Manufacturing Processes

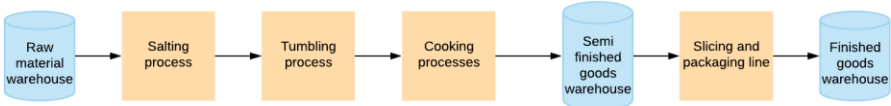Figure 4 displays the general manufacturing process and the order in which each of the process steps are performed.

Figure 4: General manufacturing process

23

4.3.1 Salting process

The first step for several of the products manufactured by Atria is the salting process, in this process a solution containing salt is either injected into the meat using syringes or the meat is placed in a bath of the salt solution. When the salting process is done through bathing the meat, the process can take several days. The purpose of this solution is to act as a preservative and to change/enhance the taste of the meat products.

4.3.2 Tumbling process

After the salting bath or injection, the meat is collected in large tumbling machines. Here the meat products are placed to roll and expel any excess of the salt solution. But it is also used to cement the taste of the salt solution into the meat and tenderizing the meat. The salt solution can also be poured into the tumbling machine with the meat.

In Atria Malmö they have a salt and preparation team with 16 employees that takes care of this salting and tumbling process. The leader of this team monitors this department and supplies it with the right raw material and staffing. The team leader also makes sure to manufacture semi-finished goods for the forecasted week. This is done as an attempt to keep inventory for the upcoming week only. However, here there are not any fluctuations in demand because all the raw materials go through this phase, so the staffing is constant at 16 people on full time. If someone of these people gets sick, they borrow personnel from the cutting unit.

Atria has a total of 8 tumbling machines of varying sizes seen in Table 2. However, these machines are only used at 60% of their capacity in manufacturing.

Table 2: Atria tumbling machine capacities

Number of tumbling machines	Total carrying capacity	Effective capacity (60% utilization)
1	8000 kg	4800 kg
3	2600 kg	1560 kg
4	5600 kg	3360 kg
Total tumbling capacity	22 920 kg	

Atria can process a total of 22 920 kg of meat at any given time in the tumbling machines. However, this capacity is shared across the factory, meaning that products from the Swedish market will occupy part of the capacity of this process.

4.3.3 Cooking process

Once the meat has been tumbled, the preparation starts for the cooking process. First the meat is tucked into a thin membrane skin, the SKU is now changing from pieces of meat into large meat cylinders. The meat cylinders are now placed on rolling-racks and is transported to their respective cooking station. There are three types of cooking processes used for these meat products. The meat can be smoked, boiled, grilled and or pressure-cooked.

While the cooking capacity has not been reached at Atria, the tucking process is limited by the manual labor. Typically, the manual labor has a maximum tucking capacity of 3000 kg/day.

Smoking and steam boiling

Products using this cooking method are rolled into the smoke rooms on racks. The smoking process and the boiling process are performed in the same room without any waiting time between the two processes. After the meat has been

smoked, hot steam fills the room in order to boil the meat. The smoking process can also be performed without the steam boiling.

Boiling

When products are boiled, they are simply submerged in hot water rather than utilizing steam.

Pressure-cooking

Pressure cooking is performed with a machine that boils the products at the same time as it is pressed into a rectangular shape. After a product has been cooked using this method it needs to rest and cool down before moving to the next process.

Grilling

The grilling of certain products only occurs after they have been smoked and/or boiled previously. Grilling is made through covering the surface area of the meat with oil and then cooked again with hot air.

After the cooking process, the meat is placed in a refrigerated area where it can further cool down. The meat usually undergoes more than one method of cooking and after the final cooking process, the meat is tempered in a freezing environment. This is done in order to prepare it for the slicing and packaging process.

4.3.5 Slicing and packaging

When the meat has been cooled it is taken to the slicing lines, where the products are also packaged and boxed. The meat is taken to the slicing line one rack at a time, and only one unit of meat can be sliced at a time in each line. Quality control personnel is also placed along the line to ensure a correct filling and closing of the packaging units.

The Malmö factory usually operates 06:00 to 00:00 with the exceptions of Fridays where production stops at 14:30 and weekends where no production takes place. Additionally, all slicing and packaging lines are usually not operated at the same time. There are currently two main slicing and packaging

lines dedicated to the Danish market products. These are not always used simultaneously. Line 6 is the older machine and is much preferred to be used regularly. Line 7 is newer, but it is primarily used to augment the capacity when there are large order quantities. The reason is that the older line 6 has a larger capacity than the newer machine.

4.3.6 Manufacturing capacity summarized

The different manufacturing capacities are summarized in Table 3. The main message from this data is that the bottleneck in manufacturing is 3000 kg/day. This bottleneck is a result of the manual tucking that occurs before the cooking process. When it comes to the final step of the manufacturing process, slicing and packaging, there is an overcapacity. This allows Atria to turn semi-finished products to finished goods in less than one day. Meaning that as long as there is inventory in the semi-finished goods warehouse, an order can be manufactured and shipped the same day as the customer requires delivery.

Table 3: Atria manufacturing capacities

Capacity in manufacturing	Value
Tumbling capacity	<22 920 kg
Salting capacity	1 700 kg/hour
Tucking capacity	3000 kg/day
Cooking capacity	>3 000 kg /day
Line 6 slicing capacity	3 600-4 000 kg/day
Line 7 slicing capacity	2 800 kg/day
Bottleneck capacity	3 000 kg/day

4.4 Lead times

Manufacturing lead times at Atria are measured in days. These lead time measurements are very inexact, but they are practical for their production planners. However, it makes lead time measurement difficult since some of the processes are relatively short. The last step of the manufacturing process *slicing and packaging* is usually performed the same day as the order is shipped effectively making the lead time between semi-finished goods and shipping <1 day.

Most products have a set lead time for manufacturing, this lead time takes into consideration the time for all processes from raw material to finished goods. However, the products referred to as C and H arrive at Atria's factory as semi-finished goods. Thus, they are immediately ready to be sliced and packaged. Therefore, the lead time for these two products (C and H) need to consider the order lead time of the supplier.

Additionally, lead times can be reduced if Atria chooses to utilize night shifts and overtime. Lead times can also be reduced by running production during the weekend. Keeping this in mind, Table 4 displays the regular manufacturing lead times, without considering overtime or weekend shifts.

Table 4: Manufacturing lead times

Product	Manufacturing lead time [working days]	Supplier lead time [working days]
A	4	-
B	4	-
C	< 1	10
D	3	-
E	4	-
F	5	-
G	8	-
H	< 1	10

4.5 Inventory Management

As Atria has different demand patterns and demand sizes in their product portfolio, they also employ different inventory management policies.

Inventory replenishments is planned in conjunction with the production planning process. The manufacturing at Atria is Make-To-Order and with the relatively fast production process they are able to also keep a low inventory, ordering cut and uncut meat in quantities that match current orders.

Inventory is managed and monitored at the raw materials inventory and the finished goods inventory. Atria does not keep track of WIP (Work In Process) levels in their factory. Additionally, stock-levels are updated every morning and not continuously.
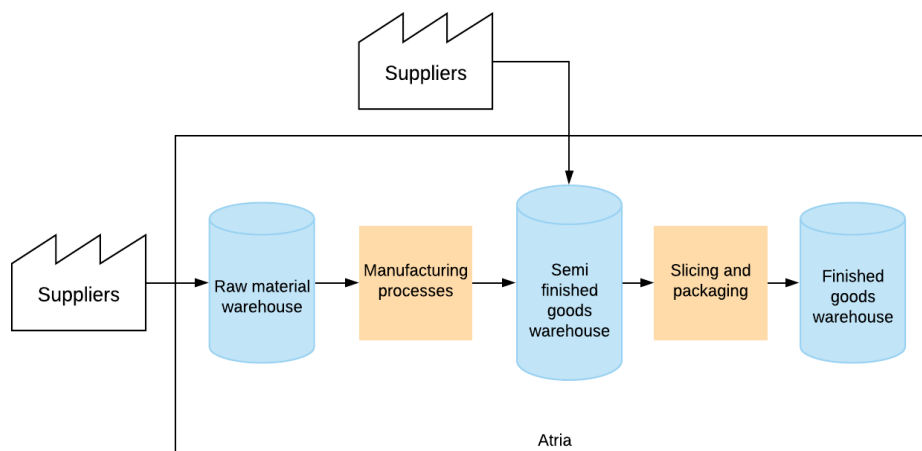
Figure 5: Atria stock locations

Atria keeps stock at three different levels of their manufacturing process as seen in Figure 5. Furthest upstream is their raw material warehouse. Stock is kept here as it is unloaded directly from suppliers. Secondly, Atria also keeps stock of semi-finished goods right before the slicing and packaging process of each product. Products are kept primarily on racks however, if more capacity is needed than their current number of racks then bins can be utilized to further increase warehouse capacity. Lastly, the Finished goods warehouse is where

Atria keeps packaged goods palletized and ready for delivery to customers. Materials in each of these warehouses has different requirements on shelf-life related to the status of the products. In the raw material and semi-finished goods warehouse, products can only be kept in stock for a certain period before products must be thrown away. In the case of finished goods, customers allow Atria to use a maximum of 5 days of the total shelf-life. A summary of product shelf-lives can be found in Table 5.

Table 5: Product shelf lives

Product	Raw material shelf life	Semi-finished goods shelf life [days]	Finished goods shelf life [days]
A	14 [days]	14	5
B	7 [days]	14	5
C	-	90	5
D	6 [months]	14	5
E	7 [days]	14	5
F	14 [days]	14	5
G	14 [days]	8	5
H	-	45	5

4.6 Service level measurement

Atria measures service levels in two ways. The first measure is the ratio of weekly delivered and ordered goods. This is measured for each of the meat products that Atria sells. This measurement only considers the weekly orders and deliveries of finished goods. This means that there is no service level or availability measurement for the raw or semi-finished goods warehouse. At a higher level, Atria also measures the service level performance of the entire meat production facility. However, this measurement does not take any individual products into consideration.

5. Process analysis

Addressing the first part of the purpose of this project, this chapter will analyze the empirical data regarding the production planning and inventory management process at the Malmö factory. The analysis will determine the current performance of Atria and important parameters to address in order to improve operational performance.

5.1 Process mapping

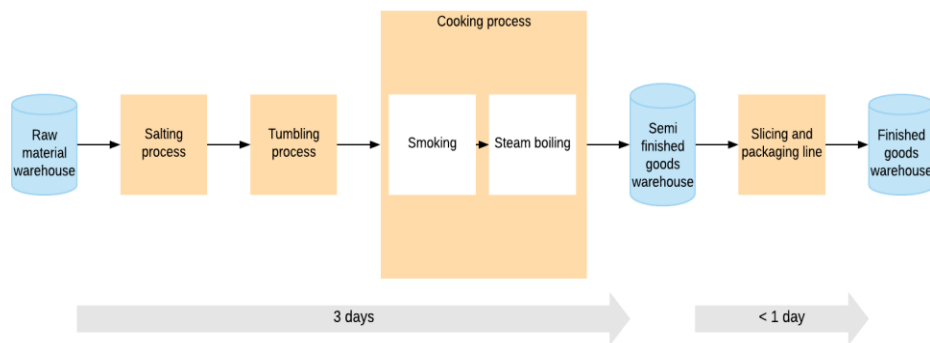Figures 6-12 show process maps of the production process and lead times of products A-G.

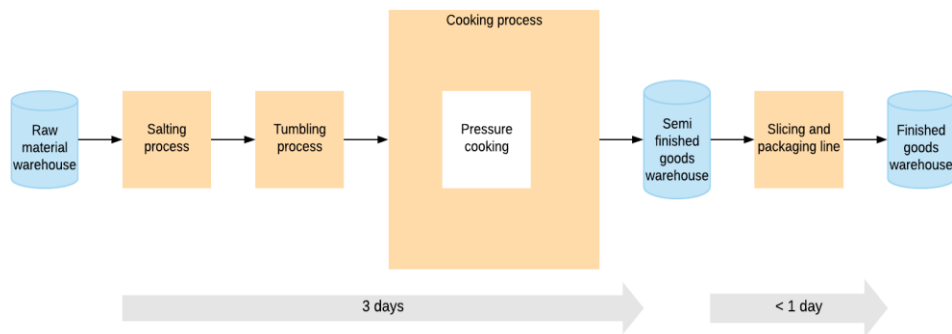

Figure 6: Product A, process map

Figure 7: Product B, process map
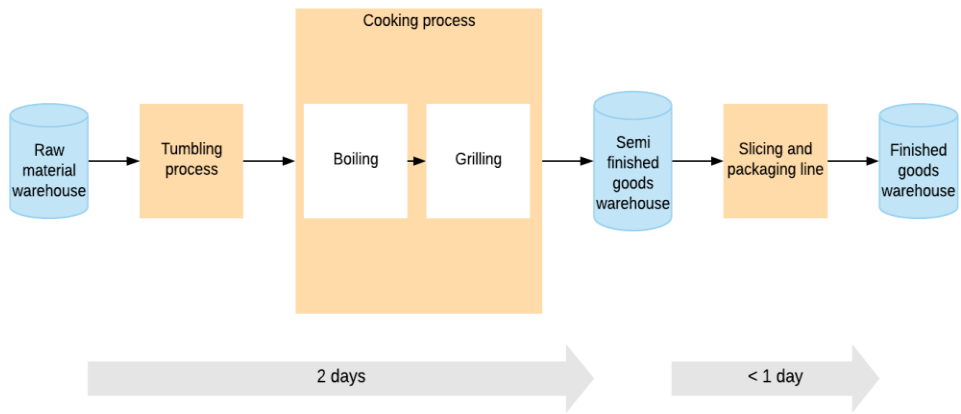
Figure 8: Product D, process map
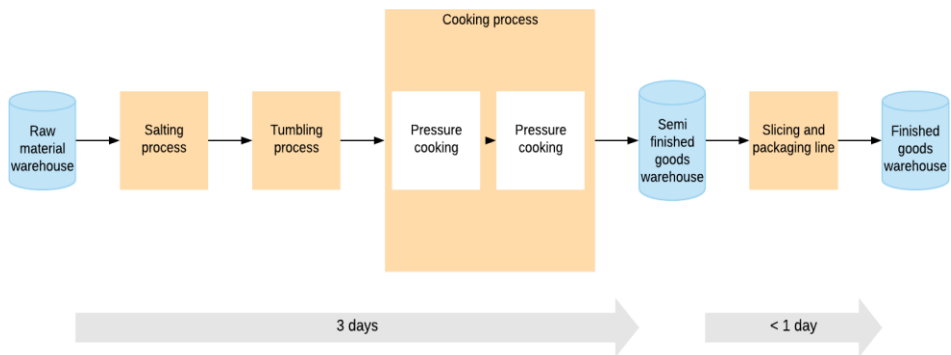
Figure 9: Product E, process map
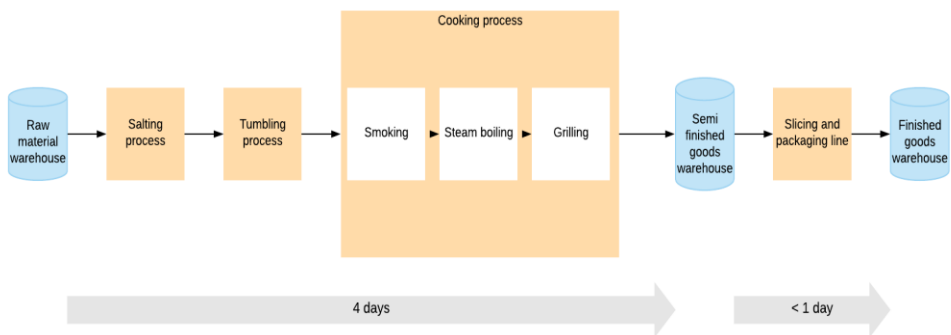
Figure 10: Product F, process map
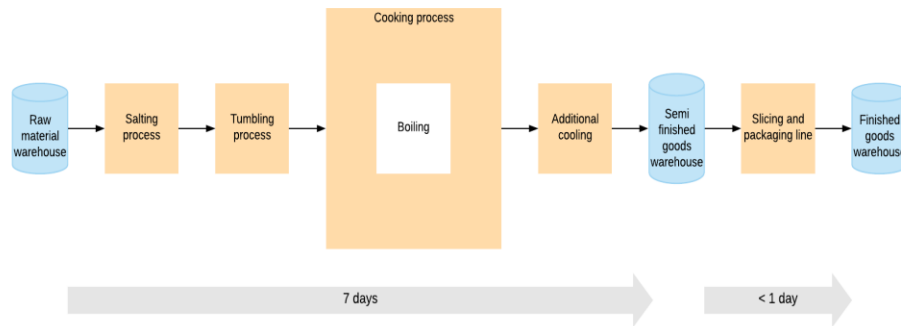
Figure 11: Product G, process map
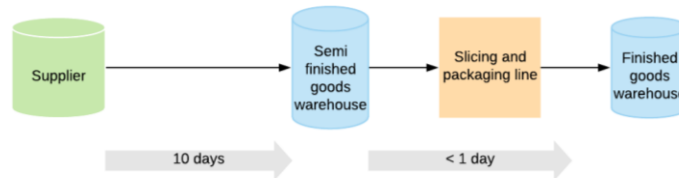
Figure 12: Product C and H, process map

5.2 Demand characteristics

The lead time demand of the analyzed goods has large standard deviations in relation to the means. As a result, there is a relatively large amount of uncertainty in the demand of these products and that modeling the demand with a normal distribution could mean a non-negligible probability of negative demand. This will also affect the amount of stock needed in order to keep a high service level. Having uncertainties as large as these will require large buffers in inventory. The mean and standard deviation of the demand for the analyzed products are presented in Table 6.

33

Table 6: Demand characteristics

Product	A	B	C	D	E	F	G	H
Product number	307202	307203	307207	307208	307211	307217	307218	307220
μ[kg/day]	751,36	618,76	454,53	386,36	252,20	379,45	417,67	186,98
σ[kg/day]	730,53	605,57	485,34	407,54	192,29	311,94	411,37	196,29
k	6,53	6,62	2,63	4,68	5,24	1,48	1,03	2,72
θ	579,96	472,22	518,24	352,37	199,87	256,45	405,17	206,06

5.3 Inventory Management

The products analyzed in this report all have set requirements in terms of lead time to customer and product shelf life. While the production lead time of most products can match this in theory, in practice production is not always able to manufacture goods during the time afforded to them from the advanced order information. The reason could be unforeseen delays in manufacturing. In order to compensate for any delays in the production Atria might utilize overtime. However, overtime is costly and should be avoided if possible. Furthermore, the strict requirements on shelf-life makes it infeasible for Atria to manufacture these finished goods products to stock. This reaches a scenario where Atria has requirements and prerequisites of manufacturing that are working against each other.

One solution to this problem that is already implemented to some extent at Atria is the utilization of a semi-finished goods warehouse. There are several benefits of moving stock to a semi-finished goods stock in this situation. Firstly, most of the manufacturing process lies before the semi-finished goods stage, meaning that the production lead time is drastically reduced. Secondly the shelf life of semi-finished products is much longer than that of finished goods meaning that it is much easier to keep higher levels of stock with lower risk of waste. Additionally, since the product shelf-life is dependent on the last

manufacturing step, the shelf-life can be extended if necessary. If the product is cut and packaged at the end of its semi-finished goods shelf life, the shelf life can be extended by the finished-goods shelf life period.

5.3.1 Current performance

Currently Atria tries to stock semi-finished product for a week's worth of forecasted goods. From historical data, the mean inventory level (*IL)* and *Q* were collected, these values can be seen in Table 7. Since Atria only measures inventory at the start of each week, the mean *IL* represented in Table 7 is not a measure of overall mean inventory levels.

The service level is defined as the fraction of demand that can be met immediately with the available stock on hand. Atria defines their service level as the amount of goods delivered on time. From the historical data this service level was computed by comparing values of orders, available stock, and manufactured products. In Table 7 the average service levels of 2018 are shown for each of the products.

Table 7: Current ordering policies

Product	A	B	C	D	E	F	G	H
Product number	**307202**	**307203**	**307207**	**307208**	**307211**	**307217**	**307218**	**307220**
Mean start of the week IL [kg]	4092,95	6178,16	4679,07	2218,96	403,00	1685,61	2088,36	560,93
Mean order quantity [kg]	2207,81	1955,80	2414,43	2041,47	1016,62	1868,11	1356,77	898,64
Service level	0,983	0,995	0,999	1,000	0,992	0,986	0,966	0,953

5.3.2 manufacturing strategy

As previously described, Atria has access to advance order information in the form of early commitments to orders from customers, as is illustrated in Figure 13. If a customer order arrives at time t_0 this order will then be shipped from Atria at t_1.
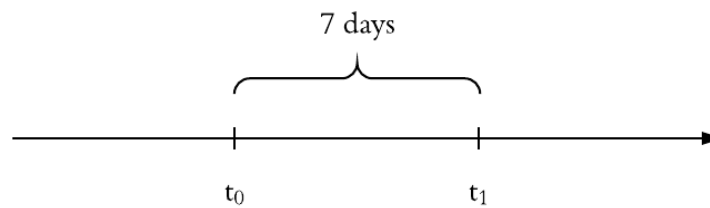

Figure 13: Warning time

36

In other words, when an order arrives at Atria it takes 7 days until that order affects the semi-finished goods inventory level. Having this type of advanced order information allows for the possibility to respond to demand before it occurs effectively eliminating uncertainties in demand. This warning period is called *DT*.

$$DT = 7\ days$$

Since this warning period allows for manufacturing to start before the actual order will affect inventory level the lead time to be considered is the following.

$$L = (l - DT)$$

Where *L* is the effective lead time and *l* is the manufacturing and supplier lead time. As a result of this *L* can now take on a non-positive value. This means that not only can these products be manufactured towards customer orders, but with a negative value on *L* the manufacturing of customer orders can even be delayed a period of time without consequence to the service level.

The placement of the Customer Order Decoupling Point (CODP) is what dictates the manufacturing strategy that is applied to each product. Where the CODP is located depends on when manufacturing can occur towards customer orders. In Figure 14, the CODP of each product is placed according to when manufacturing to customer orders can start. Before the CODP the processes must depend on forecasts. As can be seen in Figure 14 the CODP for products C, G and H are located before the last step of manufacturing. This means that this is where stock should be kept for these products and these products need to be manufactured towards this stock location (MTS). In contrast, the other products (A, B, D, E and F) have their CODP located at where the products exist as raw materials. Thus, these products only enter the manufacturing processes as they are ordered by customers. These are then made to order (MTO).
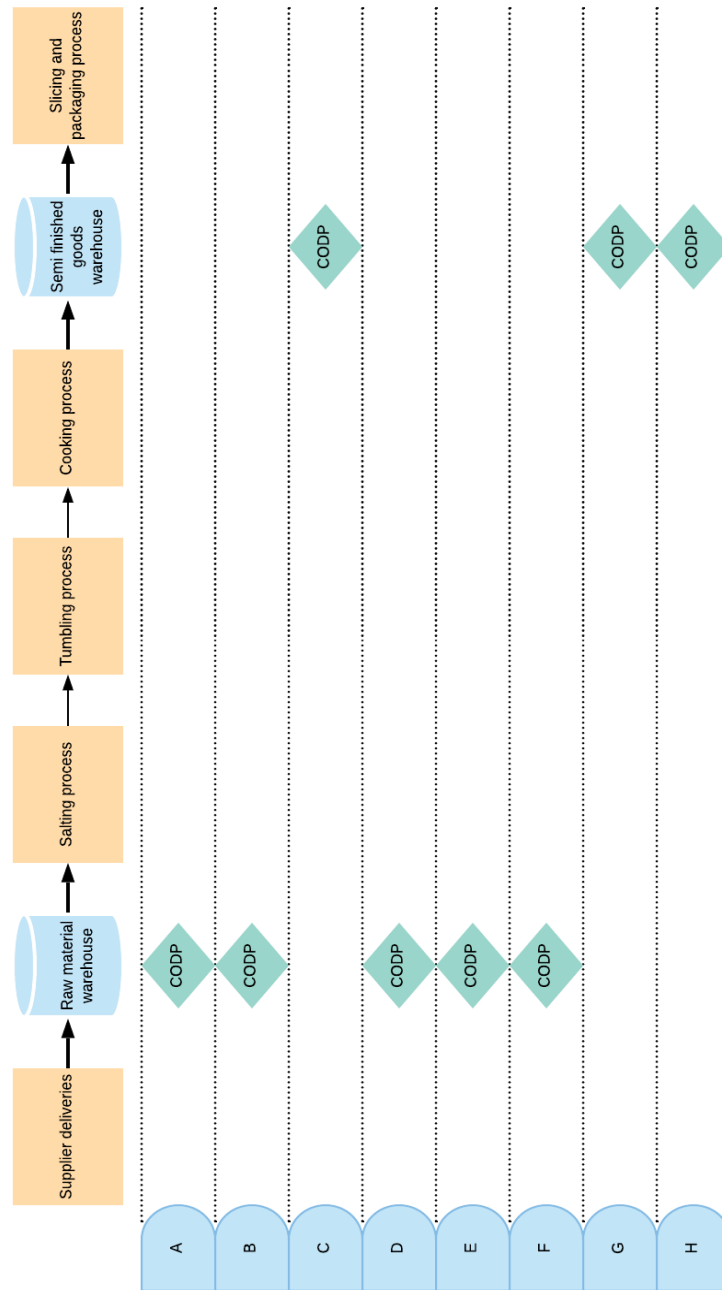
Figure 14: Customer order decoupling point location

The effective lead times and the appropriate manufacturing strategies are summarized in Table 8.

Table 8: Manufacturing lead times and appropriate strategies

Product	Manufacturing lead time [working days]	Supplier lead time [working days]	Effective lead time [Lead time - warning period]	Manufacturing strategy
A	4	-	-3	MTO
B	4	-	-3	MTO
C	< 1	10	3	MTS
D	3	-	-4	MTO
E	4	-	-3	MTO
F	5	-	-2	MTO
G	8	-	1	MTS
H	< 1	10	3	MTS

5.4 Improving service levels

To improve the service level at Atria, an (R, Q)-policy will be suggested for inventory control of products C, G and H in the semi-finished goods inventory. For this study the order quantity Q will be the mean order quantity as listed in Table 7. Therefore, the reorder point R is the main parameter to optimize to attain the sought-after service level. Now a mathematical expression for service level is needed. As stated previously this study will consider fill rate as the measure of service level. The fill rate being the proportion of demand satisfied directly from inventory on hand. Often in practice and in the literature the fill rate is calculated from lead time demand that is assumed to be normally distributed. However, because of the high standard deviation to mean ratio of the lead time demand there is a high probability of negative demand if a normal distribution assumption is used. In Appendix 2 the normal- and gamma distribution is shown layered on top of the demand products C, G and H in Figures 22-24. Additionally, in Appendix 3 the probabilities of negative

39

demand have been calculated for the three products, with the probability of negative demand being 15,5-17,5%. Therefore, this study will assume continuous gamma distributed lead time demand.

$f(x)$: probability density function of gamma distributed lead time demand

$F(x)$: cumulative density function of gamma distributed lead time demand

$D(L)$: Lead time demand

IL: Inventory level

IP: Inventory position

S: fill rate

The inventory level can be expressed in the following way using inventory position and lead time demand.

$$IL = IP - D(L)$$

Defining *F(x)* as the cumulative distribution function of the gamma distributed lead time demand.

$$F(x) = P(D(L) \leq x) \quad (1)$$

From the definition of fill rate and the continuous demand assumption, the following expression is obtained.

$$P(IL > 0): Fillrate$$

$$P(IL > 0) = 1 - P(IL \leq 0)$$

$$P(IL \leq 0) = P(IP - D(L) \leq 0) = P(D(L) \geq IP)$$

$$P(IL > 0) = 1 - P(D(L) \geq IP) = P(D(L) < IP)$$

The information needed now is the probability of demand during lead time being less than *IP* given that *IP* is distributed between the values *R* and *R+Q*. From Axsäter (2006) we assert that

$$IP \in U[R, R + Q]$$

and probability is attained from the following integral.

$$P(D(L) \leq IP) = \frac{1}{Q} \int_{R}^{R+Q} P(D(L) \leq IP|IP = y)dy$$

By inserting (1) in this expression the mathematical expression for service level is given.

$$S = \int_{R}^{R+Q} F(y)dy \quad (2)$$

Using MATLAB a program is written to calculate the service level for a given values of (R, Q, k, θ). From there the smallest value of R that leads to a service level of 98% is determined through a simple search as the fill rate is increasing in R. The result of these calculations is shown in Table 9.

Table 9: (R, Q)-policy results for semi-finished goods inventory

	C	G	H
Product number	307207	307218	307220
R [kg]	2700	1107	1120
Q [kg]	2414,43	1356,77	898,64
Service level	0,98	0,98	0,98

5.5 Historical simulation

For this part of the analysis the chosen (R, Q) policy was evaluated using historical sales orders. While the previous analysis resulted in an expected performance based on a probabilistic model, this historical simulation analysis will more accurately test the "real life" performance of the inventory

41

management model in the semi-finished goods warehouse. First the (R, Q)-policy in Table 9 were simulated using the historical sales orders of 2018. This analysis will only consider products C, G and H. Because of the location of the CODP of these products. These will be considered MTS and their inventory will be managed at the semi-finished goods warehouse. It is assumed here that manufacturing can start as soon as orders come in. It is important to note that the production sequencing that was used during this historical test could not be replicated. This test also does not provide a sequencing methodology to be used in future manufacturing schedules.

The historical simulation was conducted in Microsoft Excel, using historical demand data from the entire year of 2018. This simulation assumes that the manufacturing lead times are constant just as the mathematical model did. Additionally, the simulation looks at each product separately, thus the interactions between the different products are disregarded in this simulation. It is also assumed that maximum manufacturing capacity allows for at most Q units to be produced at any given day. Since Q is always below the bottleneck capacity this is a fair assumption. The values of R are based on the same data as the historical simulation because of the limited data availability. This simulation will show what would happen given that good estimations for the gamma distributed demand are attained. Additionally, this only studies a static (R, Q) – policy where the values of R and Q do not change, in a real implementation scenario the values of R would be updated based on forecasts. One expected flaw with this restriction is that some periods of the year will have worse service than others. Therefore, the quarterly service levels will also be measured in this analysis. Forecasting models will be considered outside the scope of this study since Atria themselves are studying and developing their own forecasting model.

Figure 15 explains the simulated process as it is performed in Microsoft Excel. The inventory position is monitored every day and when the inventory position sinks to or below the value of R an order is sent to manufacturing of Q units. This order arrives in stock after a delay L. Customer orders are shipped within DT days after an order has been made. If an order is not fulfilled during this

42

period, then it becomes backordered. This is the effect of Atria having advance order information. Essentially, this simulates an (R, Q) policy during the year 2018 accounting for the advanced order information and the production lead time of the simulated product.
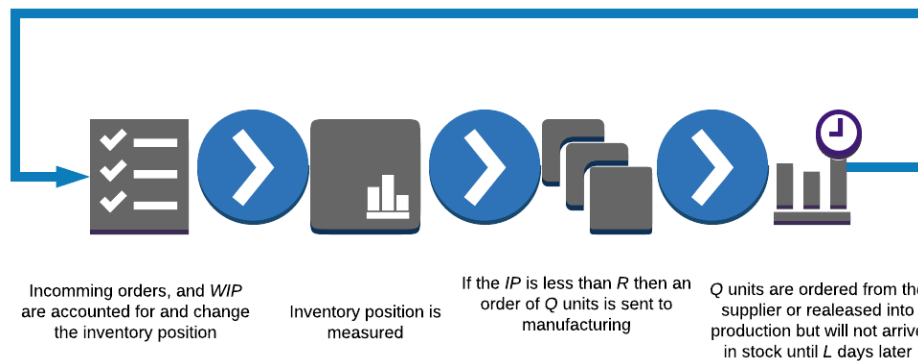

Incomming orders, and *WIP* are accounted for and change the inventory position

Inventory position is measured

If the *IP* is less than *R* then an order of *Q* units is sent to manufacturing

Q units are ordered from the supplier or realeased into production but will not arrive in stock until *L* days later

Figure 15: Simulated process

The resulting inventory levels for each product from the historical simulation can be seen in Figures 16-18. From the historical simulation the resulting service level and mean inventory level *E(IL)* are gathered and can be seen in Table 10 below.
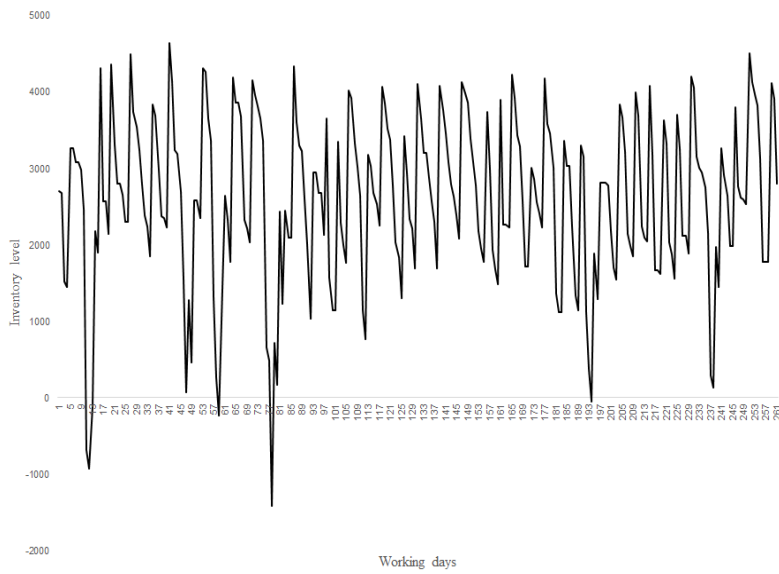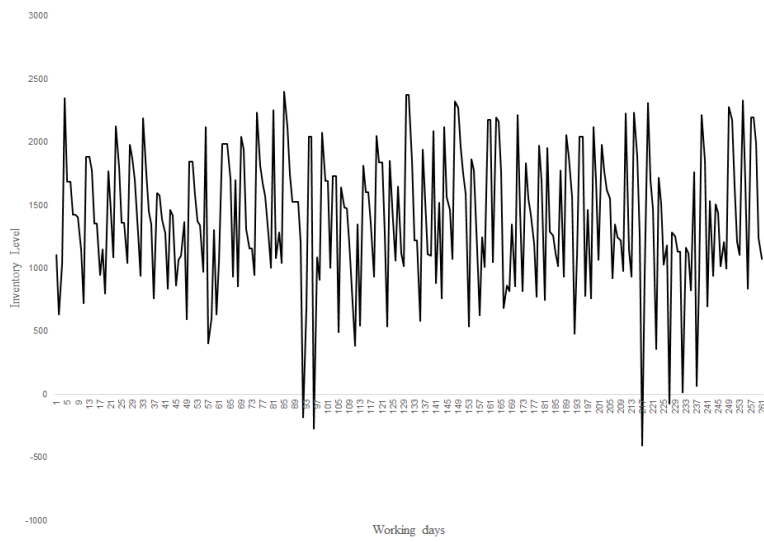
Figure 16: Inventory Simulation product C

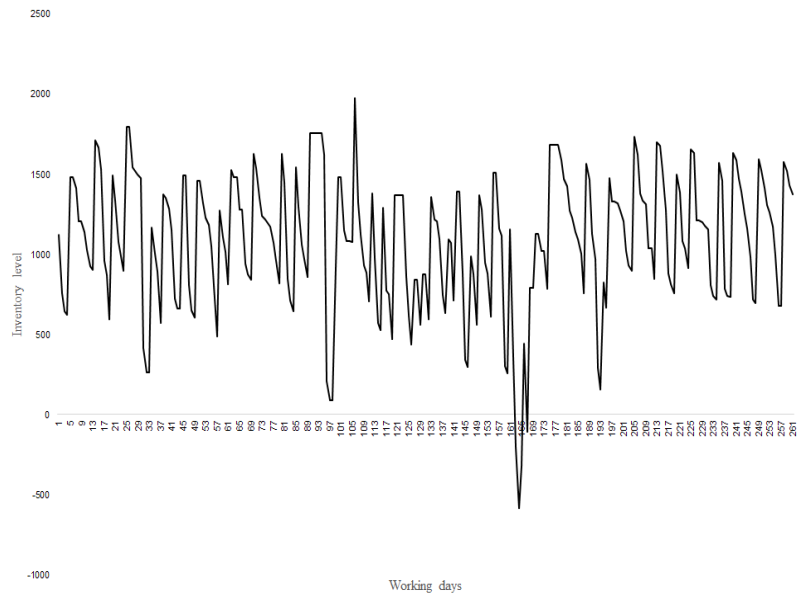
Figure 17: Inventory Simulation product G

44

Figure 18: Inventory Simulation product H

45

Table 10: Historical simulation results

	C	G	H
Product number	307207	307218	307220
R	2700	1105	1120
Service level	0,978	0,991	0,983
Mean start of the week IL	2451,88	1657,74	977,85

These results show that all the products managed to achieve service levels close to the predicted 98% as shown in Table 10. The outlier in this simulation was product G which managed to achieve service levels that was higher than what was predicted by the mathematical model. The reason for this deviation will be further investigated in the next segment. Also included in Table 10 is the mean start of the week inventory. In order to make comparisons to inventory as valid as possible, the inventory levels were measured at the start of each week just as Atria does currently.

Table 11: Quarterly performance

	C	G	H
Q1 Service level	98,9%	100%	100%
Q2 Service level	95,7%	98,3%	100%
Q3 Service level	100%	100%	96,9%
Q4 Service level	99,9%	98,5%	100%

Table 11 shows the quarterly performance of products C, G and H during the historical simulation. The service levels are not always above the set service goal of 98%. This Table shows that if R remains constant through the year the overall service of 98% may be attained but the service during certain periods might be reduced.

5.5.1 Sensitivity to order quantity

In the historical simulation, replenishment orders are triggered as the inventory position drops to below the reorder point. If the order quantity is changed the occasions at which replenishment orders are sent will also be changed in the historical simulation. This means that the inventory levels at any given occasion is dependent on the value of Q. This would also imply that the inventory could be better equipped to handle a large spike in demand if a replenishment order has been triggered shortly before this spike in demand. Likewise, the inventory could be unable to handle a large spike in demand if the inventory position is close to the reorder point just before this spike in demand occurs. In order to further analyze the robustness of the mathematical model in comparison to the historical simulation, the sensitivity of the simulation is measured with consideration to the order quantity. If Q_x is the order quantity used, then the

reorder point R_x can be optimized to achieve a theoretical fill rate S_t of 98%. By using the same values of Q_x and R_x in the inventory simulation, the simulated service level S_s can be attained. In Figures 19-21 the differences in these service levels $(S_t - S_s)$ are plotted against increasing values of the order quantity.
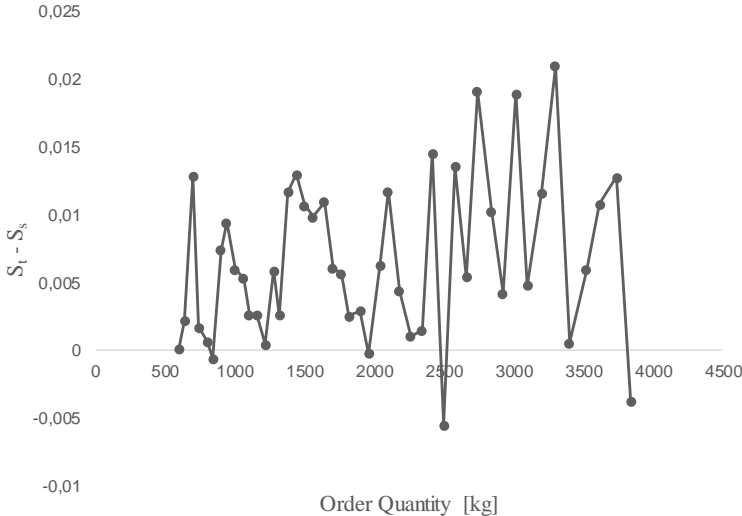

Figure 19: Difference in simulation and mathematical model product C
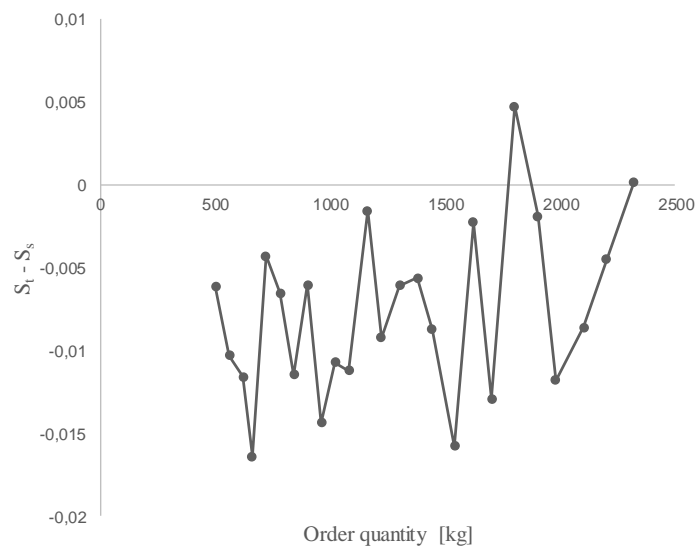
Figure 20: Difference in simulation and mathematical model product G
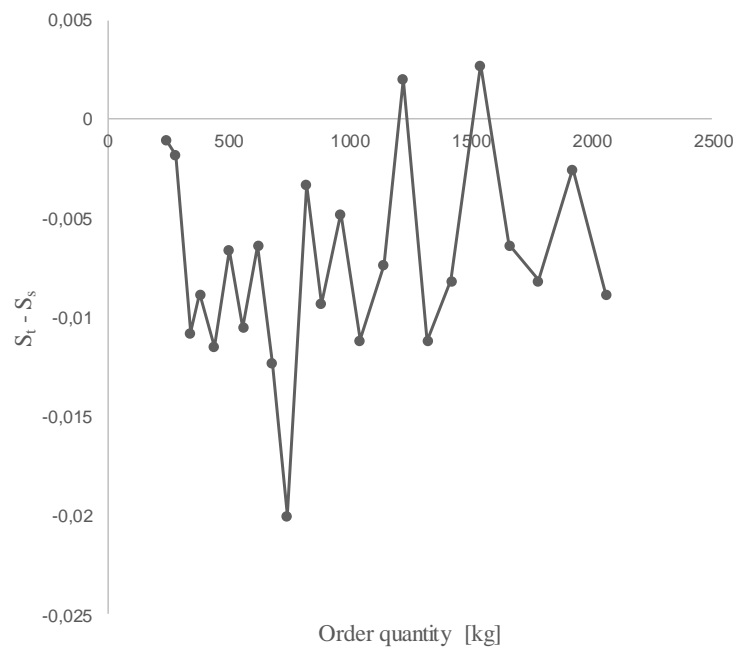
Figure 21: Difference in simulation and mathematical model product H

5.5.2 Summary of the analysis

The results of the process analysis show that Atria should be able to manufacture most of their Danish products towards customer orders. It also showed that products C, G and H should be manufactured towards the semi-finished goods warehouse. Table 12 contains a summary of the results. Including current performance numbers, results from the theoretical fill rate calculation, and the historical simulation results.

Table 12: Summary of analysis results

	C	G	H
Current performance at Atria			
Service level [%]	99,9	96,6	95,3
Mean start of the week inventory	4679,07	2088,36	560,93
Theoretical analysis			
R [kg]	2700	1107	1120
Q [kg]	2414,43	1356,77	898,64
Service level [%]	98,0	98,0	98,0
Historical simulation			
R [kg]	2700	1107	1120
Q [kg]	2414,43	1356,77	898,64
Service level [%]	97,8	99,1	98,3
Mean start of the week inventory	2451,88	1657,74	977,85

From Figure 11, it is possible to see that satisfactory service levels can be attained while also reducing the amount of inventory held for some of the products. Product C had reduced levels of service in the historical simulation, but this was expected since the optimized (R, Q)-policy aimed for a service of 98%. Additionally, the amount of inventory at the start of the week managed to

be reduced significantly. Product G saw an increase in service levels as well as a reduction in start of the week inventory. Finally, product H managed to increase its service levels but the mean inventory at the start of each week increased.

6. Discussion

This chapter will discuss the results of the analysis and their implications for Atria Sweden AB. Also addressed in this section are some of the shortcomings and possible improvements to the methodology. The utility if the results and value for the field of research is also discussed in this chapter.

6.1 Discussion of the Analysis

The purpose of this thesis was to investigate the manufacturing and inventory management processes and to find areas of improvements. This study was also specifically directed to analyze Aria's Danish products. Because of the unreliable forecasts and relatively infrequent order arrivals the manufacturing strategy to date has been to manufacture these products towards orders or forecasts rather than to stock. The results of this study show that Atria has the capacity to manufacture several of these products to orders. However, Atria does not have the capability to apply an MTO strategy to the products C, G and H. Instead they have manufactured towards unreliable forecasts which can be seen in the service level performance, specifically with products G and H. Therefore, more flexibility is needed to counter the unreliability of the demand and the forecasts.

One method of increasing the flexibility of a supply chain is to push the stock further towards the customer and the customer decoupling point. By doing this the manufacturer effectively eliminates much of the lead time up to that point. Atria does this in a way by keeping stock at three levels. Raw material stock, Semi-finished goods stock, and finished goods stock. By keeping inventory in the semi-finished goods warehouse, customer orders can be satisfied relatively fast while also utilizing the longer shelf-life of the semi-finished goods. If inventory is managed properly at this level, then this could increase service performance for Atria.

Moreover, this study has shown how a gamma distribution can be used to analyze and improve service levels. Often in practice and in literature, normal distribution is applied rather than gamma distribution. A gamma distribution offers the benefits of being a non-symmetric distribution as well as not risking

negative values of demand. One negative aspect of using a gamma distribution is the fact that it is computationally complex, this is certainly the case when comparing to a normal distribution. The consequence of this complexity is that MATLAB was needed to calculate the expression in (2).

Having an (R, Q) policy in place at the semi-finished goods warehouse could lead to service performance improvements at Atria. This is shown especially in product G, which previously did not meet the service level requirements specified by Atria. With the mathematical expression for service level presented in (2), the performance should be relatively predictable given a specified (R, Q) policy.

The results show differences in the resulting service levels from the theoretical calculations and the historical simulations. The calculated service levels are very close to the historical simulation showing that the mathematical model is robust and could be applicable to the real-life manufacturing scenario. The differences in service levels between the mathematical model and the simulation could be explained by the random elements in the simulation from the actual historical orders.

Furthermore, with the historical simulation this study assumes that, values of lead time demand are accurate. This might be from measurements or from forecasts. The lead time demand for each of the products analyzed was gathered from the year 2018, if accurate calculations are to be made of future demand then the values of lead time demand need to be updated to ensure a robust model. This simulation only considered the overall demand during the year 2018 and did not include any forecasting model. Because of this, some quarters of 2018 performed worse than others while the mean service performance remained close to 98%. In order to take full advantage of the mathematical model, forecasts should be used to continuously update the (R, Q) – policy. If demand is higher during certain periods, this would allow better service performance during these periods. When customer demand is lower, updating the (R, Q) – policy would allow for a decrease in stock.

This study uses primary information, meaning that the data gathered was done so for the purpose of this study. All information relating to demand and

inventory is gathered directly from Atria database files. However, most of the process related information, such as lead times and manufacturing capacities where gathered through semi-structured interviews with Atria employees. Improvements to the data gathering process could be made by conducting exact measurements on site of process capacities and lead times. Doing this would also improve the reliability of the gathered data. In order to ensure the validity of the gathered data, continuous contact with Atria has been upheld. Points of data has also been verified through semi-structured interviews with logistics and facility manager, production planner and manufacturing team leader.

6.2 Contribution to the research field

This thesis work has shown the applicability of gamma distributions in service level calculations in manufacturing. Previous literature has contributed primarily on the applicability of normal distributions in inventory management but there is also a precedent of research studying the gamma distributions, e.g. Burgin (1975).

This study has presented a relatively simple methodology to analyze and calculate expected service performance by assuming a gamma distributed demand as well as validating the results of the calculations. The value of the study mainly lies in the simplicity of applying this analysis methodology in manufacturing scenarios.

6.3 Future research

This study has assumed that demand can be modelled with a gamma distribution and that lead time is constant. In many real-life manufacturing scenarios this might not be the case, uncertainties in manufacturing can lead to even minor delays in the production time of products. Future research in the field could study the validity of these assumptions by studying the real-life performance of different probability distributions. Also considering how variations in lead time could affect the performance of the mathematical models.

7. Summary and Conclusion

Atria Oyj is a finish food industry company, their market is divided into four areas which are: Atria Finland, Atria Sweden, Atria Denmark & Estonia, and Atria Russia. The main focus of this work is Atria Sweden, a food manufacturer with their core business in meat products, cold cuts, convenience food, poultry products and vegetable & fresh delicatessen products. Of these products the cold cut category is manufactured for both the Swedish and the Danish market with certain brands dedicated to each of the two markets. This is the case for the factory located in Malmö where several brands of cold cut products are manufactured, this is also the manufacturing facility which is the focus of this study. As a manufacturer of food products, Atria has high customer requirements regarding the shelf life and the service level of their manufactured goods.

Despite being relatively close, the Swedish and Danish markets have different customer requirements and thus are also treated differently when it comes to manufacturing strategy.

Customers from the Swedish market order products 1-2 days before delivery while the Danish customers order products 7 working days before delivery. Atria is unable to handle the same manufacturing strategy for these two markets since they have access to reliable forecasts from the Swedish market. Additionally, orders from the Swedish market arrive much more frequently and products are shipped daily. As a result, Atria can handle the Swedish market with an MTS manufacturing strategy. The forecasts from the Danish market is unreliable and orders are relatively infrequent in comparison to the Swedish market. The short finished-goods shelf-life makes it hard to keep these products in stock. Therefore, the Danish market segment is handled by manufacturing to orders or forecasts. Difficulties arise since the studied plant in Malmö is structured to handle the efficient manufacturing strategy aimed towards the Swedish market, but it is not as well equipped to handle the effectiveness that the Danish market segment requires. Thus, this study has investigated the current production planning and inventory management processes at Atria's

factory in Malmö. The goal being to suggest improvements that will lead to increased service performance towards the Danish market.

This study has attempted to find improvements to the manufacturing and inventory management at the Malmö factory. The findings of the study suggest that Atria has the flexibility to manufacture most of their Danish products to orders (MTO). The findings also suggest that service levels can be improved by implementing an (R, Q)-policy to manage the inventory of MTS products (C, G and H) in the semi-finished goods warehouse. The work also shows that assuming a gamma distributed continuous lead time demand allows for estimations of service levels through calculating the gamma distributed fill rate.

A historical simulation was conducted in order to investigate the usefulness of the mathematical model given that the mean and standard deviation are well estimated. The results show differences in the service levels from the gamma distributed fill rate and the historical simulations. The calculated service levels are very close to the historical simulation showing that the mathematical model is robust and could be applicable to the real-life manufacturing scenario. Additionally, comparisons of the end of the week inventory suggests that inventory levels could be reduced which would lead to reduced holding costs.

In conclusion this study has shown that evaluating the performance of a (R, Q)-policy can be done with relative ease. And that the mathematical model to calculate service level has real applicability in the manufacturing case of Atria. It is also shown how performance can be estimated and planned for using the mathematical expression of service level presented in this paper.

8. Recommendations

From the analysis and discussion, it is recommended that Atria Malmö pursue the following aspects in their manufacturing and inventory management processes.

As was noted during the analysis, Atria measures service levels in two ways in their manufacturing. On a larger scale, Atria measures the service of all their cut meat in one value. The downside of this measurement is that it is impossible to find out if there is a specific product that leads to suffering service performance. Atria also measures service levels on a per-product basis. However, this service measurement simply measures the amount of delivered goods compared to the amount of ordered goods. Meaning that backorders and delayed shipments do not necessarily affect the service level of a product if it is shipped within the same week as the original shipping date. Therefore, the first aspect to pursue should be to implement fill rate as a service performance measurement for each individual product.

Secondly, strategically separate the Danish product portfolio and pursue an MTO strategy for products A, B, D, E and F. With the gathered data these products should be able to be manufactured towards orders and thus no stock is formally needed for these products. The other products (C, G and H) are to be manufactured using an MTS strategy and implement a (R, Q)-policy in the semi-finished goods warehouse.

Thirdly, continue to improve upon the model if necessary. Much of the data for this study was based on interviews rather than actual measurements. If long term and accurate measurements can be made, then this could help improve the accuracy of the proposed model for further use. The numerical results and evaluations performed assumes that the mean and standard deviation of the demand is well estimated. Therefore, it is also important that Atria measure these properties from their demand data and improve upon them with forecasted data.

Fourthly, following the implementation of this model if results indicate a successful change then this thesis could serve as a benchmark to analyze the

possibility of implementation for the MTS products of the Swedish market segment.

References

Abukhader, S. and Jonson, G. 2011. *Horizontal Environmental Assessment of Postponement Strategy – A Delphi-based Investigation.* International Journal of Management Science and Engineering Management, Vol. 6 (5), pp.382-392.

Ali, S., Madaan, J., Chan, F.T.S. and Kannan, S. 2013. *Inventory management of perishable products - a time decay linked logistic approach.* International Journal of Production Research. Vol. 51 (13), pp.3864–3879

Axsäter, S. 2006. *Inventory control.* Second edition. Boston: Springer Science + Business Media, LLC.

Berling, P. 2005. *On Determination of Inventory Cost Parameters.* Lund University: Department of Industrial Management and Logistics.

Berling, P. 2002. *The Capital Cost of Holding Inventory, A Real Options Approach.* Lund University: Department of Industrial Management and Logistics.

Burgin, T.A. 1975. *The Gamma Distribution and Inventory Control.* Operational Research Quarterly (1970-1977). Pergamon Press. Vol. 26 (3), pp.507-525.

Chopra, S. and Meindl, P. 2013. *Supply Chain Management - Strategy, Planning and Operation,* 5th Edition. Essex: Edwards Brothers, Inc.

Emanuelson, U. and Egenvall, A. (2014). *The data – Sources and validation.* Preventive Veterinary Medicine, 113(3), pp.298-303.

Eiselt, H. A. and Sandblom Carl-Louis. 2013. *Operations Research - A Model-Based Approach.* Berlin, Heidelberg: Springer.

Hariharan, R. and Zipkin, P. 1995. *Customer-Order information, lead times, and inventories.* Management Science, Vol. 41 (10), pp.1599-1607.

Herrmann, J. 2006. *Handbook of production scheduling.* University of Maryland, College Park.

Hillier, F. and Lieberman, G. 2010. *Introduction to Operations Research.* Boston: McGraw-Hill.

Hoekstra, S., Romme, J. and Argelo, S. 1992. *Integral logistic structures.* London: McGraw-Hill, p66.

Hopp, W. and Spearman, M. (2012). *Factory Physics*. Milano: McGraw Hill, pp.186-187.

Ismail, H.S. and Sharifi, H., 2006. *A balanced approach to building agile supply chains.* International Journal of Physical Distribution and Logistics Management, Vol. 36 (6), pp.431–444.

Karaesmen, F., Buzacott, J. and Dallery, Y. 2002. *Integrating advance order information in make-to-stock production systems.* IIE Transactions, Vol. 34 (8), pp.649-662.

Kotzab, H., Müller, M., Reiner, G. and Seuring, S. (2005*). Research Methodologies in Supply Chain Management*. Heidelberg: Physica, pp.19-23

Marklund, J. 2006. *Controlling Inventories in Divergent Supply Chains with Advance-Order Information,* Operations Research, Vol. 54 (5), pp.988-1010.

Magnusson, E. and Marecek, J. 2015. *Doing interview-based qualitative research.* New York: Cambridge University Press.

Moors, J. and Strijbosch, L. 2002. *Exact fill rates for (R, s, S) inventory control with gamma distributed demand.* Journal of the Operational Research Society, Vol. 53 (11), pp.1268-1274.

Pilar, I., Jose, P. and Julio, J. 2017. *A practical model for managing inventories with unknown costs and a budget constraint.* International Journal of Production Research. Vol. 55 (1), pp.118-129.

Saghiri, S. 2011. *A structural approach to assessing postponement strategies: construct development and validation.* International Journal of Production Research. Vol. 49 (21), pp.6427-6450. Kingston Business School, Kingston University London, Kingston Hill, Kingston upon Thames, Surrey KT2 7LB, UK

van Donk, D. and van Doorne, R. 2015. *The impact of the customer order decoupling point on type and level of supply chain integration.* International Journal of Production Research, Vol. 54 (9), pp.2572-2584.

van Donselaar, K. and Broekmeulen, R. 2012. *Approximations for the relative outdating of perishable products by combining stochastic modeling, simulation and regression modeling.* International Journal of Production Economics, Vol. 140 (2), pp.660-669.h

Whicker, L., Bernon, M., Templar, S. and Mena, C. (2009). *Understanding the relationships between time and cost to improve supply chain performance*. International Journal of Production Economics, 121(2), pp.641-650.

White, G. and Cicmil, S. 2016. *Knowledge acquisition through process mapping.* International Journal of Productivity & Performance Management; 2016, Vol. 65 Issue 3, p302-323, 22p

Xu, F. 2017. *Statistical measurement of the inventory shortage cost. In: Journal of Applied Statistics.* (Journal of Applied Statistics, Vol. 44 (4), pp.642-648.

Appendix 1: Interview guide

Research questions:

First Segment: Introduction and warm up questions

- Introduction for us and our research question
- Background to the research question we have chosen
- Explain the delimitations of this project and the agreed upon scope of this project.
- Who are you?
- What is your role here at Atria?

Second Segment: Main questions

- Please explain the manufacturing process here at Atria regarding the following products (the Danish product portfolio).
- How long does each manufacturing process step require?
- How does the process steps differ considering the different products?
- What capacity does each of the process step have?
- Are there any other limits on each process step (staffing limits for example, or requirements)?
- How does staffing affect the effectiveness of each of the process steps?
- What are the requirements of the product in each of its stages?
    - Raw material
    - Semi-finished product
    - Finished goods
- Please describe your stock-keeping policies (inventory management).
    - Raw material inventory
    - Semi-finished goods inventory
    - Finished goods inventory
- What information systems do you interact with and what are they used for?

Third Segment: Ending questions and follow up questions

- Could you provide us with an estimate wage value for cost calculations?

- How many employees are currently active and available for the manufacturing processes?
- What method is used in order to determine how many people works in each process?
- Is there anything you want to add to this interview or ask of us?
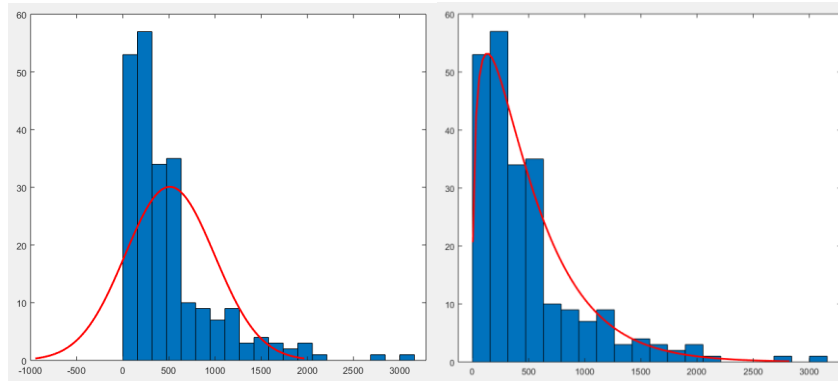
Appendix 2: Distribution fit to demand

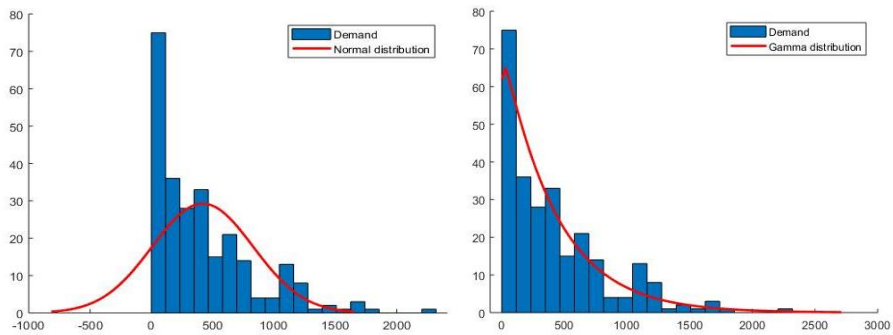*Figure 22: Product C distribution fit*
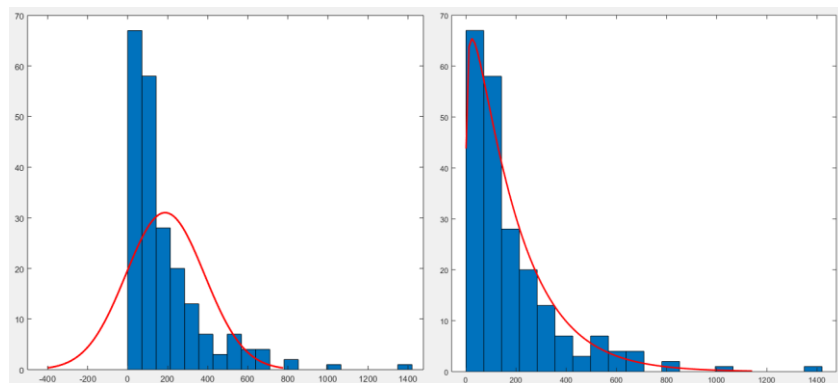

Figure 23: Product G distribution fit

Figure 24: Product H distribution fit

Appendix 3: Probability of negative demand

Table 13: Probability of negative demand assuming normal distribution

	C	G	H
Probability of negative demand	17,5%	15,5%	17%