UNIVERSITY OF TWENTE.

MASTER THESIS

THE OPTIMIZATION OF INVENTORY PLANNING PARAMETERS

COMMISSIONED BY ZWANENBERG FOOD GROUP B.V.

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Document title:	The optimization of planning parameters
	Master thesis for the program Master of Science in Business Administration, with the specialisation track Supply Chain Management at the University of Twente
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Management Summary

This research is conducted at Zwanenberg Food Group (ZFG) as part of the education program Master of Science in Business Administration. ZFG is one of the leading European producers and exporters of meats, preserved meat, snacks, soups, sauces, vegetarian and vegan products. The versatility of its products and the rapid growth of the company do require attention for more efficient production planning. This thesis focuses on the Zwanenberg Food Group Oss (ZFO) production location, which was acquired in 2018 by ZFG from Unilever. The need to have clear planning parameters for achieving the best results for the production location as a part of ZFG is key for an organization. Furthermore, the level of cost savings will be analyzed through the reduction of obsolescence by implementing the new Q, R policy. The acquisition of the production location in Oss led also to a vendor-managed inventory at the warehouse in Veghel (The Netherlands), this triggered the interest to optimize the stock levels. To conceptualize these problems the following research question is designed;

How to determine the optimal production parameters to minimize setup costs and the inventory holding costs, by considering the obsolescence of products?

The added scientific value of this thesis to the existing research is to determine the relationship of planning parameters to setup costs. Giving insights whether the setup costs can be considered a direct improvement to the heuristic production planning. The research design which enabled to answer the research question as unambiguously as possible. The research question refers to a performance measurement of a process, this means that the interconnected information and material flow, and supply chain are interlinked. The main objective of the thesis is cost reduction, efficient supply chain is needed to minimize the production costs. The production location Oss includes multiple factories that produce soup, sauce, and meat products. The scope of this thesis holds the current three production lines that produce at max capacity throughout the week, these are the Line-A, Line-B, and the Line-C production lines. By means of gathered information from the sub-questions is fundamental in answering the main research question. Chapter four, literature review, introduces previous research of what kind of planning tools are used to optimize the production planning. Second, the theoretical framework to

redesigning the inventory policy will elaborate on how planning parameters introduced earlier be able to smooth the production. Third, a set of three sub-questions will elaborate on the topics set-up time, obsolescence, and inventory costs. Finally, the conclusion of the thesis and the implementation of the new design in the factory are discussed. The research methodology is as follows;

Literature review (Chapter 4)

Which theoretical framework is needed to redesign the policy? (Chapter 5)

What is the effect of the new policy on the set-up time? (Chapter 6.1)

What is the effect of the new policy on obsoletes? (Chapter 6.2)

What is the effect of the new policy on the inventory costs? (Chapter 6.3)

Conclusion and recommendations (Chapter 7)

One of the goals of this thesis is to minimize the setup costs and holdings costs. The calculated economic order quantity (EOQ) illustrates the trade-off between fixed ordering costs and holding costs. Using the lot size-reorder point system as a planning parameter to manage inventory and determine the lot size per production run. The EOQ consists of two variables, one of the variables is the order size (Q) and the other the reorder point (R). Since the goods produced at the ZFG are perishable, it is crucial that the inventory does not exceed the its shelf-life. The limitation on the EOQ in this case is that each SKU the inventory of the product must leave the supply chain before the end of their internal shelf-life.

The data will be gathered from the weekly production plan of week 37 up to week 46 of the year 2019, this historical provides insight on what the average setup time per week is. In order to find Q and R, the order to stock forecast for the three production lines is used. This enables finding the new total setup costs per production line and make a comparison with the historical data, in line its influence on obsolescence and the holding costs.

This research showed that the following improvements can be achieved when implementing the new policy at the production site;

I. Obtaining clear parameters which can be used as the default for the production planning department.

II. Reduction in set-up time for the Line-A and Line-C production lines.

III. Reduction in set-up costs for the Line-A and Line-C production lines

IV. Reduction in RPM obsolescence costs for the Line-A and Line-C production lines as a consequence of reduction in the number of setups.

By introducing the new Q, R policy as a planning parameter, the results show that the number of setups reduce for the Line-A and Line-C production lines. The reduction of the number of setups results in a more efficient production plan. With these results it is showed that there is a relationship between the Q, and R policy and the setup costs. The Q and R policy determines the production run length and in consequence the number of setups per year for each SKU. The lower the annual number of setups for an SKU the lower the setup costs and vice versa.

With the reduction of the number of setups, the obsolescence costs for the Line-A and Line-C in terms of labor and material is reduced. However, these results for the Line-B production line show that by implementing the new Q, R policy the number of setups would increase. This could be caused by the long production runs that are planned for this production line in the period from the historical data.

In terms of inventory costs, the new Q, R policy showed not to have a cost reduction impact for all three production lines.

For implementing the new Q, R policy as a default planning parameter for the production site, the parameters should be captured in the master data and kept up to date by a key-user to function as a guideline for the production planners. These parameters should be integrated into the long-term production planning and used as a tool to reduce the setups, obsolescence and manage the inventory costs. The Q, and R policy functions as the new min and max that will indicate when the stock level has reached the safety stock mark and that a new production run is needed. When major shifts in the forecast data occurs, the new policy should be reviewed in order to represent the current situation and function as a parameter that optimizes the production plan. The planners need to be trained on what the importance of using the parameters and how these parameters can be integrated in their daily job. Finally, for continuous improvement and making sure that the current way of working is satisfactory an evaluation is needed. This can be done by analysing whether there is indeed a reduction in setup time, obsolescence, and holding costs. This should be done by the person responsible for the department, in the case of setup time, it would be the production manager or continuous improvement manager. For the holding costs, the supply chain managers should analyse whether costs reduction are indeed noticeable.

Management Samenvatting

Het onderzoek voor deze thesis is uitgevoerd bij Zwanenberg Food Group (ZFG), dit maakt een deel uit het 'Master of Science in Business Administration' studie bij de Universiteit van Twente. ZFG is één van de Europese marktleiders in de productie en export van vleesproducten, snacks, soepen, sauzen, en vegetarische producten. De verscheidenheid aan producten en de snelle groei van het bedrijf vraagt aandacht voor een efficiëntere productieplanning.

De thesis richt zich op de acquisitie van de Oss productielocatie door ZFG, van de voormalige eigenaar Unilever. Daarmee werd de voorraad aangelegd in het magazijn Veghel de consignatievoorraad die voortaan door ZFG gereguleerd zal worden. In deze situatie is het van belang om duidelijke planning parameters op te stellen om het meest gunstige resultaten te behalen op het gebied van het aantal omsteltijden en verspilling. Daarmee is het ook van belang om het effect van de planning parameters op de voorraden in Veghel en de mogelijkheden te analyseren om de opslagkosten te verlagen. De vragen kunnen we conceptualiseren tot één onderzoeksvraag;

Op welk manier kunnen de optimale productie parameters gedefinieerd worden die het aantal productie omschakelingen en de opslagkosten reduceren, rekening houdende met verspilling.

De toegevoegde wetenschappelijke waarde van deze thesis is het bepalen van het verband tussen de planning parameters en de omstelkosten. Waarbij de omstelkosten als een directe veroorzaker van de betering op het productieplan beschouwd kunnen worden. Het onderzoek-ontwerp zorgt ervoor dat de onderzoeksvraag beantwoord kan worden. Waarbij de onderzoeksvraag als een prestatiemeter van de processen fungeert, dit betekent dat de informatie, materiaal stroom, en logistieke keten met elkaar verweven zijn. Het voornaamste doel van deze thesis is kostenbesparing, een efficiëntere planning is nodig om de productiekosten te minimaliseren. De productielocatie Oss bevat meerde fabrieken die soep-, saus-, en vleesproducten produceren. Het domein van deze thesis omvat de productielijnen waar gedurende hele week op maximale capaciteit geproduceerd wordt, dit zijn Lijn-A-, Lijn-B-, en Lijn-C- productielijnen. De sub-vragen dienen als een bron van informatie om uiteindelijk de onderzoeksvraag te beantwoorden.

Hoofstuk vier, literatuurstudie, introduceert bestaande onderzoeken over planningsmethodieken die gebruikt worden om de productieplanning te optimaliseren. Ten tweede, de theoretische opzet om het voorraadsbeleid te herinrichten, gebaseerd op de hiervoor genoemde planningsparameters, dragen bij het verfijnen van de productieplanning. Ten derde, een reeks van drie sub vragen zullen verder ingaan op de vraagstukken omsteltijden, verspilling en voorraadkosten. Als laatste, de conclusie van de thesis en het implementatieplan van het nieuwe beleid in de fabriek zal verder besproken worden. Het onderzoekontwerp is als volgt;

Literatuurstudie (Hoofdstuk 4)

Welk theoretisch raamwerk is nodig om het beleid te herinrichtingen? (Hoofdstuk 5)

Wat is het effect van het nieuwe beleid op omsteltijden? (Hoofstuk 6.1)

Wat is het effect van het nieuwe beleid op verspilling? (Hoofstuk 6.2)

Wat is het effect van het nieuwe beleid op voorraadskosten? (Hoofdstuk 6.3)

Conclusie en aanbevelingen (Hoofdstuk 7)

Eén van de doelen van deze thesis is het minimaliseren van de omstelkosten en voorraadskosten. Het berekende economische order hoeveelheid (EOQ) weerspiegeld de afweging tussen vaste orderkosten en voorraadskosten. De lot grootte-bestelpunt wordt gebruikt om de voorraden te beheren en de runlengte per productie te bepalen. De economische order hoeveelheid bestaat uit twee variabelen, één daarvan is de ordergrootte (Q) en de andere het bestelpunt (R). Omdat de producten die geproduceerd worden beperkt houdbaar zijn, is het noodzakelijk dat de voorraadhoogte niet de houdbaarheid van het product overschrijdt. De limitatie op de EOQ in dit geval is dat elk producteenheid op voorraad de logistieke keten moet verlaten voordat de interne houdbaarheid verstreken is.

De data zal verzameld worden uit de wekelijkse productieplanningen van week 37 tot en met week 46 van het jaar 2019. Deze historische date geeft inzicht op wat de gemiddelde wekelijkse omsteltijd is. Om Q en R te vinden, worden de vraagoverzichten (forecast) van de drie productielijnen gebruikt waarvoor voorraden aangemaakt worden. Dit maakt het mogelijk om de omstelkosten per productielijn te bereken en een vergelijking te maken met de historische data, en tevens invloed op verspilling en voorraadkosten.

De implementatie van het nieuwe beleid bij ZFG Oss zal leiden tot de volgende verbeteringen in de processen;

I. Het verkrijgen van duidelijke parameters die als standaard kunnen worden gebruikt voor de afdeling productieplanning.
II. Reductie van het aantal omschakelingen voor de productielijnen Line-A en Line-C.
III. Reductie van de hoeveelheid omstelkosten voor de productielijnen Line-A en Line-C.
IV. Reductie in RPM-verspilling voor de productielijnen Line-A en Line-C als gevolg van vermindering van het aantal omschakelingen.

Door de introductie van de nieuwe planning parameters kunnen het aantal omschakelingen voor de Lijn-A en Lijn-C-productielijnen verminderd worden. Doordat er per jaar het aantal productwisselingen verminderd zijn ontstaat er een efficiëntere productieplanning. Deze resultaten laten zien dat er een verband bestaat tussen de Q- en R-beleid en de omstelkosten. De Q- en R-beleid bepaald de productierun lengte en als gevolg het aantal jaarlijkse productwisselingen voor elk product. Hoe lager het jaarlijkse aantal productwisselingen voor elk product des te lager de omstelkosten zullen zijn en andersom.
Door het aantal productwisselingen te verlagen zullen de verspillingskosten voor de Lijn-A en Lijn-C ook lager zijn doordat arbeid en materiaal efficiënter benut wordt. Echter, de resultaten laten zien dat voor de Lijn-B de implementatie van het nieuwe beleid zal leiden tot een hogere hoeveelheid productwisselingen. Mogelijk wordt dit veroorzaakt doordat er in de periode waarin de historische data afgenomen langere runs gepland stonden. Betreft voorraadskosten, het nieuwe Q- en R-beleid liet geen kostenbesparende resultaten zien voor alle drie productielijnen.

Voor de implementatie van het nieuwe beleid bij ZFG Oss zullen alle parameters in de masterdata op een centrale locatie ingevoerd moeten worden en deze laten beheren door een aangesteld persoon. Deze richtlijn zal gebruikt worden om overige bestanden en systemen aan te vullen. De planning parameters zullen in de lange-termijn productieplanning verwerkt moeten worden om zo het aantal omschakelingen, en verspilling te verminderen en de opslagkosten beter te reguleren. Het nieuwe Q- en R-beleid functioneert als de nieuwe min en max die de grenzen vormen tussen de maximale voorraadhoogte en de veiligheidsvoorraad. Bij grote forecastwijzingen zal het beleid opnieuw geëvalueerd moeten worden om een weergave te blijven van de actualiteit die het productieplan optimaliseert. De productieplanners zullen opgeleid moeten worden om het belang van het gebruik van de planning parameters te begrijpen en hoe deze in de dagelijkse werkzaamheden geïntegreerd kunnen worden. Als laatste, voor het continue verbeteren en het ervoor zorgen dat de huidige werkwijze voldoet is er een evaluatie nodig. Dit kan door het analyseren of de omstelkosten, verspillingkosten, en voorraadkosten daadwerkelijk gedaald zijn. Dit kan gedaan worden door de persoon die aangewezen wordt om het beheer van de data actueel houden, echter is het ook in het belang van de productiemanager en continue verbeterspecialist om efficiënter te produceren en kunnen zij ook in dit proces meedenken. Betreft de voorraadkosten, de logistiekmanager zou een analyse moeten uitvoeren of het uiteindelijk hierop een significant effect heeft.

Acknowledgments

It is exciting that I have finished my master thesis after a long and rocky road. The thesis is conducted at Zwanenberg Foodgroup sourcing unit Oss for the study program Business Administration, with the specialisation track Supply Chain Management. The company has been going in developmental stages, and currently is still expanding which makes it an interesting company to conduct research for.

I was fortunate enough to have done my graduation research at the same company for who I was working for. Having gained the knowledge of the operations of the company by having worked there for years next to my study, allowed me to give the thesis more depth. I want to thank my manager Youri Robeerst for motivating and giving me the chance do my graduation research at the location. Many thanks to my colleagues of the “bedrijfsbureau” who kept me going.

Thankful to Dr. Engin Topan for taking me in, even though coming from different study program, and allowing me to do my thesis in an engineering topic. I would also like to thank Dr. Klaas Stek who agreed to supervise me throughout the thesis. Most of all thank you both for your patience with me and getting me to the finish line.

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List of Abbreviations

Business Purchase Agreement	BPA
Centraal Magazijn Oss	CMO
Economic Order Quantity	EOQ
First Expired First Out	FEFO
First In-First Out	FIFO
Fast-Moving-Consumer-Goods	FMCG
Fulltime-equivalent	FTE
Make-to-Stock	MTS
Make-to-Order	MTO
Minimum Order Quantity	MOQ
Overall Equipment Effectiveness	OEE
Raw and Pack Material	RPM
Service Level Agreement	SLA
Stock Keeping Unit	SKU
Supply Chain	SC
Quality Assurance	QA
Vendor Managed Inventory	VMI
Zwanenberg Food Group	ZFG
Zwanenberg Food Group Oss	ZFO

1. Introduction

The real world of production management, planning, and control problems is usually imprecise, complex, and critically dependent on human activities. A real Supply Chain (SC) operates in an uncertain environment, these include uncertainties in judgment, some lack of evidence, as well lack of certainty in available evidence (Patidar, Pratap, & Daultani, 2018).

Optimizing the tactical planning of a fast-moving consumer goods (FMCG) company is important to ensure that the products remain profitable while ensuring that these products are available in the right place at the right time (Elzakker et al., 2014). Aiming to minimize the total costs of operating the supply chain can come with challenges e.g. taking into account the shelf-life and over-sales. The company's existence depends on customers satisfaction, this Key Performance Index (KPI) can be optimized by delivering on time, correct demand, and good quality (Patidar et al., 2014). By enabling the comparison of planned and achieved results one can have better control over the service delivery (Islam, Meier, Aditjandra, & Zunder, 2013). This thesis will examine the transition of the sourcing unit Oss from Unilever to Zwanenberg Food Group (ZFG). Per February 2018 Unilever sold the sourcing site in Oss to ZFG, with the agreement of implementing consignment stock later in the year. This will be implemented at several warehouses located spread out over Europe. ZFG has a different vision on efficient planning which makes it interesting to re-examine the planning parameters.

This chapter will elaborate on the current situation of the sourcing unit, the purpose of this research will be defined, finally, the problem description and the research question of this paper will be introduced.

1.1 Sourcing Unit Oss

The sourcing unit in Oss has a long history that has always played a part in the community and history of the city. Being one of the main work providers of the city, the shrunken number of jobs had an impact on the community and its perception of the plant. The sourcing unit includes three factories, which are the meat factory, glass factory, and can factory (mainly soups). The meat factory is the only one that includes different production lines, producing canned meat (Line-A & Line H), 'meat in pouch' (Line C, Line I, Line E, and finally the Line F which is an artisanal line for the production of short shelf-life sausages. All the final goods are stocked in the site warehouse (CMO) before being shipped to the distribution centre. The customers gather information on the sales and communicate this with the sourcing unit. In figure 1 the production and information flow are outlined. Some of the stock-keeping units produced at the site are shown in figure 2.

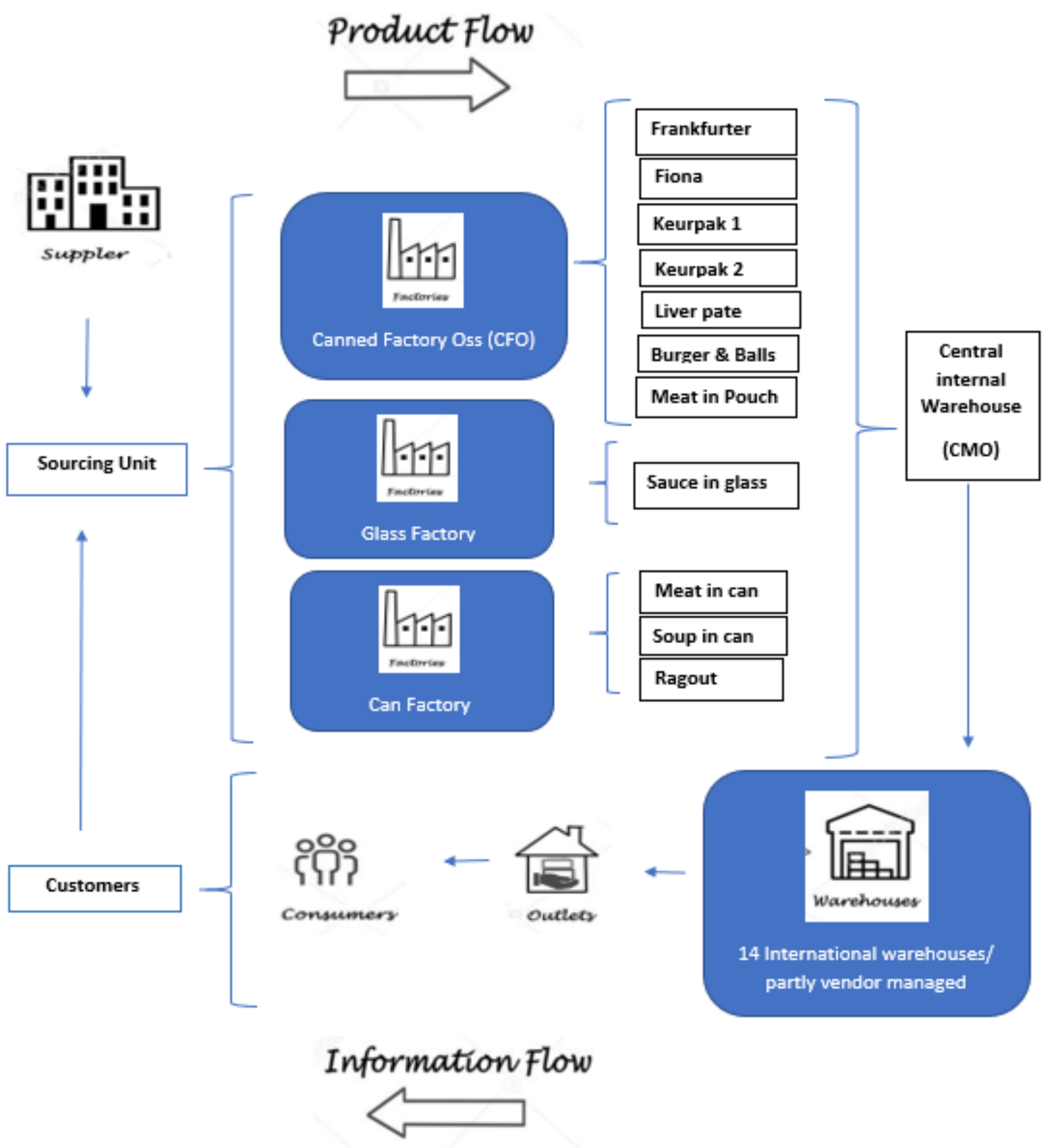

Figure 1. the product and information flow

Figure 2. Some of the stock-keeping units are produced at the sourcing unit.

The following sections will elaborate on the current situation of the company. This will include production, operational, planning, managerial, service, and stock keeping. These parameters are only derived from the sourcing unit in Oss.

1.2 The stock keeping units

The sourcing unit Oss has three factories which are the meat (108 SKUs), sauce (56 SKUs), and can (54 SKUs) factories. In total, the site produces 223 SKU’s at the moment, is produced on nine production lines (see table 2). The soups and smoked sausages are considered seasonal products. The sales in autumn and the winter (high season) are significantly higher than in other seasons, the forecast provided by the customers is often diversified and unreliable, and the available production capacity is limited. These items often face out-of-stock risks in the high season. The other items have a more stable forecast throughout the year. Most items are produced on a 'make to stock' basis (150 SKU’s), the other 73 SKU’s are 'make-to-order,' this paper will focus on the 'make to stock items.' Unilever is the only customer who orders on a make-to-stock basis, all of the other (four) customers work with a make-to-order method which is not the focus of this thesis. The make-to-stock items are distributed to different national and international

warehouses (Germany, Belgium, Greece, Italy, Sweden, etc.). All items have a quarantine time of three days before being available for distribution to customers, this gives the quality assurance (QA) the time to recall productions when needed. For each item there is also an internal shelf-life, meaning that the item has to be sold to the customer before that date, also agreements are made on the maximum stock per item.
Each product is produced for a specific customer with its recipe and packaging, this reduces the planning flexibility.

Production Line	SKU amount	Internal Shelf-Life
Line-B	**54**	**900 days**
Line-D	56	250 days
Line-E	7	7 days
Line-A	**28**	**1020 days**
Line-F	13	180 days
Line-C	**17**	**35 days**
Line-G	10	35 days
Line-H	26	720 days
Line-I	6	90 days
Total	223	

Table 1. Overview stock-keeping units per production line, this paper will focus on Line-B, Line-A and Line-C.

The factory has nine production lines in total, however, this thesis will focus only on three lines, i.e., Line-A, Line-B, and the Line-C. The reason why these three production lines are chosen is that all lines have similar characteristics concerning capacity and control policy but work with different parameter settings. It would be interesting to identify the optimum parameters and compare the outcomes.

1.3 Production and information systems

The average production interval for each of the factories is based on a three-shift regime providing 116 hours of production time, time is needed for building up the production lines at the beginning of the week and cleaning at the end of the week. Each of the nine lines has its restrictions and sometimes the production lines restrict each other due to lack of technical solutions, human capital, or other issues. Some of the production lines provide the material for another line, e.g. the Line-E line provides the content of the Line-B and Line-I products. If this line faces production issues the other lines will be limited in the production of some items, these types of production systems are also known as serial production systems (see figure 6).

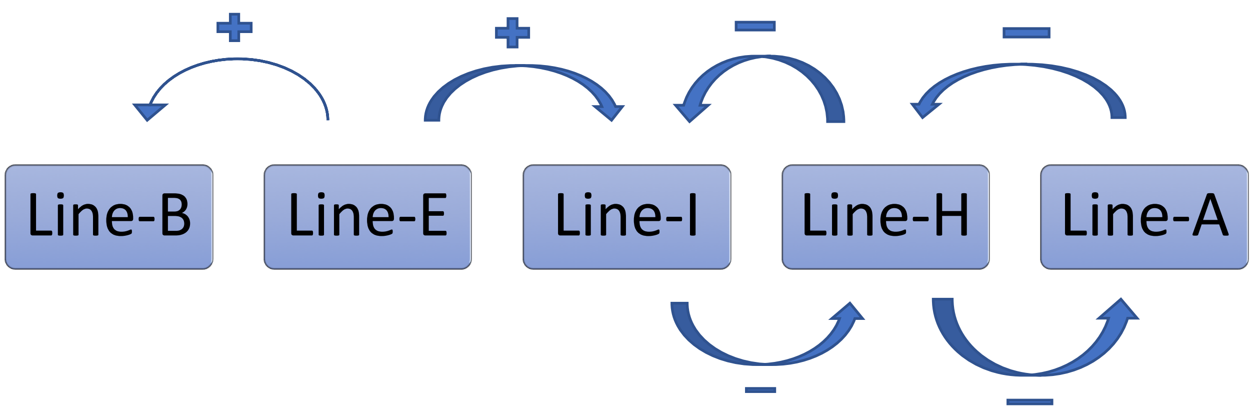

Figure 3: The inter-relations of production lines.

These restrictions are known to the production planning team, aligning all productions plans before confirming these. The alignment of the production plan is done through weekly meetings and including production leaders in this process. Each production line is assigned to one planner who is responsible for updating and planning according to demand, pack material, and flagging when needed. It is important to have a reliable forecast, while this can determine how the production plan is made. When planning one can take into mind building stock, impacts a lower number of changeovers, and minimizing the set-up time.

Resulting in a smoother production process with less setup time and obsoletes.

Production planning can be divided into two types, short-term (two weeks) and long-term planning (up to one year). The short-term planning is shared within the company every week. Long-term planning is used for long-term material planning, managing production in terms of occupation, analyses, and informing customers whether the factory can meet the demand. The focus of this paper is long-term planning because analysing the inventory cost would be over a longer period.

As stated, before the factory mainly works on a make-to-stock basis (forecast). This is a weekly updated report communicated through the ERP/APO system with the e.g. total stock, total demand, scrap stock, and unfulfilled demand. For the three other customers, the production is planned on a make-to-order basis. This is usually a less regular demand, having gaps per item between weeks. This is communicated by an excel spreadsheet sent by e-mail on a weekly and monthly basis. Just as in every company the service level, based and stock availability is considered an important performance indicator in which missed sales cause a decrease in service level. Communication is an important tool for managing expectations and minimizing losses for the customers. A weekly risk-list is sent to Unilever, listing the risk of not meeting the demand. Unilever communicates a dashboard elaborating on the missed sales, reasons for the missed sales, stock availability, days on hand, and forecast bias. At end of 2018 has been a shift in ERP and production process systems. ZFG will implement their systems in production location Oss, meaning that SAP/APO will be replaced by JD Edwards and FOBIS. JD Edwards will be used for planning and costing purposes, while FOBIS will ensure the business administration in terms of production processes and logistics.

1.4 Conclusion Chapter One

This chapter has introduced the current situation of the company, the production lines in further detail, elaborating on the O.E.E. and the shelf-life. Furthermore, the transportation and stocks in the international warehouses are discussed. The following chapter will elaborate on the transition of ownership, factory- and warehouse details, and introduce the complication that this thesis will tackle.

2 The Transition from Unilever to ZFG

From the 1st of October 2018, the transition of inventory ownership in Veghel has taken place. Zwanenberg Food Group (ZFG is the supplier) has the inventory ownership in this warehouse with Unilever (as customers). This means that there is a transition from a hybrid model with no consignment stock at all, to a hybrid model with consignment stock (figure 1). This is part of the Business Purchase Agreement (BPA) between the two parties, which is established since Unilever sold the plant to ZFG. In this BPA there is an agreement on principles that are translated to a way of working for the UL items, a new way of working is needed for the remainder.

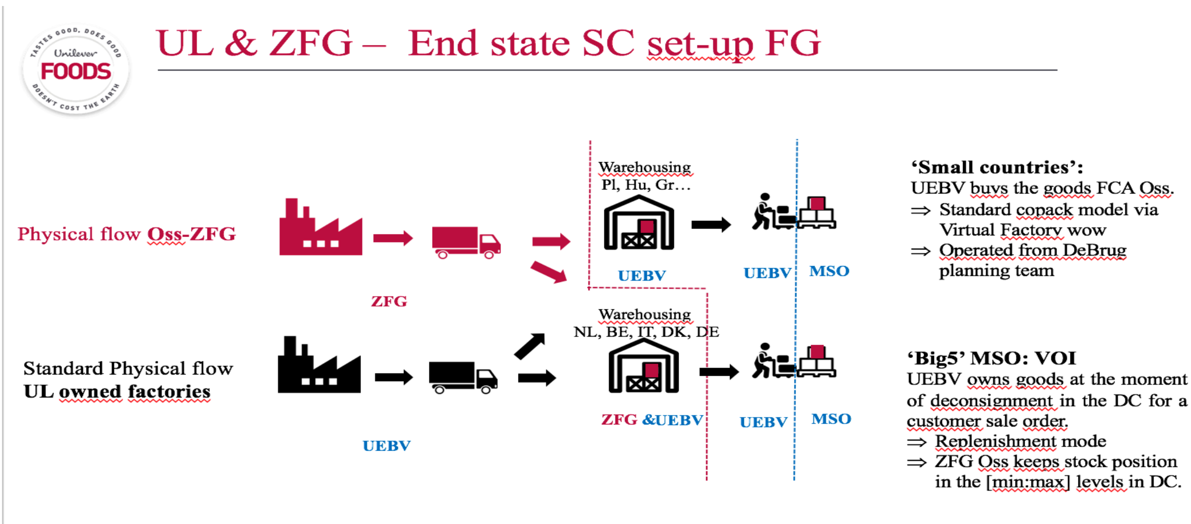

Figure 4. The transition of the inventory ownership from Unilever Europe BV (UEBV) to ZFG, the red portrays the non-VMI which will transition to the lower illustration.

The initial transition on the first of October 2018 took place in Veghel (The Netherlands), the other four warehouses with the largest volumes will follow. This indicates that this first transition should be regarded as a learning moment for the following transitions. The transition has three main challenges that have to be thoroughly researched; the first one is that other non-Unilever items require separate principles. Secondly, ZFG works with a different system (JDE) than Unilever does (SAP). This transition needs to be regulated properly to minimize the chance of a stock situation. Finally, the existing Unilever procurement contracts need to be transitioned to ZFG contracts.

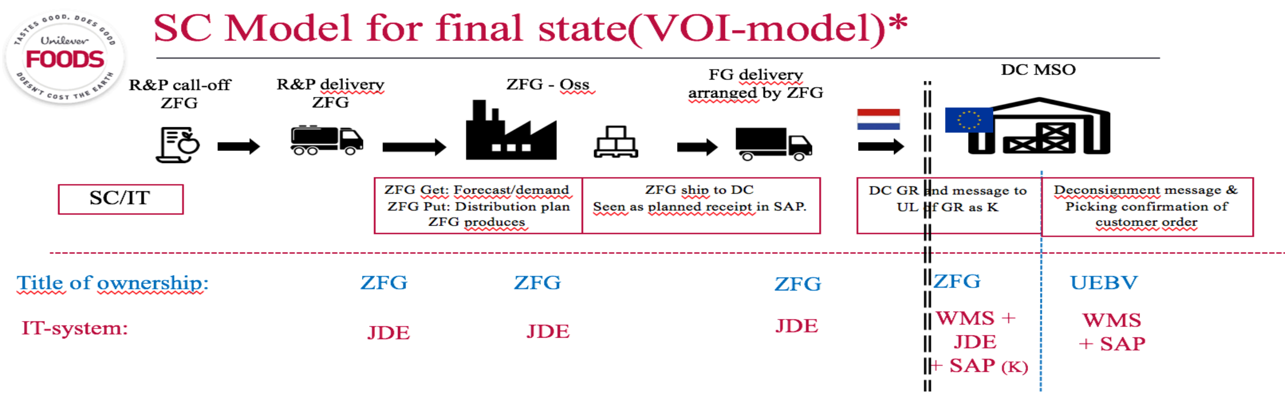

Figure 5. the transition from a hybrid model to a hybrid model with consignment stock.

The way of working consists out of three levels;

1. *Through systems;* ZFG has an overview of the total stock and forecast, Unilever will be able to view the ZFG distribution plan. There is a need for a good system integration regarding communication between ZFG systems and Unilever (SAP ERP systems).
2. *Operational level;* communication is needed to assure performance and get clarity on a day to day activities.
3. *Tactical*; coordination is needed of the full Unilever group of products that are outsourced to Oss.

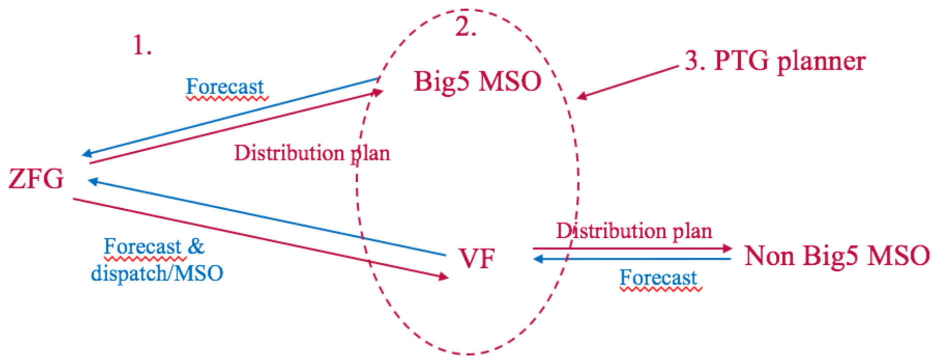

Figure 6. The Way of Working model

2.1 Research Motivation

The goal of this research is to lead to a better and smoother way of working and performing for the company. This paper is meant to provide better insight for the company on the planning parameters. Since ZFG became the owner of the site and with the transition of consignment stock ownership, it has become interesting which planning parameters should be used to optimize the operations in this new situation.

2.2 The planning parameters and performance measurement

Some of the main planning parameters have been mentioned before in this paper, but what are the consequences of setting these parameters in the current situation? Below are planning parameters listed which are currently integrated into the operations.

1. *The internal- and total shelf-life*; the internal shelf-life, as it is introduced in section 3.1, is the number of days that the produced products can be sold to the customers, all products that exceed this amount are considered as obsoletes. The total shelf life is the best used before the date stated on the products, more explicitly it is the encompassing time between the very first moment of production and the stage at which it is rejected for a determined purpose (Bremner, 2002).
2. *'The stock level'*; the stock of the SKU's is monitored and replenished constantly. The quantity of the stocks depends on the demand.
3. *The changeover matrix*; the changeover matrix gives an overview of the set-up time needed to change production settings from one SKU to another. This can be because of the content (mix), packaging, or allergenic substances.

2.2.1 The overall equipment effectiveness

There are several KPI's that can give insight into how well the site is performing on different levels, this thesis will mainly focus on the production performance. This is the planned (theoretical) versus the produced (actuals) quantities, the difference between the two is the productivity of the production line in that week. This shows how well the production can keep track of what they should produce, if there is continuous lower output then it might be wise to adjust the change-over-time or the line speed. This way of working regarding the performance measurement is by using an excel spreadsheet which has to be filled by planning and production on a day or week basis.

Each production line works with specific O.E.E. which gives a realistic view of the expected output (see table 3). This table shows that the Line-E line' and Line-C have the highest O.E.E.'s, while the Line-B line has the lowest one. Again, when output has a high bias, then the production planners might need to consider adjusting the O.E.E. norms, this would provide a better and more reliable overview of the estimated production output.

Production Line	O.E.E.
Line-B	54 %
Line-D	74%
Line-F	N/A
Line-A	81%
Line-E	95%
Line-C	85%
Line-G	77%
Line-H	70%
Line-I	64 – 70 %

Table 2. The O.E.E.'s per production line, focusing only on three (Line-A, Line-B, Line-C).

2.22 Material Waste/Obsolescence

Not all materials are converted into finished goods, some of the material will end up as waste. During production raw- and packaging material will run to waste, this is an inevitable occurrence. There are several reasons why waste can occur, some of these are;

- Changeovers (reel of the raw material)
- Obsoletes raw material (expiry date exceeded)
- Human/mechanical errors
- Obsoletes packaging material (relaunches, expiry date exceeded)

This thesis will discuss waste as a consequence of changeovers, optimizing this procedure should minimize this amount.

To assure that there won't be a shortage of material during production and risking a downtime a scrap for each material of an SKU is calculated through the SAP software. This is the waste percentage per material that has to be added to the calculated finished goods. Figure 7 shows the scrap percentages for the mix (raw materials) for all the production lines, while figure 8 shows the scrap percentages for the packaging materials as well for all of the production lines. This does not only minimize the risk that the production lines face any downtime but also gives insight on which mixes and packaging materials for the SKU's cause the most waste. It can be useful and cost-saving if the outliers will be tracked and find ways to minimize the waste during the production process.

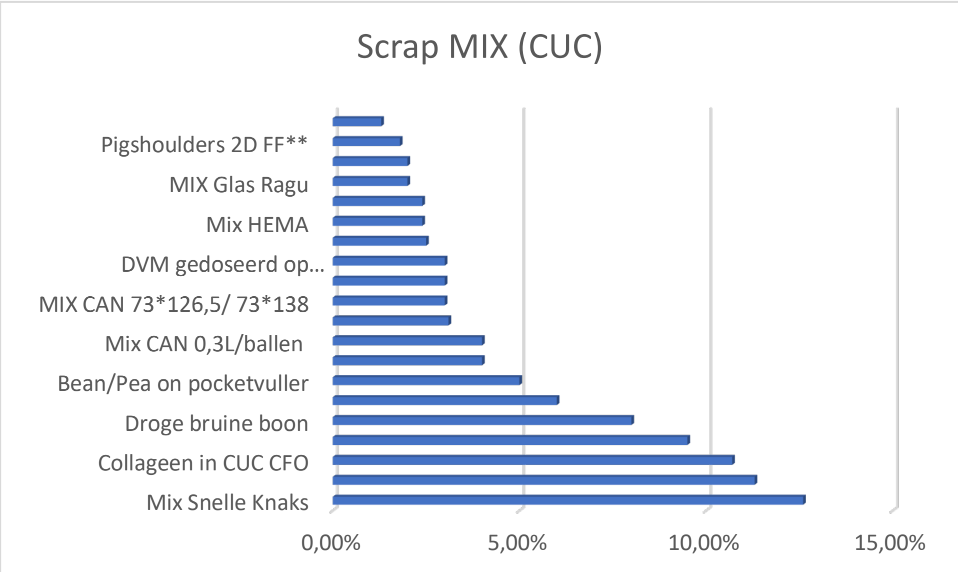

Figure 7. The scrap percentages for the mix in the meat, sauce, and can factories in the current planning systems.

Figure 8. The scrap percentages for the packaging materials in the meat, sauce, and can factories.

2.3 Transportation and stocks

The goal is to ship the products as soon as possible after being packaged, transportation is booked based on the production plan one week in advance. Besides the booked transportation there is a shuttle that continuously transports the goods to the main warehouse in the Netherlands location Veghel (see figure 9).

The goods are transported to fourteen warehouses around Europe. As mentioned before there are five warehouses with the largest receipt of goods, these include Veghel (The Netherlands), Heilbronn (Germany), Lodi (Italy), Bornem (Belgium), and Astorp (Sweden). These warehouses will take part in the consignment stock, Veghel already went to a VMI way of working and the other warehouses will follow. The five warehouses will contain ZFG stock and the goods will be deconsigned before leaving the warehouse. For the other non-VMI warehouses, the stock will be the property of the customers at the moment the goods are received in the warehouses, we are only going to focus on these five warehouses. This is because we are interested in the warehouses with consignment stock.

In the service level agreement, the level the min and max stock are stated, these have to be followed and if the stock reaches higher or lower than these numbers ZFG will be responsible for any risk. The internal and total shelf-life of the products are important parameters for determining the maximum days on hand. The current average is six to eight weeks cover, separate agreements also known as seasonal readiness allow the cover to build up higher than the default settings. This is due to the limited capacity and mitigating the risk of possible losses.

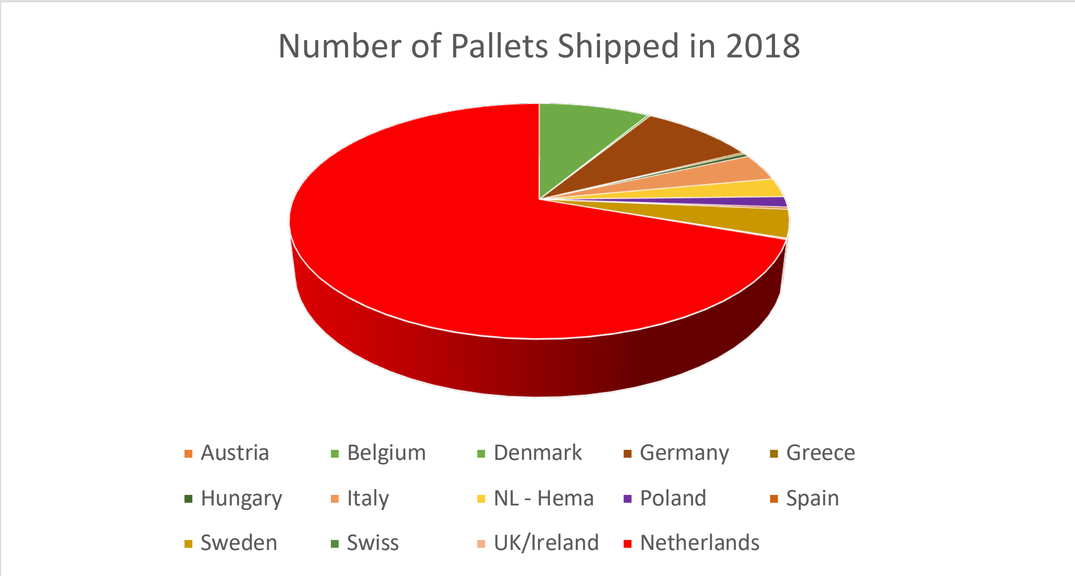

Figure 9. The number of pallets shipped in the year 2018 to the warehouses.

The warehouse in Veghel is the only warehouse with consigned stocks at this stage, this means that this warehouse will be analysed this thesis in order see whether a reduction in holding costs could be gained.

2.4 Problem Description

The transition of ownership has led to different situations and opportunities for the company, these can be beneficial for customer satisfaction, operational efficiency (e.g. production runs), and a change in costs. Through researching the overall equipment effectiveness (O.E.E.) and the waste rate (e.g. obsoletes) by having more suitable or different planning parameters. If these adjustments will lead to higher output and higher stocks, this means the inventory value will increase. What is the difference between VMI and non-VMI if this value increases?

This proposal is meant to introduce the topic and research question;

How to determine the optimal production parameters to minimize setup costs and the inventory holding costs, by considering the obsolescence of products?

With the transition of ownership, the current planning parameters might not be the most suitable, and adjustments might be needed which can lead to better performances.

2.5 Scientific Value

The purpose of this research is to determine the optimal production parameters and how these can minimize obsolescence, setup costs, and inventory holding costs. The added value of this thesis to the existing research is determining the relationship of planning parameters to setup costs. This would provide insight into how the selected planning parameters affect the setup and how these can result in cost savings. Set-up costs are considered for the tentative production planning, and not directly in the improvement procedure of the heuristic production planning (Park, 2004).

2.6 Conclusion Chapter Two

Many changes have occurred during the transition, with this comes a new way of working and opportunities. It is important to examine new settings that would make the supply chain of the factory more efficient regarding production and costs. This thesis will focus on determining the optimal production parameters to minimize obsolescence, setup costs, and inventory holding costs. The next chapter will introduce the research design, by discussing the research approach, research objective, research questions, and the research methodology.

3 Research design

In this chapter, the research design of this research will be discussed. The function of a research design is to ensure that the evidence obtained enables us to answer the initial question as unambiguously as possible (Jackson, 2017).

3.1 Research approach

The research question refers to a performance measurement of a process, Meier et al (2013) define this as the extent to which the outcome of the process can fulfil the requirements of the internal or external customers of this process. Within a company this process cannot be measured separately, the interconnected information and material flow, complex process chain performance are interlinked (Meier et al. 2013). Several key performance objectives must be delivered by planning and production processes, it depends on the business which one of these objectives weighs heavier. Some examples of the objectives are (BDC, 2018);

- Quality; minimizing mistakes and providing the level of product and service quality desired.
- Speed; high response time to the customer needs to decrease both inventories and risks.
- Dependability; developing trust with the customer that the provided service is regarded as accountable.
- Flexibility; the ability to adapt to changing demands.
- Cost; efficient waste-free supply chain is needed to minimize production costs.

The production- and material planning at ZFG are part of the Business Office, which is mainly responsible for the work preparation, production scheduling, and analyzing trends. All the above-mentioned objectives are considered as important for the planning team as a measurement for performance. (Cannella, Dominguez, Ponte, & Framinan, 2018) state that “increasing the capacity limit of the manufacturer has a positive effect on the supply chain dynamics derived from maintaining a lower and constant lead-time.” However, ZFG deals with a constrained capacity, which faces challenges mainly during its high season, best before dates, working capital, obsolete risks through relaunches, and delisting. High responsiveness is a crucial element to provide the customer with the ultimate service. The transition might not directly influence the speed, flexibility, dependability, and quality while these have always been optimized and the same standards remain. The costs aspect can be a more interesting objective to research, while the planning parameters can be adjusted to favorable settings for the company to benefit from.

3.2 Research objective and scope

To adapt better to the changing environment, new optimization parameters will be needed for production planning. This need can be defined by the following research question;

How to determine the optimal production parameters to minimize setup costs and the inventory holding costs, by considering the obsolescence of products?

The scope of the research will hold the production output of the current three production lines within the factory, specifying the research on some of these product lines will lead to better outcomes. The focus will be put on three production lines that would be suitable for this research, namely the Line-C, Line-A and the Line-B production lines. The stock-keeping units (SKU's) of these production lines will function as data for the performance.

If the production performance would improve due to the adjustment of the planning parameters, what are the consequences of the inventory value for this change? To what extent would a higher inventory value result in better financial and overall performance? Looking further than only the performance in the production location broadens the scope of this thesis.

3.3 Research questions

To answer the research question mentioned in the previous chapter, the sub-questions must be answered. The collected information from these chapters will be fundamental for the research question. Before these, a literature review will elaborate on previous research on what kind of planning tools are used to optimize inventory. The following chapters and sub-research questions will be discussed;

Literature review (Chapter 4)

Based on previous research what kind of planning tools are used to optimize inventory?

Which theoretical framework is needed to redesign the policy? (Chapter 5)

What is the effect of the new policy on the set-up time? (Chapter 6.1)

What is the effect of the new policy on obsoletes? (Chapter 6.2)

What is the effect of the new policy on the inventory costs? (Chapter 6.3)

How should the new design be implemented in the factory? (Chapter 7)

3.4 Research methodology

Research Question		Chapter	Topic	Research Methodology
		Ch. 3	Current Situation	Observations Organizational Information Management Information
		Ch. 4	Literature Review	Literature search
SUB-RQ1		Ch. 5	Which theoretical framework is needed to redesign the policy?	Data Analysis Case study
SUB-RQ2		Ch. 6.1	What is the effect of the new policy on obsoletes?	Case study
SUB-RQ3		Ch. 6.2	What is the effect of the new policy on the set-up costs?	Case study
SUB-RQ4		Ch. 6.3	What is the effect of the new policy on the inventory costs?	Case Study
SUB-RQ5		Ch. 7	How should the new design be implemented in the factory?	Case Study

3.5 Conclusion Chapter Three

This chapter has introduced the research design of the thesis, the focus of this paper will be on costs reduction. This thesis will focus on the changeovers and their relations with minimizing the obsoletes and set-up time. This can be done by examining the change-over matrix, which is used by the company when making a production plan and its relationship to inventory cost. The outcome will be applicable in the factory in general, however only the parameters of three production lines will be examined (Line-B, Line-A, and Line-C). The following chapter will introduce literature that can substantiate this thesis and finding the appropriate policy models.

4 Literature Review

The performance of a planning framework is highly influenced by the chosen parameters, these have to be optimized in order to ensure well performing system (Hartl, 2013). The purpose of this chapter is to create a firm foundation for advancing knowledge, theory development, extracting existing knowledge, and potentially uncovering areas where research is still needed (Watson & Webster, 2002). This chapter will elaborate on the literature needed for this study.

4.1 Production optimization

Two competing objectives of capacity planning are maximizing the market share and maximizing capacity utilization. However, inventory can become obsolete risks and increase the holding costs resulting in financial burdens (Nahmias, 2015). Still, the competitiveness of manufacturing companies depends on the availability and productivity of their production facilities, which companies are striving to optimize to remain competitive. If the production losses were identified and eliminated so that the manufacturers could bring their products to the market at minimum cost, this would be enabled by introducing a performance measurement system that can take into account different important elements of productivity in a manufacturing process (Muchiri & Pintelon, 2008). Nakajima (1988) introduced the total productive maintenance (TPM) concept, which provided a quantitive metric called the overall equipment effectiveness (OEE). It identifies and measures the losses of important aspects of manufacturing, mainly the availability, performance, and quality rate. Manufacturers have embraced this tool to improve their asset utilization (Muchiri & Pintelon, 2008). The OEE is designed to identify losses that reduce the equipment effectiveness, these losses are activities that absorb recourses but create no value, these can be due to manufacturing disturbances that are either chronic or sporadic. The chronic disturbances are the small and hidden ones that can have various causes, while the sporadic are more obvious since they occur quickly (Jonsson & Lesshammar, 1999). This is a bottom-up approach where an integrated workforce strives to achieve overall equipment effectiveness by eliminating six large losses (Nakajima, 1988), this paper will focus on the set-up and adjustment losses;

Downtime losses:

1. *Breakdown losses* are categorized as time losses and quantity losses and it is caused by equipment failure or breakdown.
2. *Set-up and adjustment losses* occur when production is changing over from the requirement of one item to another.

Speed losses:

3. *Idling and minor stoppage losses* occur when production is interrupted by a temporary malfunction or when a machine is not working or has troubles.
4. *Reduced speed losses* refer to the difference between equipment design speed and actual operating speed.

Quality losses:

5. Quality defects and rework are losses in quality caused by malfunctioning production equipment.
6. Reduced output during start-up is output losses that occur from machine start-up to stabilization.

As one of the goals of this thesis is to minimize the set-up costs the focus will be put on the set-up and adjustment losses. Considering the changeover matrix to calculate unit set up cost and use set-up cost to find the optimal order quantity that will minimize losses due to changeovers, set-up, and inventory holding costs.

4.1.1 Set-up time

In a factory, each food production order must be scheduled on available production lines. The set-up time and set-up costs for producing each food type strongly depend on the product type produced in the previous run. Meaning that the set-up time and the set-up costs are sequence dependent (Farahani et al, 2012).

Farahani et al (2012) introduce a hierarchical modeling approach that subdivides the entire planning problem into sub-problems of considerably reduced complexity (see figure 10). The first one reduces the number of entities in the production scheduling stage, grouping consistent customer orders into a set of production batches. Secondly, with the introduction of the block planning concept, one can capture sequence dependencies in setup costs and times which simplifies the scheduling problem. Block planning exploits the advantages of both continuous-time representation and the use of predefined setup sequences (Farahani et al, 2012). Finally, distribution planning seeks to minimize a trade-off between transportation cost and the quality decay of the perishable goods.

This thesis will examine how planning parameters can minimalize the set-up time. However, this will be done based on historic production planning data and not scheduling.

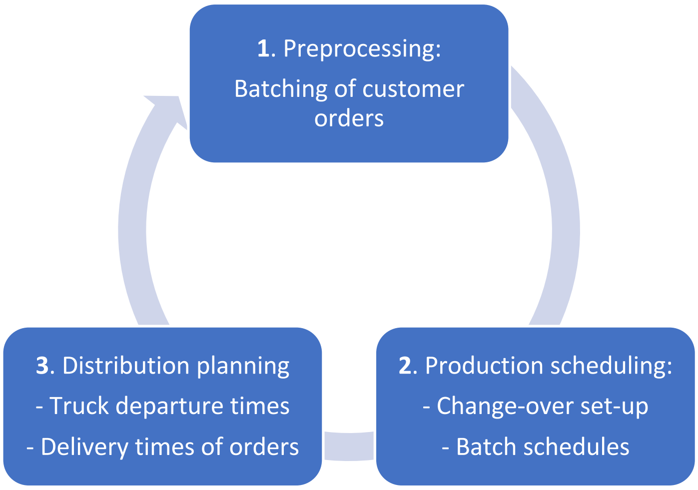

Figure 10. The hierarchical modeling framework

4.1.2. Obsolescence

Producing in large batches is a way to keep production costs low and limit the number of set-ups, this would reduce material obsolescence during production (Rajaram & Karmarkar, 2004). However, obsolescence can also come in a form where material, e.g. packaging, raw material, is not usable anymore. Another form of obsolescence is the perishability issue (shelf-life), here the products exceed their internal shelf-life before leaving the warehouse then the goods can be considered waste (Van Donk, 2001). By campaigning, running several batches of a particular product sequentially, producing an appropriate quantity while avoiding a part of the set-up. The set-up would be incurred when switching between different SKUs (Rajaram & Karmarkar, 2004). The focus of this paper is the obtained obsolescence as a consequence of changeovers during production, which is why this thesis will only elaborate further on this part.

4.2 Inventory

After the components are processed and made into finished goods, the goods are shipped out to the warehouses. The warehouses hold inventory while it is probably cheaper to order or produce in large batches, lower uncertainties, optimize transportation, smooth issues (irregular demand forecast), and control cost.

4.2.1 Types of Inventory Costs

All inventory models have as the optimization criterion the cost minimization this will lead to profit maximization. All inventory costs can be placed into three categories; holding cost, order cost, or penalty cost (Nahmias, Production and Operations Analysis, 2015);

- Holding cost is the sum of all costs that are proportional to the amount of inventory physically on hand at any point in time (e.g. cost to store, taxes, insurance, spoilage)
- Order cost: include includes all those costs that are proportional to the amount of inventory on hand (e.g. setup, bookkeeping)
- Penalty costs: stock out cost is generated when not having sufficient stock on hand to satisfy the demand (e.g. lost in sales, bookkeeping, loss of good-will)

One of the aims of this thesis is to find the inventory holding costs, thus regarding the different types of costs, the focus will be put on holding costs and finding a way to minimize them when determining the optimal planning parameters.

When items are used to satisfy demand, the inventory will decrease and it will increase when units are produced or new orders arrive. For one to compute the holding cost of the inventory level *I(t)* during some interval *(t1, t2)* as shown in *figure 10*, one has to multiply the inventory costs by the area under the curve described by *I(t).* When the curve of I9t) is complex, the average inventory level would be determined by computing the integral of I(t) over the interval (t_1, t_2) and dividing by $t_2 - t_1$.

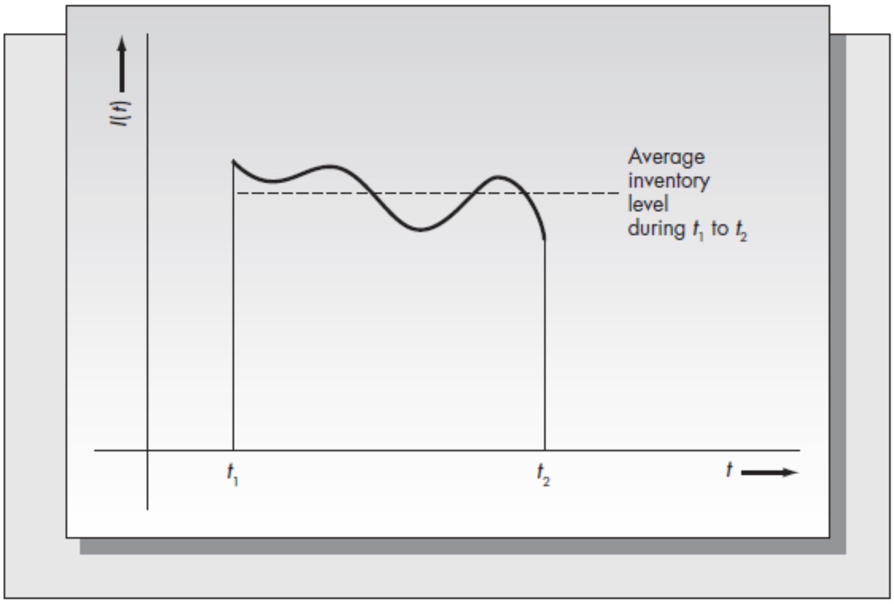

Figure 11. Inventory as a function of time, source: (Nahmias, Production and Operations Analysis, 2015, p. 206)

4.2.2 Lot size re-order point

The economic order quantity model (EOQ) is the simplest and most fundamental of all inventory models. It describes the important trade-off between fixed ordering costs and holding costs.

When distinct products are produced on a single production line, the goal is then to determine the optimal sequence to produce the items, and the optimal batch size for each of the items to meet the demand and minimize costs. However, this thesis will not focus on the optimal sequence instead historical planning data will be used to find the change-over-time per SKU.

Inventories have to be reviewed continuously rather than periodically, meaning the state of the system is known at all times. In this case, the lot size-reorder point system is used, this consists of two decision variables: Q and R. Where Q is the order size and R is the reorder point. When the inventory of stock on hand reaches R, an order for Q units is placed. Also, a positive order lead time (T), can be held. Uncertainty is generated if the demand exceeds the lead time, where the lead time is regarded as the response time of the system. In this case, D represents the demand over the lead time, and F(t) the cumulative distribution function of D. Cost parameter includes a fixed order cost K, a unit penalty cost *h,* and interpreting λ as the average annual demand rate. The optimal values of the Q and R, are optimal when*;* $Q = \sqrt{2\lambda}\big(K + pn(R)\big)$ *and* $1 - F(R) = Qh \quad /p\lambda$. To assure that the re-order point won't be placed at a lower point than R itself, one bases the reorder decision on the inventory position rather than on the inventory level. The inventory position is the total stock on hand plus an order (varies from *R* to *R+Q*), as shown in *figure 11* (Nahmias, 2015).

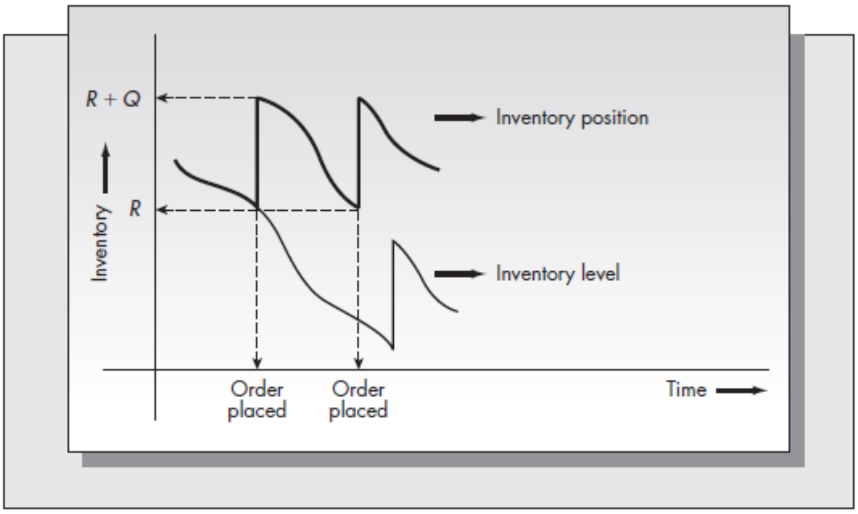

Figure 12. Expected inventory level for (Q, R) inventory model (Nahmias, 2015)

4.2.3 First in First out (FIFO) and First Expired First Out (FEFO) principle

For food products, there is always a "best consumed before" date attached due to its perishability. There is a fixed lifetime known as the number of periods or length of time independent of all other parameters of the system. In these models, it is always optimal to issue the oldest items first according to the first in first out method (Nahmias, 1982). By taking into account the expected shelf life of products the first expired first out (FEFO) principle can be maintained. This prevent that unnecessary product losses throughout the supply chain occur, thus minimizing the economic losses as well (Hertog, Uysal, McCarthy, Verlinden, & Nicolai, 2014).

4.3 Conclusion Chapter Four

Chapter four introduced the literature needed for answering the main research question, elaborating on the importance of production optimization and efficiency. Providing further information on the obsolescence, setup time, safety stocks, re-order point and the holding costs and what one should take into account when trying to optimize the current situation. The next chapter will discuss how the literature mentioned in this chapter will be used as a tool to answer the main research question of this thesis.

5. Theoretical Framework to Redesigning the inventory policy

This chapter will elaborate on the policy design, how are the planning parameters introduced earlier be able to smooth the production and have a positive impact on inventory costs. The OOE is the utilization of production to calculate and inform on the set-up time and the possible obsoletes. Then the min-and max re-orders points are calculated, determining the stocks in the warehouses.

5.1 The process

To find the most suitable planning parameter settings, taking into account the 'shelf-life, 'days on hand' and the 'changeover matrix', one needs to examine historic data. The change-over-time should be brought to a minimum. This smoothing process of the production would result in costs savings in terms of production, the impact on inventory should then be examined (figure 10). This chapter will focus on finding the most suitable planning parameters settings to minimize obsolescence, setup costs, and inventory holding costs. The following chapters will elaborate on the impact of the planning parameters on obsolescence, set-up time, and inventory holding costs.

Figure 13. the steps to find the optimal planning parameters

5.2 The changeover matrix

The part will elaborate on how the change-over matrices are used in the factory and what their effect is regarding the production process. The production lines have their identical changeovers (e.g. packaging, content, technical set-up, etc.), but some of the change-overs are for all production lines the same (allergenic substances, flavor, etc).

The canned meat factory includes the production line-C and Line-A which have the following changeovers in common; the emulsifier and the allergenic, these result in set-up time and cleaning time. Changeovers between production runs could likely include multiple changeovers, e.g. pipe change (3 min), knife change (15 min), and cleaning (150 min). In total, the change-over would cost 168 minutes that could have been spent on actual production (*see figure 11*).

Emulsifier		x
pipe change	3	min
knife change	15	min

Allergenic		
clean	150	min

Figure 14. Changeover-time per set-up for the CFO production lines

Each production line has also its specific changeovers, these are related to the packaging size and content. For the production line-A, these include can size, sausage size, and the number of sausages that go into the can. For the Line-C the production line-specific changeovers are only related to the size of the sausage (*Appendix A UTAI D*).

The change-over matrices for the can-line are more sophisticated as the production line processes are different kinds of meats, vegetables, and sauces. Taking into account the volume filler, pocket fillers, vacuum filler, can height, can diameter, and the sterilization time (program). This means that the planning and scheduling of the can production line need to be bundled to minimalize the change-over and set-up time. The many changeovers are reflected in the low O.E.E. rate (54% see table 3) of the production line.

For this thesis the average change-over-time per SKU can be calculated by using the following formula;

$$\text{Average Changeover time per week per SKU} = \frac{\mathit{Average\ Changeover\ per\ SKU\ x\ Demand\ of\ SKU\ per\ week}}{\mathit{Optimal\ Order\ Quantity}}$$

The data will be gathered from production plans from the past, these include the OOE for that specific planning. Gathering this information from fifteen weeks would provide a reliable average change-over-time per SKU. Using the week production, which shows the change-over times between products based on their sequence, and the number of transitions. Finding an average set-up time per SKU type based on the number of observations, each observation can be regarded as weight. This can then be multiplied by the price of the SKU to find the set-up costs (K). These calculations are necessary for finding the optimal lot size for the corresponding SKU. This has to be done for every production line within the scope of this research, thus regarding the Line-B, Line-A, and Line-A.

5.2 Min/max settings

As mentioned before, min and max settings are currently used when planning the production, these are based on the MOQ and agreements made with the customers. The transition has made it interesting to recalculate these settings and find possible more suitable min and max settings. The re-order point has to be calculated in terms of the on-hand inventory. The re-order point would be the min, and the planned production plus the re-order point would equal the max setting.

5.3 Shelf-life of SKU's

In tactical planning, shelf-life limitations are seen as a crucial part to avoid lost sales and disposal costs if the inventory exceeds its shelf-life. A desired safety stock level is given for each SKU in each location, to avoid disposal costs all SKU's must leave the supply chain before the end of their shelf-life. This also means that the stock level may not meet the demand resulting in possible missed sales. The FEFO method is important in this case since sending the SKU with the shortest remaining shelf-life to the retailers will minimize the risk that the inventory turns into waste (Elzakker et al, 2014). In chapter three, table 2 showed that the internal shelf-life of the Line-B (900 days) and the Line-A (1020 days) is high, in these cases, perishability is not a huge factor regarding production batch sizes and the inventory levels. For the Line-C production line the internal shelf-life is quite shorter (35 days), this means that the number of batches planned of the SKUs is highly restricted by the shelf-life.

5.4 Conclusion Chapter Five

In chapter five the application of the literature in the current way of working is discussed and which process is needed a provide a clear answer to the main research question. Furthermore, several potential limitations that could impact the new policy. The next chapter will discuss for the policy would be set up and how it impacts the performance in comparison to the current process.

6. The effect of the Q, R Policy on the setup time, obsolescence, and holding costs.

Chapter six will provide insights on how the Q, R policy would be set up, and what its effect is on setup time, obsolescence, and holding costs. Each component will be substantiated with the discussed literature, historical data, and calculations.

6.1 What is the effect of the new policy on the set-up time?

In chapter four the set-up time for the production lines has been discussed. As the set-up time and the set-up costs are sequence-dependent, clustering the customers' orders into a set of production batches would reduce the time needed for the change-over. The sequence, minimizing the transportation costs of the end products, and considering the quality decay of the perishable goods are also main factors in the planning process (Farahani et al, 2012). This thesis will examine how planning parameters can minimalize the set-up time based on historic production planning data, thus the sequence, transportation costs, and the decay of goods will not be taken into account in this thesis.

6.1.1 The current set-up time per production line

The set-up time will be calculated for each production line individually, the data will be gathered from the weekly production plan from ten weeks. The collected data for the three production lines (Line-B, Line-A and Line-C) originates from week 37 up to and including week 46 in the year 2019. The capacity in this period is constant to represent a valid comparison. There are other restrictions concerning the number of full-time-equivalent (FTE) and implications with other productions lines within the plant that require extra changeover time. However, this thesis will not include these variables as a factor for the change-over time. The set-up time and the number of SKUs planned every week are distracted from these production plans. Figure 14 represents the gathered data in one graph and in figure 15 the average amounts of these data are represented to get a better picture overall;

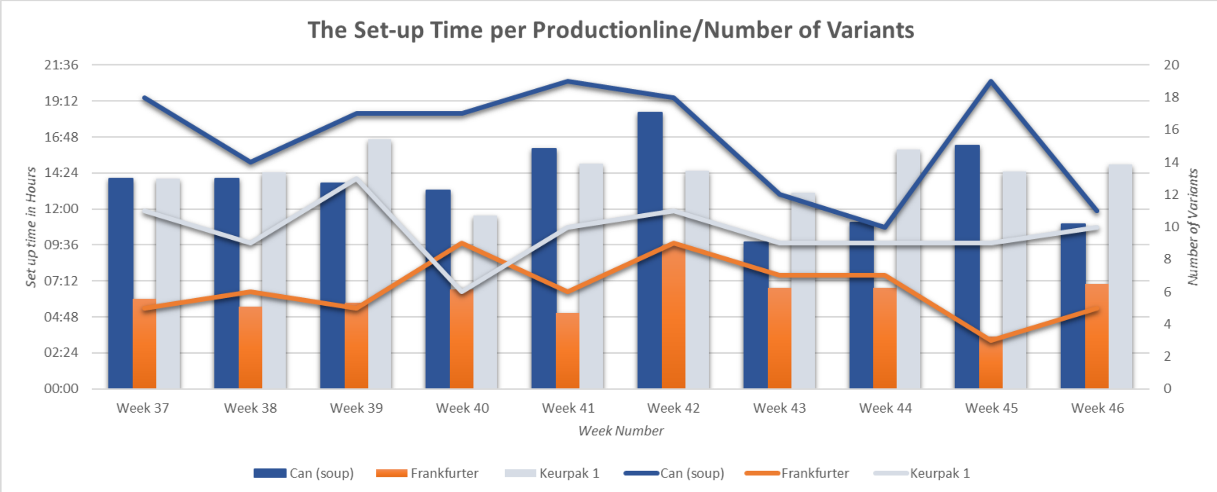

Figure 14. The set-up time and the number of variants per production line for weeks 37-46 in the year 2019.

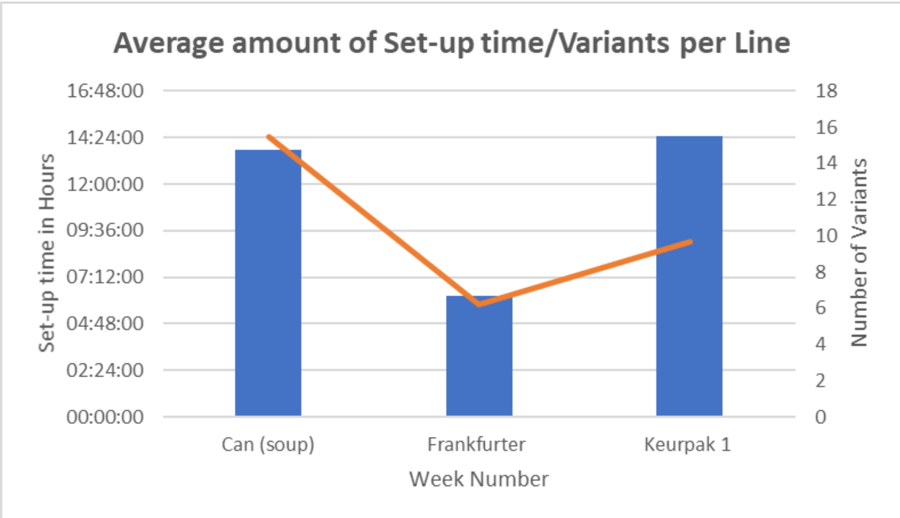

Figure 15. The average set-up time and the number of variants per production line for weeks 37-46 in the year 2019.

For the can production line, we can see it has the highest number of planned variants per week with an average of 15 SKU's. The can production shows also the highest average amount of set-up time, the average set-up time in the given period is 13:44 hours every week. *Appendix F* shows the amount of set-up time needed per change over per variant. By optimizing the production scheduling and maximizing the run lengths the change-over-time can be reduced. It is noteworthy to mention has one of the highest amounts of SKUs (see Table 1), which may affect the change-over time.

The Line-A production line shows the lowest number of planned variants per week and the lowest number of planned variants every week. The set-up time in hours is the lowest for this production line as well in comparison to the other two production lines. The Line-

A has a quite lower number of SKUs produced as to the Line-B production line. *Appendices A, B, and C* show the required set-up time per change-over.
The Line-C production shows a high amount of set-up time needed every week. The number of variants planned every week is relatively low in comparison to the high set-time needed, this is due to the fixed change-over time of 7 hours after 36 hours of production to clean the production line thoroughly and secure the food safety of the products. Appendices A, B, and D illustrate the set-up time needed for the Line-C production line.

6.1.2 Finding (Q, R) per SKU

In chapter 5 was mentioned that the average change over time per week per SKU can be calculated by multiplying the average changeover per SKU by the demand per SKU per week and dividing them by the optimal order quantity.

$$\text{Average Changeover time per week per SKU} = \frac{Average\ Changeover\ per\ SKU\ x\ Demand\ of\ SKU\ per\ week}{Optimal\ Order\ Quantity}$$

The first one has to calculate the optimal order quantity per SKU, in chapter four displayed that the optimal order quantity is finding the optimal value between order size *(Q)* and the reorder point *(R)*. The optimal values of the Q, and R, are optimal when*;*

$Q = \sqrt{2\lambda}\big(K + pn(R)\big)$ *and* $1 - F(R) = Qh \quad /p\lambda.$

Chopra & Meindl (2007) simplified this formula into the following;

$Optimal\ Lot\ size, (Q) = \sqrt{\frac{2DS}{hC}}$, where the inputs mean (Chopra & Meindl, 2007);

D = Annual demand of the product

S = Fixed cost incurred per order

C = Cost per Unit

h = Holding cost per year as a fraction of product cost

The annual demand of the product (D) is a given as the forecast goes approximately up to two years. The fixed cost incurred per order (S) will not vary with the quantity of the order, they incur every time an order is placed. The cost per unit (C) is also a given, which indicates the cost of production per unit. Lastly, the holding costs per year as a fraction of product cost (h) can be calculated through the following formula *H = hC*.

The optimal quantity order will be calculated for all the SKU's of the three production lines, to find out the average change over time per week of these SKU's. In *table 3* an overview is given of the number of SKUs per production line.

Production Line	**SKU amount**	**Internal Shelf-Life**
Line-B	54	900 days
Line-A	28	1020 days
Line-C	17	35 days

Table 3: the number of SKUs for the production lines and the internal shelf-life.

Example for calculating the optimal lot size:

Product-A

D = Annual demand of the product = 626.653 units

S = Fixed cost incurred per order;
These are the transportation cost which is €400.- per commute, one truck fits 34 pallets. One pallet holds about 120 units. The truck is always fully loaded for shipping, we can assume that these numbers per order are fixed. With this information, one can say that *S = €400.-*

C = Cost per Unit = €10,24.-

*h = Holding cost per year as a fraction of product cost = hC = 15,7% * €10,24 = €1,607*
the holding costs percentage is calculated using the following data;

- *The average value of inventory = €6.994.000.-*
- *The annual cost of storage = €0,20 per pallet a year * 70.700 pallet yearly = 15.000*

- *The cost of loading and unloading the goods = 70.700 pallets / 34 a wagon = 2.079 commutes a year. One commute costs €400.- thus yearly its 2.079*400= €831.764.-*
- *The cost of obsolescence of the goods = 1 percent of the total inventory = €6.994.00.- * 1% = €6.994.-*
- *Warehouse operators' salaries: 40.000* 6 = €240.000.-*

Holding cost percentage (h) = (15000+2.079+831.764+6.994+240.000)/6.994.000 = 0,15668 = 15,7%

Then, the $Optimal\ Lot\ size, (Q) = \sqrt{\frac{2DS}{hC}}$ is;

$$(Q) = \sqrt{\frac{(2*626653)*400}{1,607}} = 17.662 \text{ units}$$

Besides the order quantity (Q) of the SKU's, the re-order point of the SKUs must be calculated. Here one assumes that the demand follows a normal distribution and that the inventory position is continuously reviewed. Furthermore, one assumes that an order will arrive after the lead time (*L*) and if there is no inventory on hand the demand will be backordered. Lastly, the inventory manager specifies a required service level.

Reorder point = Average lead time demand + Safety inventory;

$$R = D_L + k*\sigma_L$$

Here D_L is the average lead time demand (average cycle inventory), this can be calculated by the average demand per day with the lead time (*D*L*). Replenishment lead time is the time that elapses from the moment an order is placed, until the moment that the product is physically available on the shelf for the customer. For calculating the safety stock Silver et al. (2017) refer to this as the equal safety factors, where he defines the safety stock of the product of two factors: $SS = k\sigma\sqrt{L}$, where *k* is the safety factor and $\sigma\sqrt{L}$ the standard deviation of the errors of the forecast of total demand over the replenishment lead time (*L*). Here one takes into account that the demand is independent across periods (Silver, Pyke, & Thomas, 2017).

Example for calculating the Reorder point:

Product-A

Average cycle inventory = EOQ/L = …/2 =

Monthly demand: 626.653/12= 52.221 units, standard deviation = 5.786

Replenishment lead time L = 2 weeks

Cycle service level: CSL = 0.98

Safety factor z = NORM.S.INV (0.98) = 2.05

Demand over lead time mean = 52221 * (2*12/52) = 24.102

Demand over lead time standard deviation = 5786 * √(2*12/52) = 3931

Safety inventory = 2.05*3931 = 11883

ROP = 24.102+11.883 = 35.985 units

Moreover, one needs to retrieve the average set-up time per SKU to calculate the average change over time per week per SKU.

Line	Total SUT	Number of SKU's	Average SUT per SKU
Line-B	13:44:48	16	0:54
Line-A	06:14:48	6	1:02
Line-C	14:28:42	10	1:31

Table 3: Overview of the total set-up time (SUT), number of SKUs, and the average set-up time per SKU per production line. This data has been extracted and calculated from planned production during weeks 37-46 in the year 2019

The calculations per production line of the total set-up time, the number of weekly planned SKU’s are shown in table 3. Additionally, this overview provides the average set-up time per SKU. The average set-up time per SKU has also been calculated by dividing one week’s total set-up time and dividing it by the number of planned SKU's for that week. Taking the average of the period from week 37 to week 46.

Having calculated the ROP and the average SUT, the average change over time per week per SKU can be calculated.

$$\text{Average Changeover time per week per SKU} = \frac{1{:}02 \ x \ 12.051}{35.985}$$ = 00:20 minutes

6.1.3 What is the effect of the new policy on the set-up time?

For most items, the demand for the different SKUs varies over time. Some have a high and low season and others are more promotions orientated, which is the case for these products. In this case, it becomes difficult to use cyclic schedules to smoothen out the production. Nevertheless, the set-up time can be reduced by planning long production runs of the same or similar SKUs to smoothen the load as much as possible.

The simplified formula used to calculate the $Optimal\ Lot\ size, (Q) = \sqrt{\frac{2DS}{hC}}$, here the fixes cost per order (*S*) which includes the set-up time are multiplied by the annual demand of the product (*D*) multiplied by two. Furthermore, the outcome of this calculation is the dividend part of the total formula. The outcome of *2DS* is divided by the holding cost per year as a fraction of product cost and the cost per unit (the divisor). In this simplified formula of the optimal lot size, one can say that the higher the set-up time, the larger the optimal lot size will become. This can be viewed as a logical statement, one would like to avoid frequent production runs of a product that requires a long setup time as the is no productive output during the period. By introducing the EOQ values as the new planning parameters the planned lot size would be appropriate for the costs made during the given setup time of the given order. Now the EOQ for all the SKU's of the three production lines is calculated the EOQ can be used as a tool to regulate and reduce the setup costs. The first one should calculate how many times in a year setup for a certain SKU are needed, then multiplying the number of yearly setups with the setup costs results in the total setup cost per year. This input can be illustrated in the following formula;

$$Total\ setup\ costs\ per\ year\ per\ SKU\ = \frac{S*D}{EOQ}$$

Here *'A'* is the total setup costs for the given SKU and *'D' is* the total annual demand of the given SKU. The cost of obsolete material, logistics costs, and manning costs will give us the total setup costs per order for the Line-A production line.

Product-A

A = 160,68 + €400,00 + 93,75 = €653,43

D = 626.653 units

EOQ = 17.662 units

$$\boldsymbol{Total\ setup\ costs\ per\ year\ for\ Product-A} = \frac{400*626.653}{17.662} = €14.192,12.-$$

The outcome shows that the annual setup cost for Product-A is €23.218, 80.- if the EOQ is maintained as the production quantity standard. Comparing this outcome to the current setup time standard should give insights into whether the newly calculated setup costs for this SKU have decreased. The actual productions that have occurred in the year 2019 are used as the input of calculating the setup costs per SKU in the current situation. For the *Product-A* SKU the following calculations can be made;

$$\boldsymbol{Production\ setup\ costs\ per\ SKU\ in\ the\ year\ 2019\ (in\ €)} = Number\ of\ setup\ for\ SKU\ x * Setup\ cost\ (A)$$

$$\boldsymbol{Production\ setup\ costs\ for\ Product-A\ in\ the\ year\ 2019\ (in\ €)} = 48 * 653{,}43 = €\ 31.412{,}46$$

When comparing both outcomes one can say that maintaining the EOQ for this variant will lead to lower setup costs;

Difference in setup cost = current setup costs for the *Product-A* - Setup costs when implementing the EOQ = € 31.412,46 - €23.218, 80.- = € 8.193,66.-

For the variant *Product-A,* we can say that implementing the EOQ as the production planning parameter will lead to lower setup costs on annual basis. To find out whether for the other SKU's of the three production lines a similar positive outcome is generated one has to make the same calculations for all of the SKU's for these production lines. The results of the total setup costs in both scenarios are displayed in table 4;

Line	Number of productions in the year 2019	Production setup costs per SKU in the year 2019 (in €)	Number of yearly productions needed according new EOQ	Setup COST EOQ (€)	Change in Setup costs
Line B	344	€ 327,773.52	421	€ 400,770.85	-72,997.33
Line A	217	€ 142,011.00	206	€ 134,555.16	€ 7,455.84
Line C	313	€ 306,139	211	€ 206,063.14	€ 100,075.90

Table 4: Overview of the total set-up time (SUT) in the year 2019 retrieved from the ERP system JDE based on the actuals, comparing this data with the number of setups based on the EOQ production run. The change in setup costs shows whether there is a positive or negative consequence when implementing the EOQ as a planning parameter.

From the results shown in table 4, one can say that by implementing the EOQ as a default planning parameter the setup costs for the Line-B production line would increase. This means that implementing the EOQ for this production line instead of the planning method used in the year 2019 will increase the costs. However, for the production Line-A production line there is a positive result after implementing the EOQ as the default planning parameter. Furthermore, for Line-C even better results are gained after the implementation of the EOQ as the default planning parameter.

6.1.4 Scientific Value

This thesis will provide added value to the existing research by determining the relationship of planning parameters to setup costs. Providing insight into how the selected planning parameters affect the setup and how these can result in cost savings. The Q, R policy showed a positive impact on two of the three production lines discussed, reducing the number of setups for the Line-A and Line-C production lines. The most likely underlying cause that the Line-B production line has not shown a reduction in the number of setups when implementing the Q, R policy would be that the current MOQ does provide higher stock coverages than what is agreed upon at the service level agreement. This phenomenon is difficult to change as the batch size of the product is large in proportion to the demand. With these results it is showed that there is a relationship between the Q, and R policy and the setup costs.

6.2 What is the effect of the new policy on obsoletes?

In chapter four the obsolescence was shortly introduced, focusing on obsolescence as a consequence of changeovers during production. By planning long production runs the number of setups during the production week can be reduced and this will have a positive effect on the production output of the production line, this would also mean that material obsolescence can be reduced by targeting that as a planning target. We can divide the obsolescence of material as a consequence of setups into two categories; raw material (meat, greens, herbs, etc.) and packaging (RPM). Moreover, obsolescence may also incur when the finished product is stored at the warehouse and the shelf life of the product expires or that the product can't be sold due to delisting's by the customers. This chapter will mainly elaborate on the obtained obsolescence as a consequence of changeovers during production and how implementing the new Q and R policy as a planning parameter would influence the level of obsoletes. Furthermore, insights will be given on the obsolescence of the stocks at the warehouse. As the finished products are perishable goods it is important to also take into account what stock coverages the new Q and R policy will result in and what effect it will have on the obsolescence risk of the goods in at the warehouse.

6.2.1 Obsolescence due to Setup

The obsolescence caused by the setups when finishing one order and moving on with the next one can be divided into three category costs; manning, materials, and transportation costs. Figure 16 illustrates the weights of each component of the total setup costs per order for the Line-A production line.

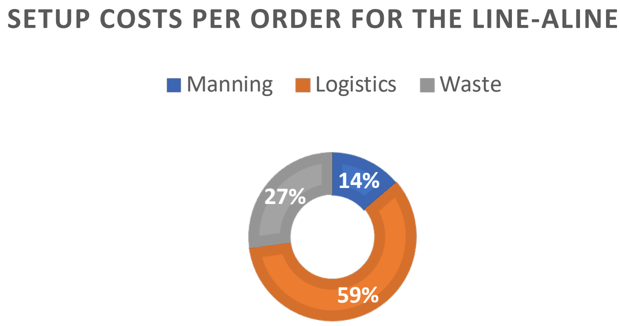

Figure 16. The setup costs per order for the Line-A production line can be divided into three categories; Manning, Logistics, and Waste.

The following calculations have led to the mentioned setup costs per order.

I. The logistics component is the transportation cost which is €400.- per commute, one truck fits 34 pallets. One pallet holds about 120 units. The truck is always fully loaded for shipping, we can assume that these numbers per order are fixed.

II. The manning costs are the costs of the employees working on the production line during the setup. The setup time can be conceptualized as nonproductive in terms of output, the costs made can be calculated as such;

*Manning costs per Setup = Setup time * (amount of FTE * hourly wage per FTE) →*

*- Line-Aproduction line: 45 min * (10 FTE * €12,5.-) = €93,75.-*

*- Line-C production line: 50 min * (11 FTE * €12,5.-) = €114,58.-*

*- Line-B production line: 45 min * (15 FTE * €12,5.-) = €140,63.-*

III. The three production lines this thesis focuses on have different processes and obtain different material waste percentages to calculate the obsolescence the production lines generate. In table 5 the obsolescence percentages are shown;

	Mix Waste %	Mix waste in €	Packaging waste %	Packaging waste in €	Total Costs per Setup
Line-B	1.0%	€ 137.40	2.0%	€ 274.80	€ 412.20
Line-A	0.3%	€ 37.08	1.0%	€ 123.60	€ 160.68
Line-C	1.0%	€ 185.40	1.5%	€ 278.10	€ 463.50

Table 5: Overview of the total material waste due to setups per order per production line, this is the combination of both mix- and packaging waste.

6.2.2 How will the new Q, R Policy impacts the obsolescence due to Setups?

By implementing the new Q, R policy as a default planning parameter, the number of setups done annually will change. In Chapter 6.3 the number of setups for the new Q, R policy was calculated, wherein the policy had a positive effect on the number of setups for the Line-A and Line-C production lines and a somehow negative effect on the Line-B production line. Table 4 gave an overview of how the setup costs per order changed from the status quo point of view and when the new Q, R policy would be implemented. Since the obsolete costs on the material are a part of the total setup costs one can expect that the obsolescence on the material will have a similar trend as the higher number of setups will increase the obsolescence costs due to setups.

Production Line	Material Obsolescence Costs 2019	Material Obsolescence Costs EOQ	Difference in Material Obsolescence Costs
Line-A	€ 34,867.56	€ 32,966.32	€ 1,901.24
Line-B	€ 141,796.80	€ 173,375.89	-€ 31,579.09
Line-C	€ 145,075.50	€ 97,650.77	€ 47,424.73

Table 6: Overview of the total material waste due to setups per production line comparing the total waste costs for 2019 and when the new policy is implemented.

In table 6 the material costs are separated from the total setup costs, the comparison contains the material obsolescence due to setups for the year 2019 and when the EOQ is implemented as a default planning parameter. The comparison shows that there is a positive effect for both the Line-A- and the Line-C production line, while the Line-B production line shows a negative effect when implementing the EOQ as a standard planning parameter. This outcome is in line with the effect shown for the total setup costs for these product lines.

6.2.3 How will the new Q, R Policy impacts the obsolescence of the Finished Good?

The new policy has set the optimal lot size of a product is and the safety stock this product should have. This policy does also take into account that there is no overstocking as the formula used to calculate Q takes the holding costs into account, where the higher the holding costs of the items are the lower the optimal lot size will become.

The finished goods produced have perishability attached, when the product is sold within a certain period the goods will become obsolete. The obsolescence of finished goods has a financial consequence as material, labor, transportation costs and holding costs are already made. What can we say about the new policy in terms of the perishability of the finished and the risk of obsolescence? When the optimal lot size and reorder point exceed the latest product delivery date, then Q has to be readjusted.

Production Line	**SKU amount**	**Internal Shelf-Life**
Line-B	54	900 days
Line-A	28	1020 days
Line-C	17	35 days

Table 7. Overview stock-keeping units per production line and the internal shelf life agreed for the finished goods, this paper will focus on the Line-B, Line-A and Line-C.

The internal shelf life per production line is presented in table 7. This table shows that the Line-B- and the Line-C production lines have internal shelf lives which are greater than 900 days. The long shelf life for these two production lines will probably give no issues in maintaining low risk in terms of obsolescence of the finished goods.

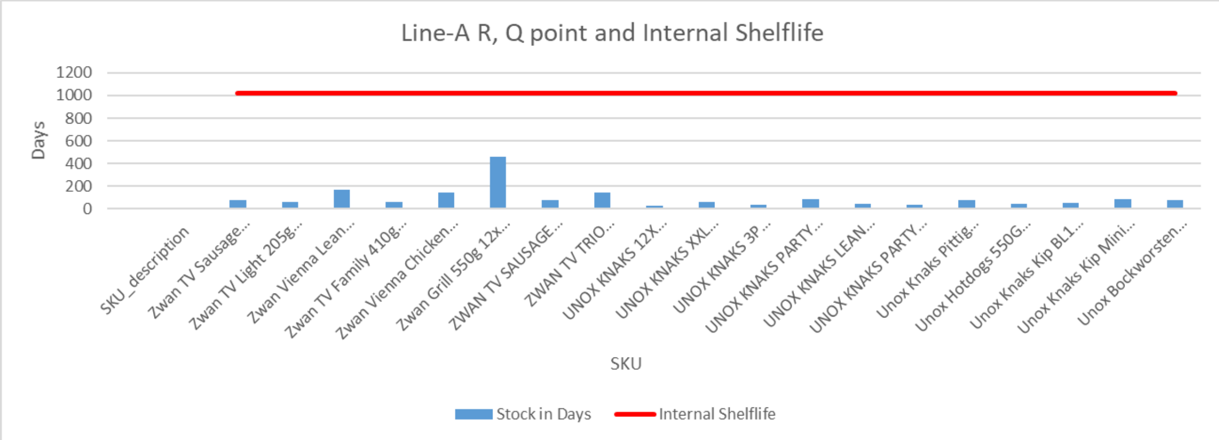

Figure 17. The stock in days per SKU is in proportion to the internal shelf life for the Line-A production line.

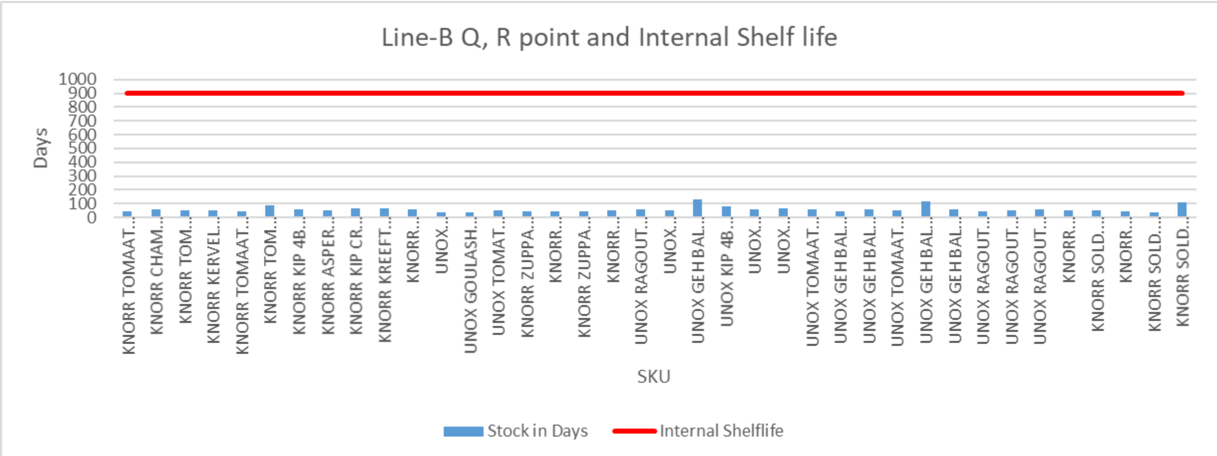

Figure 18. The stock in days per SKU in proportion to the internal shelf life for the Line-B production line.

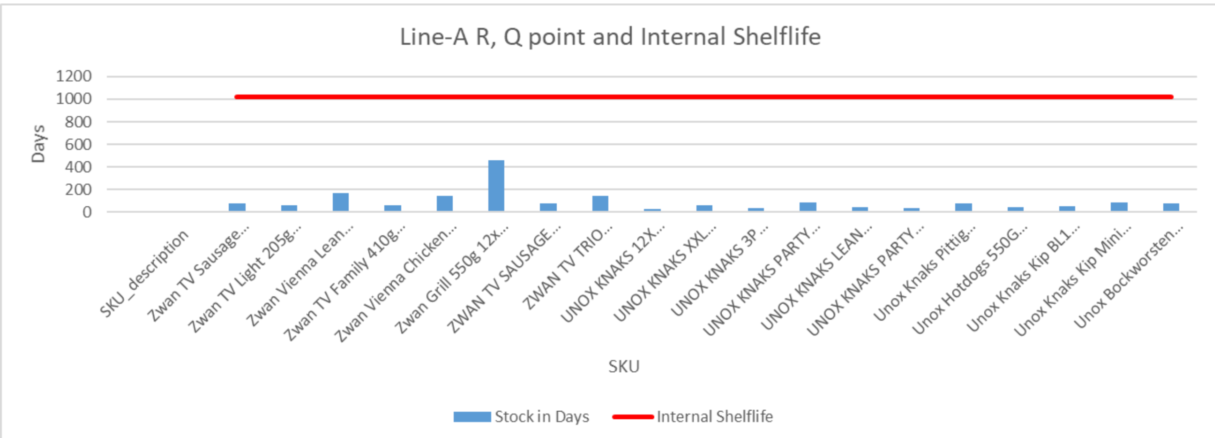

Figure 19. The stock in days per SKU is in proportion to the internal shelf life for the Line-C production line.

The internal shelf life and the Q, R quantity for the three production lines are shown in figures 17, 18, and 19. From these figures, one can see that that as expected the Q, R policy does lead to obsolescence or higher risk for a product to become obsolete. However, for the Line-C production line the Q, R policy will lead to obsolescence for almost all of the SKU's. This outcome indicates that the Q, R policy cannot be implemented for the Line-C production line, the internal shelf life would be the limiting factor that determines Q, R for the SKU's of this production line. Unless with the consent of the customer to store the finished goods under certain conditions that would extend the shelf life of the finished goods, then the Q, R policy could be implemented for the KP production line as well.

6.3 What is the effect of the new policy on the inventory costs?

Having discussed the consequences in terms of setup costs and obsolescence when the Q, R policy would be implemented as a planning parameter, the new policy would also affect the inventory costs as the optimal lot size and re-order point will influence the stock levels at the warehouses. The EOQ can be used as a tool for controlling finished goods inventories in such a way that it can maintain an even flow of production. The new policy can be useful for avoiding excessive investments in inventories (Kumar, 2016). This chapter will dive into the development of the inventory costs if the Q, R policy would be implemented for the SKU's of the three production lines in question.

6.3.1 The current finished goods stock levels

The fast-moving goods products that are produced at the Zwanenberg Oss factory are mainly seasonal items, the peak for the Line-B and the Line-C items is during the winter period. The higher demand during the winter season creates a need for higher safety stocks, there is a clear pattern in the stock development for these products. *Figure 20* shows the stock development for the three productions lines throughout the year 2019, here the higher stock levels for the Line-B and the Line-C production line are noticeable.

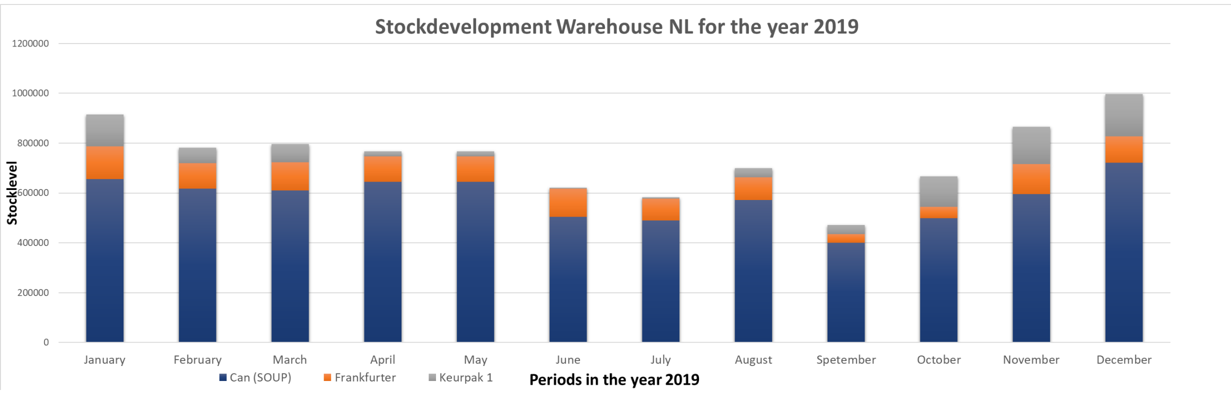

Figure 20. Realized stock development in the year 2019 for the Frankfurter, Line-B & Line-C production line at the warehouse in Oss.

The stocks levels shown in *Figure 20*, are retrieved from the historical data from the warehouse in Veghel (The Netherlands). The Line-B production line has the highest amount of annual stock levels than all of the other production lines (*Table 8*), followed by the Line-A and the Line-C. The warehouse in Veghel is the only VMI location, only this warehouse that will be discussed in this this chapter. The products on the productions line with the destination Veghel will be filtered out to calculate the holdings for these product groups.

Stock in Pallets						
	2019		**2019**	**2019**	**2019**	**2019**
	Annual	**CoS**	**Handling**	**Salary**	**Obsolescence**	**Holding Costs**
Line-A	**6,825**	€ 1,365.00	€ 80,294.12			
Line-C	**9,458**	€ 1,891.60	€ 111,270.59			
Line-B	**16,686**	€ 3,337.20	€ 196,305.88			
Total	32,969	€ 6,593.80	€ 387,870.59	€ 240,000.00	€ 6,994.00	€ 641,458.39

Table 8: Annual stock levels and the current storage stocks for the three production lines in the year 2019.

h = The holding costs for the year 2019 were;

- *The annual cost of storage = €0,20 per pallet a year * 32.969 pallet yearly = €6.593,80*
- *The cost of loading and unloading the goods = 32.969 pallets / 34 a wagon = 970 commutes a year. One commute costs €400.- thus yearly its 970*400 = €387.870,59.*
- *The cost of obsolescence of the goods = 1 percent of the total inventory value = €6.994.000.- * 1% = €6.994.-*
- *Warehouse operators' salaries: 40.000* 6 = €240.000.-*

Holding cost for the year 2019 = 6.593,80 + 387.970,59 + 6.994+ 240.000 = € 641.458,39

The holding costs for the year 2019 were *€ 641.458,39.-*, to find out whether the implementation of the Q, R policy will reduce these costs the same calculation has to be done for the new scenario.

6.3.2 Holding Costs development after the Q, R policy

Earlier in this thesis the role of the holding costs on the Q, R policy was briefly mentioned.

As the $Optimal\ Lot\ size, (Q) = \sqrt{\frac{2DS}{hC}}$ the outcome of the dividend part of the formula of (*2DS*) is divided by the holding cost per year as a fraction of product cost and the cost per unit (the divisor). From this formula, one can argue that higher holding costs would lead to a lower optimal lot size. Holding costs is the total operating costs, labor costs, material handling costs, etc., in this chapter the outcome of implementing the Q, R policy on the holding costs will be discussed.

The ordering costs and the holding costs are the opposite of each other, if the intention is to have low holding costs one should produce in small production runs which increases the ordering costs. For a production factory, long production runs are more suitable as they will lower the number of setups and the ordering costs. In figure 21 the minimal total costs are achieved at the intersection point of the fixed and variable costs curves. The total costs curve makes a deep dive at the beginning, then lays flat, and then peaks again. This flatness of the curve in the minimal region suggests that small changes in EOQ will not have a significant impact on the total costs (Ivanov & Schonberger, 2017).

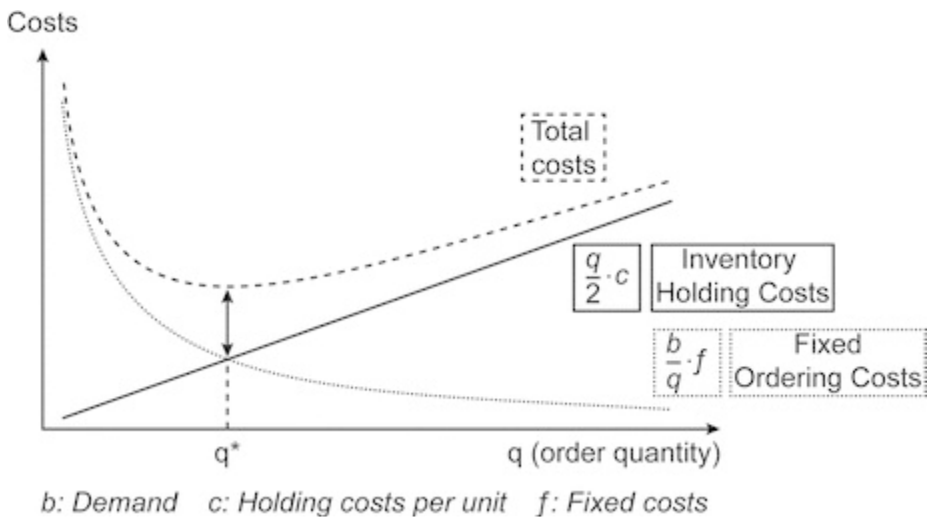

Figure 21. The minimal total costs can be achieved at the intersection point of the fixed and variable costs curves (Ivanov & Schonberger, 2017)

The holding costs of the average inventory when the Q, R policy is implemented can be calculated as follows;

*Carrying costs of average inventory = (EOQ/2 + k**σ_L*) * C*

Here EOQ is the optimal lot size, k is the safety factor, σ_L is the demand over lead-time, and "C" the carrying cost per unit (Kumar, 2016). This results in the following;

Line-A:

Carrying costs of average inventory = €291.480,63.-

Line-B:

Carrying costs of average inventory = € 588.840,10.-

Line-C:

Carrying costs of average inventory = € 456.628,54.-

Total carrying costs when the Q, R policy is implemented would be € 1.336.949,27

Now the holding costs of the year 2019 and the holding costs when implementing the new policy can be compared. The calculated holding costs for the year 2019 were *€641.458,39* and when holding costs after implementing the new policy would be €1.336.949,27. This shows that there would be a significant increase in holding costs after implementing the new policy.

6.4 Conclusion Chapter Six

In chapter six the current setup time per production line was examined and showed the variation of setup time needed for the three production lines. Furthermore, we found *Q* and *R* for all the SKU's of the production lines. With this data, the number of setups needed when implementing the EOQ policy would be implemented as a default planning parameter in the organization. Comparing the results with the actual production from the year 2019 showed that the new policy does have a positive impact on the setup costs for the Line-A and the Line-C production line. The number of planned productions on an annual basis for the Line-A production line will reduce with 11 productions after the implementation of the new policy, this leads to €7.455,84 in costs savings. For the Line-C production line the number of setups on an annual base can be reduced with 102 when implementing the new policy at the production location, resulting into a cost reduction of

€100.075,90 on an annual base. However, a negative outcome on the Line-B production line is also shown. The implementation of the new policy for the Line-B production line would lead to 77 additional setups and €72.997,33 in additional costs on an annual base. Furthermore, this chapter elaborated on the obsolescence due to setups after implementing the Q, R policy as a planning parameter at the production site in Oss. The setup costs are divided into three categories; waste in material, manning costs, and logistics. The obsolescence of material due to setups can be decreased for the Line-A and the Line-C production line when implementing the Q, R policy. The cost reduction in terms of material obsolescence for the Line-A production is €1.901,24 after implementing the new policy at the production location. For the Line-C the cost reduction would we again higher, a total amount of €47.424,73 difference in material obsolescence costs on an annual base. However, for the Line-B production line the obsolescence cost of materials due to setup increased with a total of €31579,09 on an annual base. This would mean that in the status quo situation higher lot sizes are kept which leads to lower setup costs for the Line-B production line. Furthermore, the obsolescence on the finished good level was investigated, this has led to the conclusion that the Line-A and the Line-B production line face no higher obsolescence risks when implementing the Q, R policy. Although, the Line-C production line shows for almost all the SKU stock levels higher than the internal shelf life. This means that the Q, R policy obtained cannot be implemented for the Line-C production line, unless with the consent of the customer to store the finished goods under certain conditions that would extend the shelf life of the finished goods.

Finally, chapter six discussed the effect of the Q, R policy on the holding costs. The equation showed that with higher holding costs the EOQ becomes smaller. There is an intersection of fixed order quantity and inventory holding cost wherein the total costs are minimalized. The introduction of the Q, R policy as a planning parameter will provide the most cost-efficient solution in terms of inventory. A comparison of the holding costs from the year 2019 and that of the new Q, R policy was made, which showed a great gap between the total holding costs. No costs reductions have been found regarding holdings costs. The holding costs according the calculations for the year 2019 were *€641.458,39,* these are significantly lower than the holding costs after implementing the new policy which would be a total of €1.336.949,27.

To conclude, the new policy does lead to cost setup and waste costs reductions for the Line-C and the Line-A production lines. The Line-C production line should be managed well under consent of the customer in order to avoid finished goods obsolescence risk. Furthermore, it can be stated that the Q, R policy shouldn't be implanted as a planning parameter for the Line-B production line as these would lead to higher costs in terms of waste of material and setups costs.

7. Conclusion & Recommendations

Chapter seven will provide a conclusion based on the finding in this thesis and answer the main research question. Furthermore, recommendations based on this research will be given and how the new policy should be implemented in the factory.

7.1 Conclusion

ZFG has been able to become a market leader in Europe due to innovations, acquisitions, and mergers in the past years. For a company to maintain its position it is important to have continuous optimization within the operations. As improvements in production are often seen as a given, the planning parameters are often left out. This thesis discussed how implementing a new policy as a default planning parameter will have a positive impact on the current situation. The following research question is used as a guideline for this thesis;

How to determine the optimal production parameters to minimize setup costs and the inventory holding costs, by considering the obsolescence of products?

The Q, R for the three production lines was calculated on an SKU basis, given the optimal parameters for the planners in managing the inventory at the warehouses. The effect of these optimal planning parameters on the number of setups for the production lines showed a decrease in the number of setups for two of the three production lines. The lower annual setups for the Line-A and the Line-C production lines reduce the setup costs. However, the new policy showed an increase in the number of setups for the Line-B production line. This increase could be caused by the restriction that there is production MOQ based on the batch size, the MOQ might be considered large in proportion to the demand resulting in high coverages. Furthermore, the effect of the new policy on holding costs has shown to be reduced for the Line-A production line. For the Line-B production line the Q, R policy has been shown to increase the holding costs for these variants, this would be the same as the before mentioned reason. The holding costs of the Line-C variants show also an increase, which could be caused by the fact that the Q, R policy does not consider the internal shelf life of the products. This means the Q, R values for the Line-C production line should be adjusted to the max internal shelf life or what is agreed upon in the service level agreement. Finally, the new policy showed to have a positive impact on obsolescence as a consequence of setups for the Line-A and the Line-C production lines. The reduction of obsolescence is caused by having more optimal production runs that lead to fewer setups.

With the outcomes mentioned the following improvements in the current process can be obtained by implementing the new policy;

I. Obtaining clear parameters which can be used as the default for the production planning department.

II. Reduction in set-up time for the Line-A and Line-C production lines.

III. Reduction in set-up costs for the Line-A and Line-C production lines.

IV. Reduction in RPM obsolescence for the Line-A and Line-C production lines as a consequence of reduction in the number of setups.

To conclude, there is variation in outcome for the production lines on each component consequently when introducing the Q, R policy as the new default planning parameter. The policy reduces setup costs, obsolescence, and holding costs for the Line-A production line. It resulted to lower setup costs for the Line-C production line. However, the Q, R doesn't consider the limited internal shelf life of the SKU's which can lead to obsolescence on the finished goods level. Adjustment of the Q, R values to the internal shelf life might be necessary to obtain planning parameters that are suitable to the shelf life of this product. Finally, the Line-B production line showed the least favourable outcomes because of the new policy. This can be caused by SKUs with low monthly demand, where the Q, R policy does not consider a minimum of two batches. We can say that each production line is unique and should be handled as such, considering the limitations and adjusting the policy to these standards to obtain the optimal outcome.

7.2 Recommendations

To conclude the findings of this research, recommendations for Zwanenberg Food Group Oss will be provided in this chapter. Taking into account the potential optimization actions and their limitations. Furthermore, the implementation of the new policy at ZFO will be discussed.

- The new planning parameters should be documented at a central location that can be used as input for other files. The central location should be assigned to someone responsible for the correctness and keeping the data up to date when new SKU's are added, delisted or a change in demand occurs.

- By implementing a program that takes into account the minimum lot size, change over and efficiency of the week production would help the production planners upfront in scheduling the most efficient outcomes.
- The production planners should connect their planning files to the master data, using this data as a guideline for their short- and long-term production planning.
- Training the production planners on the importance of the new policy as they have to represent the production plan according to the planning parameters, the need of understanding what it entails is crucial.
- A tool should be implemented that matches all production lines together, giving insight with the given demand what the best smoothing possibilities are in terms of FTE, capacity, and demand.
- Establish a project team to implement the new policy at the factory and what the needed budget is.
- Expand the scope of the planning parameters to other production lines and ZFG production sites.

7.2.1 How should the new design be implemented in the factory?

The Q, R policy would become a new planning parameter in the ZFG factory located in the city of Oss. The implantation of the policy as a default planning parameter requires certain adaptations of the current way of working and simultaneously the planning parameter should be entered in the master data files to have a central reference of what the actual planning parameters are and in case of new SKU introduction what these have to become. This chapter will elaborate on how the policy should be implemented at ZFG Oss.

The implementation of the new Q, R policy at ZFG Oss would require the following stages;

1. *Appointing Key-Users;* to have a clear understanding and uniformity within the company on the importance of implementing the new policy in terms of costs savings and efficiency, the data gained should be documented at a central location

and kept updated by the key user. The key user is responsible and accountable for the correctness of the data in the file.

2. *System-update;* the file managed by the key-user can be used as a tool for other files and programs that are currently used or will be implemented in the future. The production planner will have to use the master file as input for their short- and long-term production plan, these planning parameters will have to become the default setting for production. Furthermore, the implementation of a scheduling program that takes into account the new policy principles that will help gain a better and more practical way of working. The scheduling program will be installed with the new planning parameters, through this the program will let the planner know when the EOQ for each SKU has been reached. By implementing this system at ZFO the workload becomes less as the planner can rely on the program to act as a control mechanism for making sure that the planning parameters are respected.
3. *Training;* the production planners must understand the effect and the consequences of the new policy within the company is, and how it affects the inventory costs. This understanding will provide better clarity and improve the chance that these parameters are used at a constant paste. The planning parameters will be used to plan the long-term productions, and this will give upfront that the new policy leads more efficient planning. The appointed key-user functions as the source of information regarding planning parameters and is expected to forward the needed knowledge to planners.
4. *Evaluation*: for continuous improvement and making sure that the current way of working is satisfactory an evaluation is needed. This can be done by analysing whether there is indeed a reduction in setup time, obsolescence, and holding costs. This should be done by the key-user, in the case of setup time, it would be the production manager or continuous improvement manager who is triggered by the supply chain analyst. For the holding costs, the supply chain managers should analyse whether costs reduction are indeed noticeable.

Figure 22. Implementation plan of the new policy at ZFO.

The flow of the implantation is illustrated in *Figure 22*, the implementation starts at appointing key users for setting up the project. Then, the program and master data have to be set at a central location and integrated into the system. At the later stage, the planner and key-users should be trained to fully understand and be capable of working with the new policy. Finally, the new policy is adopted an evaluation is needed whether the output is beneficial and leads to cost saving for ZFO. The responsibilities and communication are illustrated in figure 23, providing an overview of the stakeholders. The supply chain report and analyst functions as the key-user for the planning parameters and should inform the planners and the planning manager. The planning manager provides the tools necessary for operation and gives feedback on the results to the supply chain report and analyst. The production planners provide feedback to the supply chain report and analyst on the performance of planning parameters.

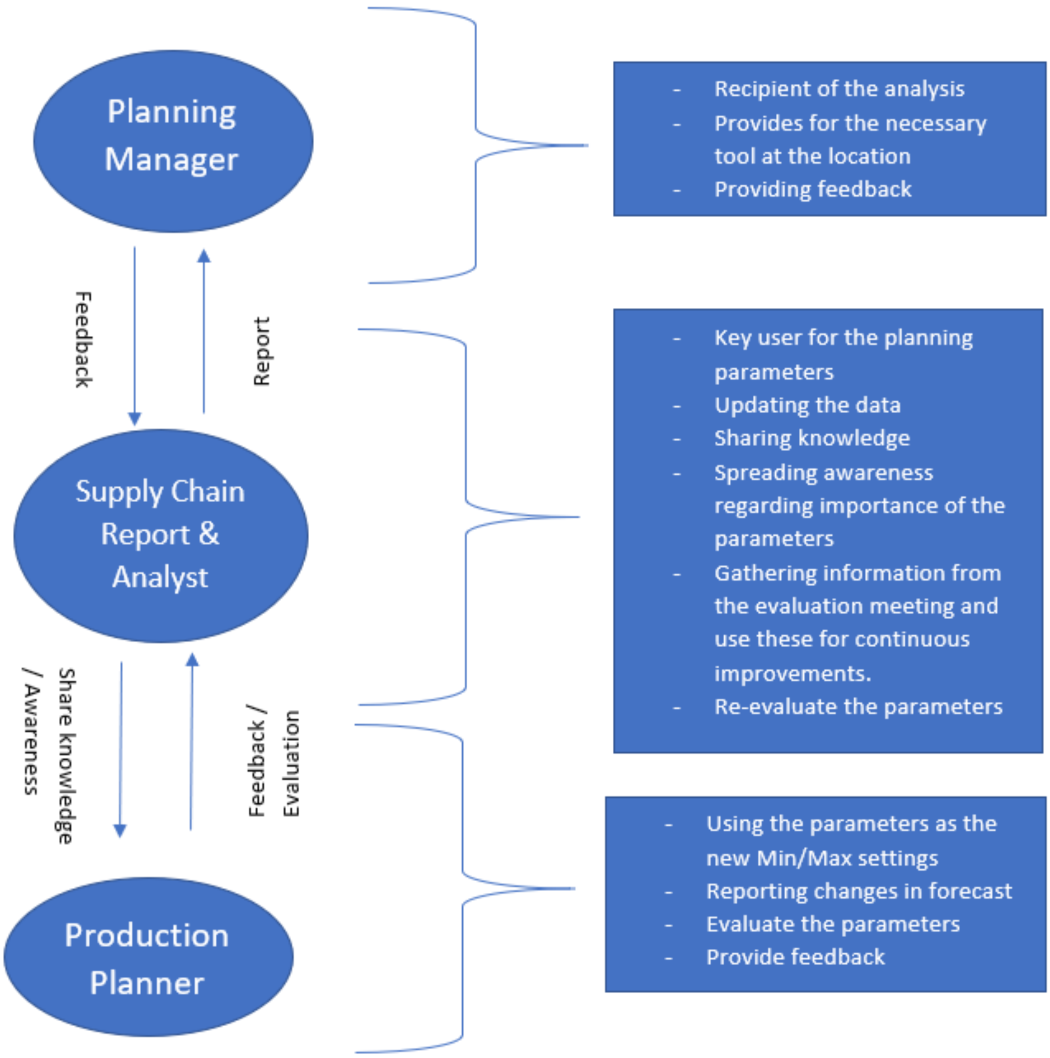

Figure 23. Responsibilities and communication flow.

With the given recommendations and implementation plan, the new policy should lead to costs saving for ZFG. Every stakeholder must be aligned with the new policy and intentions, the process does take time and patience to be implemented. Therefore, the managers should make sure that the key users have enough time to be able to engage in this project.

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Appendix

from: \ to:	NONE	without	s	m	t	sm	st	tm	smt	tmo	mtmo	meatless
NONE	~~0~~	0	0	0	0	0	0	0	0	0	0	60
without	0	~~0~~	0	0	30	0	0	0	0	0	0	60
s	0	150	~~0~~	150	150	0	0	150	0	0	0	60
m	0	150	150	~~0~~	150	0	150	0	0	0	0	60
t	0	150	150	150	~~0~~	150	0	0	0	0	0	60
sm	0	150	150	150	150	~~0~~	150	150	0	0	0	60
st	0	150	150	150	150	150	~~0~~	150	0	0	0	60
tm	0	150	150	150	150	150	150	~~0~~	0	0	0	60
smt	0	150	150	150	150	150	150	150	~~0~~	0	0	60
tmo	0	0	0	0	60	0	0	0	0	~~0~~	0	60
mtmo	0	0	0	0	60	0	0	0	0	0	~~0~~	60
meatless	0	150	150	150	150	150	150	150	150	150	150	~~0~~

s = soja
m = milk
t = wheat gluten (tarwe in Dutch)

Appendix A: the changeover matrix of Meat items concerning the allergenics

from: \ to:	NONE	lean	normal	garlic	italian	beef	chicken	chicken BL	spicy(ff)	spicy	chili	curry
NONE	~~0~~	0	0	0	0	0	0	0	0	0	0	0
lean	0	~~0~~	30	30	60	480	60	60	30	60	60	60
normal	0	30	~~0~~	30	30	480	30	30	30	45	30	30
garlic	0	480	480	~~0~~	30	480	480	480	480	30	480	480
italian	0	*150*	*150*	*150*	~~0~~	*150*	*150*	*150*	*150*	*150*	*150*	*150*
beef	0	60	60	60	60	~~0~~	60	60	30	60	60	60
chicken	0	60	60	60	60	480	~~0~~	30	30	60	60	60
chicken BL	0	60	60	60	60	480	30	~~0~~	30	60	60	60
spicy(ff)	0	60	60	60	60	480	60	60	~~0~~	60	60	150
spicy	0	*150*	*150*	*150*	30	*150*	*150*	*150*	*150*	~~0~~	30	30
chili	0	480	480	480	30	480	480	480	480	480	~~0~~	0
curry	0	*60*	*60*	*60*	30	*60*	*60*	*60*	*60*	*60*	*60*	~~0~~

Appendix B: the changeover matrix of CFO items concerning the flavours

to: / from:	None	krat	58-12	65-13	65-16	110-7	110-8	110-10	110-11	110-12	110-24	110-30	110-32	110-34	145-6	145-8	145-10	145-30
None	~~0~~	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
krat	0	~~0~~	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90
58-12	0	90	~~0~~	45	45	60	60	60	60	60	45	75	75	75	75	75	75	60
65-13	0	90	45	~~0~~	30	60	60	60	60	60	45	75	75	75	75	75	75	45
65-16	0	90	45	30	~~0~~	60	60	60	60	60	45	75	75	75	75	75	75	45
110-7	0	90	60	60	60	~~0~~	30	30	30	30	45	60	60	60	75	75	75	60
110-8	0	90	60	60	60	30	~~0~~	30	30	30	45	60	60	60	75	75	75	60
110-10	0	90	60	60	60	30	30	~~0~~	15	15	45	60	60	60	75	75	75	60
110-11	0	90	60	60	60	30	30	15	~~0~~	15	45	60	60	60	75	75	75	60
110-12	0	90	60	60	60	30	30	15	15	~~0~~	45	60	60	60	75	75	75	60
110-24	0	90	45	45	45	45	45	45	45	45	~~0~~	60	60	60	75	75	75	60
110-30	0	90	75	75	75	60	60	60	60	60	60	~~0~~	15	15	60	60	60	75
110-32	0	90	75	75	75	60	60	60	60	60	60	15	~~0~~	15	60	60	60	75
110-34	0	90	75	75	75	75	60	60	60	60	60	15	60	~~0~~	60	60	60	75
145-6	0	90	75	75	75	75	75	75	75	75	75	60	60	60	~~0~~	30	30	45
145-8	0	90	75	75	75	75	75	75	75	75	75	60	60	60	30	~~0~~	30	45
145-10	0	90	75	75	75	75	75	75	75	75	75	60	60	60	30	30	~~0~~	45
145-30	0	90	60	60	60	60	60	60	60	60	60	75	75	75	45	45	45	~~0~~

Appendix C: the changeover matrix of Line-A items concerning the packaging

to: / from:	None	16x225gr	14x250gr	12x275gr	14x275gr	14x285gr	8x325gr	12x375gr	9x200gr	14x300gr
None	0	0	0	0	0	0	0	0	0	0
16x225gr	0	0	40	40	40	40	40	40	30	40
14x250gr	0	40	0	35	35	40	40	40	40	40
12x275gr	0	40	35	0	20	40	40	40	40	40
14x275gr	0	40	35	20	0	40	40	40	40	40
14x285gr	0	50	50	50	50	0	40	40	50	40
8x325gr	0	50	50	50	50	40	0	40	50	40
12x375gr	0	50	50	50	50	40	40	0	50	40
9x200gr	0	30	40	40	40	40	40	40	0	40
14x300gr	0	50	50	50	50	40	40	40	50	0

Appendix D: the changeover matrix of Line-Citems concerning the packaging

volumefiller

	none	so	wa	by
none	0	0	0	0
so	0	45	45	8
wa	0	13	0	5
by	0	5	5	0

Appendix E: the changeover matrix of Line-B volume filler

Pocket filler

	none	us	by
none	0	0	0
us	0	45	13
by	0	10	0

Appendix F: the changeover matrix of Line-B pocket filler

Customer code	Production Line	Annual Demand	Optimal lot size	Optimal lot size / 2	Carrying Costs	Safety Factor (K)	Demand over LT (σL)	Annual Holding Costs
Forecast	**Line-A**							
MSO_item_coc	SKU_description							
1	Product-A	626653	17662	8831	€ 11.76	2.05	3931	€ 146,746.70
2	Product-B	47770	4877	2438	€ 11.76	2.05	391	€ 10,638.02
3	Product-C	176118	9364	4682	€ 11.76	2.05	1027	€ 27,113.85
4	Product-D	17209	2927	1463	€ 11.76	2.05	152	€ 4,404.03
5	Product-E	150892	8667	4334	€ 11.76	2.05	854	€ 22,755.42
6	Product-F	185356	9606	4803	€ 11.76	2.05	892	€ 23,923.52
7	Product-G	34604	4150	2075	€ 11.76	2.05	528	€ 13,765.42
8	Product-H	89606	6679	3339	€ 11.76	2.05	538	€ 14,640.89
9	Product-I	67711	5806	2903	€ 11.76	2.05	443	€ 12,147.02
10	Product-J	21514	3273	1636	€ 11.76	2.05	258	€ 7,048.19
11	Product-K	26821	3654	1827	€ 11.76	2.05	306	€ 8,297.58
								€ 291,480.63

Appendix G: EOQ & HC calculations for the Line-A production line.

SU_item_code	Line-B	Annual Demand	Optimal lot size	Optimal lot size / 2	Carrying Costs	Safety Factor (K)	Demand over LT (σL)	Cases Per Pallet
12	Product- L	66328	5746	2873	€ 11.96	2.05	710	€ 18,852.18
13	Product- M	57814	5365	2682	€ 11.96	2.05	41	€ 2,340.19
14	Product- N	4831	1551	775	€ 11.96	2.05	5	€ 507.83
15	Product- O	16812	2893	1446	€ 11.96	2.05	71	€ 2,459.93
16	Product- P	34852	4165	2083	€ 11.96	2.05	136	€ 4,372.34
17	Product- Q	30841	3918	1959	€ 11.96	2.05	91	€ 3,205.41
18	Product- R	39158	4415	2208	€ 11.96	2.05	123	€ 4,111.68
19	Product- S	93540	6824	3412	€ 11.96	2.05	115	€ 4,521.09
20	Product- T	41192	4528	2264	€ 11.96	2.05	54	€ 2,447.97
21	Product- U	66950	5773	2887	€ 11.96	2.05	206	€ 6,486.15
22	Product- V	6782	1837	919	€ 11.96	2.05	5	€ 572.06
23	Product- W	42845	4618	2309	€ 11.96	2.05	79	€ 3,097.04
24	Product- X	136228	8235	4118	€ 11.96	2.05	1301	€ 33,965.98
25	Product- Y	90806	6723	3362	€ 11.96	2.05	936	€ 24,633.62
26	Product- Z	126586	7938	3969	€ 11.96	2.05	2138	€ 54,412.96
27	Product- AB	218170	10422	5211	€ 11.96	2.05	993	€ 26,954.46
28	Product- AC	45592	4764	2382	€ 11.96	2.05	312	€ 8,837.37
29	Product- AD	31944	3988	1994	€ 11.96	2.05	897	€ 22,999.55
30	Product- AE	129431	8027	4014	€ 11.96	2.05	837	€ 22,535.27
31	Product- AF	109901	7397	3698	€ 11.96	2.05	399	€ 11,640.89
32	Product- AG	133439	8150	4075	€ 11.96	2.05	520	€ 14,791.03
33	Product- AH	249972	11155	5578	€ 11.96	2.05	1272	€ 33,988.28
34	Product- AI	110908	7431	3715	€ 11.96	2.05	437	€ 12,584.82
35	Product- AJ	52471	5111	2555	€ 11.96	2.05	467	€ 12,740.13
36	Product- AK	254146	11248	5624	€ 11.96	2.05	2850	€ 72,711.06
37	Product- AL	24508	3493	1746	€ 11.96	2.05	328	€ 8,913.07
38	Product- AM	165100	9066	4533	€ 11.96	2.05	810	€ 22,137.78
39	Product- AN	73373	6044	3022	€ 11.96	2.05	411	€ 11,587.73
40	Product- AO	89446	6673	3336	€ 11.96	2.05	709	€ 19,050.59
41	Product- AP	11454	2388	1194	€ 11.96	2.05	327	€ 8,621.70
42	Product- AQ	84148	6472	3236	€ 11.96	2.05	362	€ 10,499.01
43	Product- AR	132580	8124	4062	€ 11.96	2.05	880	€ 23,613.69
44	Product- AS	105583	7250	3625	€ 11.96	2.05	604	€ 16,636.28
45	Product- AT	154749	8777	4389	€ 11.96	2.05	797	€ 21,748.32
46	Product- AU	40879	4511	2256	€ 11.96	2.05	282	€ 8,042.62
47	Product- AV	17682	2967	1483	€ 11.96	2.05	210	€ 5,887.87
48	Product- AW	47823	4879	2440	€ 11.96	2.05	728	€ 19,064.02
49	Product- AX	67991	5818	2909	€ 11.96	2.05	237	€ 7,268.12

Appendix H: EOQ & HC calculations for the Line-B.

SU_item_code	Line-C	Annual Demand	Optimal lot size	Optimal lot size / 2	Carrying Costs	Safety Factor (K)	Demand over LT (σL)	Cases Per Pallet
50	Product- AY	14212	2660	1330	€ 11.96	2.05	254	€ 6,900.00
51	Product- AZ	131120	8079	4040	€ 11.96	2.05	694	€ 19,038.07
52	Product- BA	38409	4373	2186	€ 11.96	2.05	412	€ 11,201.18
53	Product- BB	27389	3693	1846	€ 11.96	2.05	153	€ 4,687.73
54	Product- BC	73433	6046	3023	€ 11.96	2.05	732	€ 19,465.34
55	Product- BD	100945	7089	3544	€ 11.96	2.05	898	€ 23,795.92
56	Product- BE	80275	6322	3161	€ 11.96	2.05	495	€ 13,724.75
57	Product- BF	9029	2120	1060	€ 11.96	2.05	80	€ 2,501.36
58	Product- BG	19257	3096	1548	€ 11.96	2.05	267	€ 7,312.56
59	Product- BH	278051	11765	5883	€ 11.96	2.05	2322	€ 59,902.28
60	Product- BI	550448	16554	8277	€ 11.96	2.05	3883	€ 99,371.72
61	Product- BJ	268631	11564	5782	€ 11.96	2.05	3372	€ 85,591.86
62	Product- BK	70490	5924	2962	€ 11.96	2.05	1266	€ 32,522.82
63	Product- BL	96313	6924	3462	€ 11.96	2.05	1419	€ 36,543.96
64	Product- BM	49053	4942	2471	€ 11.96	2.05	856	€ 22,232.05
65	Product- BN	27969	3731	1866	€ 11.96	2.05	445	€ 11,836.95

Appendix I: EOQ & HC calculations for Line-C.

ZFG-code	Production Line	Fixed Material Obsolescence Costs	Number of productions in the year 2019	Material Obsolescence Costs 2019	Number of yearly productions needed accoring new EOQ	Material Obsolescence Costs 2021	Difference in Material Obsolescence Costs
	Line-A						
	SKU_description						
1	Product-A	€ 160.68	8	€ 1,285.44	7	€ 1,065.12	€ 220.32
2	Product-B	€ 160.68	6	€ 964.08	8	€ 1,311.51	-€ 347.43
3	Product-C	€ 160.68	3	€ 482.04	3	€ 456.26	€ 25.78
4	Product-D	€ 160.68	8	€ 1,285.44	9	€ 1,431.31	-€ 145.87
5	Product-E	€ 160.68	2	€ 321.36	3	€ 542.32	-€ 220.96
6	Product-F	€ 160.68	4	€ 642.72	5	€ 873.23	-€ 230.51
7	Product-G	€ 160.68	2	€ 321.36	2	€ 373.30	-€ 51.94
8	Product-H	€ 160.68	10	€ 1,606.80	10	€ 1,564.41	€ 42.39
9	Product-I	€ 160.68	0	€ 0.00	4	€ 604.20	-€ 604.20
11	Product-K	€ 160.68	48	€ 7,712.64	35	€ 5,700.83	€ 2,011.81
12	Product- L	€ 160.68	9	€ 1,446.12	10	€ 1,573.99	-€ 127.87
13	Product- M	€ 160.68	22	€ 3,534.96	19	€ 3,022.22	€ 512.74
14	Product- N	€ 160.68	6	€ 964.08	6	€ 944.72	€ 19.36
15	Product- O	€ 160.68	22	€ 3,534.96	17	€ 2,797.42	€ 737.54
16	Product- P	€ 160.68	25	€ 4,017.00	19	€ 3,100.47	€ 916.53
17	Product- Q	€ 160.68	5	€ 803.40	8	€ 1,339.64	-€ 536.24
18	Product- R	€ 160.68	18	€ 2,892.24	13	€ 2,155.72	€ 736.52
19	Product- S	€ 160.68	12	€ 1,928.16	12	€ 1,873.93	€ 54.23
20	Product- T	€ 160.68	2	€ 321.36	7	€ 1,056.30	-€ 734.94
21	Product- U	€ 160.68	5	€ 803.40	7	€ 1,179.40	-€ 376.00

Appendix J: Obsolescence calculations for the Line-A production line.

ZFG-code	Line-B	Fixed Material Obsolescence Costs	Number of productions in the year 2019	Material Obsolescence Costs 2019	Number of yearly productions needed accoring new EOQ	Material Obsolescence Costs 2021	Difference in Material Obsolescence Costs
22	Product- V	€ 412.20	16	€ 6,595.20	15	€ 6,222.76	€ 372.44
23	Product- W	€ 412.20	10	€ 4,122.00	8	€ 3,450.22	€ 671.78
24	Product- X	€ 412.20	9	€ 3,709.80	11	€ 4,340.43	-€ 630.63
25	Product- Y	€ 412.20	10	€ 4,122.00	9	€ 3,873.73	€ 248.27
26	Product- Z	€ 412.20	10	€ 4,122.00	12	€ 5,034.04	-€ 912.04
27	Product- AB	€ 412.20	6	€ 2,473.20	7	€ 2,798.37	-€ 325.17
28	Product- AC	€ 412.20	11	€ 4,534.20	8	€ 3,317.69	€ 1,216.51
29	Product- AD	€ 412.20	7	€ 2,885.40	10	€ 4,178.98	-€ 1,293.58
30	Product- AE	€ 412.20	8	€ 3,297.60	7	€ 3,020.33	€ 277.27
31	Product- AF	€ 412.20	6	€ 2,473.20	9	€ 3,654.44	-€ 1,181.24
32	Product- AG	€ 412.20	9	€ 3,709.80	8	€ 3,260.25	€ 449.55
33	Product- AH	€ 412.20	15	€ 6,183.00	17	€ 7,143.35	-€ 960.35
34	Product- AI	€ 412.20	15	€ 6,183.00	21	€ 8,640.05	-€ 2,457.05
35	Product- AJ	€ 412.20	12	€ 4,946.40	11	€ 4,598.09	€ 348.31
36	Product- AK	€ 412.20	11	€ 4,534.20	15	€ 6,176.73	-€ 1,642.53
37	Product- AL	€ 412.20	9	€ 3,709.80	17	€ 7,126.92	-€ 3,417.12
38	Product- AM	€ 412.20	9	€ 3,709.80	14	€ 5,839.67	-€ 2,129.87
39	Product- AN	€ 412.20	8	€ 3,297.60	12	€ 4,815.06	-€ 1,517.46
40	Product- AO	€ 412.20	7	€ 2,885.40	12	€ 4,757.94	-€ 1,872.54
41	Product- AP	€ 412.20	8	€ 3,297.60	11	€ 4,442.09	-€ 1,144.49
42	Product- AQ	€ 412.20	2	€ 824.40	3	€ 1,284.07	-€ 459.67
43	Product- AR	€ 412.20	5	€ 2,061.00	6	€ 2,395.41	-€ 334.41
44	Product- AS	€ 412.20	9	€ 3,709.80	8	€ 3,448.93	€ 260.87
45	Product- AT	€ 412.20	9	€ 3,709.80	8	€ 3,244.41	€ 465.39
46	Product- AU	€ 412.20	8	€ 3,297.60	9	€ 3,655.79	-€ 358.19
47	Product- AV	€ 412.20	12	€ 4,946.40	14	€ 5,650.28	-€ 703.88
48	Product- AW	€ 412.20	9	€ 3,709.80	9	€ 3,749.53	-€ 39.73
49	Product- AX	€ 412.20	9	€ 3,709.80	12	€ 4,780.20	-€ 1,070.40
50	Product- AY	€ 412.20	3	€ 1,236.60	4	€ 1,521.42	-€ 284.82
51	Product- AZ	€ 412.20	9	€ 3,709.80	9	€ 3,824.03	-€ 114.23
52	Product- BA	€ 412.20	10	€ 4,122.00	17	€ 6,818.74	-€ 2,696.74
53	Product- BB	€ 412.20	10	€ 4,122.00	14	€ 5,567.09	-€ 1,445.09
54	Product- BC	€ 412.20	7	€ 2,885.40	16	€ 6,573.00	-€ 3,687.60
78	Product- BD	€ 412.20	8	€ 3,297.60	10	€ 4,101.07	-€ 803.47
79	Product- BE	€ 412.20	9	€ 3,709.80	10	€ 4,304.30	-€ 594.50
80	Product- BF	€ 412.20	11	€ 4,534.20	15	€ 6,298.13	-€ 1,763.93
81	Product- BG	€ 412.20	16	€ 6,595.20	19	€ 7,729.00	-€ 1,133.80
82	Product- BH	€ 412.20	2	€ 824.40	4	€ 1,739.35	-€ 914.95

Appendix K: Obsolescence calculations for the Line-B production line.

ZFG-code	Line-C	Fixed Material Obsolescence Costs	Number of productions in the year 2019	Material Obsolescence Costs 2019	Number of yearly productions needed accoring new EOQ	Material Obsolescence Costs 2021	Difference in Material Obsolescence Costs
83	Product- BI	€ 463.50	8	€ 3,708.00	5	€ 2,476.51	€ 1,231.49
84	Product- BJ	€ 463.50	45	€ 20,857.50	16	€ 7,522.24	€ 13,335.26
85	Product- BK	€ 463.50	25	€ 11,587.50	9	€ 4,071.26	€ 7,516.24
86	Product- BL	€ 463.50	25	€ 11,587.50	7	€ 3,437.96	€ 8,149.54
87	Product- BM	€ 463.50	32	€ 14,832.00	12	€ 5,629.35	€ 9,202.65
88	Product- BN	€ 463.50	33	€ 15,295.50	14	€ 6,600.17	€ 8,695.33
89	Product- BL	€ 463.50	36	€ 16,686.00	13	€ 5,885.76	€ 10,800.24
90	Product- BO	€ 463.50	10	€ 4,635.00	4	€ 1,973.93	€ 2,661.07
91	Product- BP	€ 463.50	1	€ 463.50	6	€ 2,882.75	-€ 2,419.25
92	Product- BQ	€ 463.50	16	€ 7,416.00	24	€ 10,954.05	-€ 3,538.05
93	Product- BR	€ 463.50	29	€ 13,441.50	33	€ 15,412.42	-€ 1,970.92
94	Product- BS	€ 463.50	15	€ 6,952.50	23	€ 10,766.90	-€ 3,814.40
95	Product- BT	€ 463.50	11	€ 5,098.50	12	€ 5,515.39	-€ 416.89
96	Product- BU	€ 463.50	10	€ 4,635.00	14	€ 6,446.96	-€ 1,811.96
97	Product- BV	€ 463.50	11	€ 5,098.50	10	€ 4,600.93	€ 497.57
98	Product- BW	€ 463.50	6	€ 2,781.00	7	€ 3,474.17	-€ 693.17

Appendix L: Obsolescence calculations for the Line-C product