# Reducing inventory while attaining the desired service performance

Bachelor thesis Industrial Engineering and Management


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# Preface

Dear reader,

In front of you lies my bachelor thesis ‘Reducing inventory while attaining the desired service performance’. This research was conducted for Slimstock and a customer of Slimstock a big Beneleux DIY company between March and August 2021.

Hereby, I want to thank all people who supported me in the past few months. I primarily want to thank Robert van Steenbergen, my first supervisor from the UT, for all his time and effort to supervise this research. Secondly I want to thank Dennis Prak for the feedback he provided as second supervisor.

I also want to thank the people at Slimstock, for their time and interest and I want to thank Eric van Dijk for giving me the opportunity to complete this research at Slimstock. I also want to thank the people at the  big Benelux DIY company with whom I had several meetings during this research.

I sincerely hope that you enjoy reading this thesis, and it generates new insights concerning inventory management.

Kind regards,

Willem Vincent

Enschede, August 2021

## Management Summary

Slimstock is Europe's leading inventory optimization specialist. Slimstock's inventory software package is an integrated solution for forecasting, demand planning, and inventory control and is designed and built to help their customers get the right inventory to the right place at the right time. A Big Benelux DIY company is a customer of Slimstock and uses Slimstocks inventory optimization software to forecast demand and make ordering decisions for 4800 products in their central warehouse.

The problem that the DIY company and Slimstock are facing is that they expect that for some products they miss their desired service performance. Service performance can be too low such that fewer products are sold on time than targeted or service performance can be too high such that too much inventory is in place for the desired service performance. Service performance is indicated on an aggregated level for every product group. However, it is not known which products have a lower service performance than desired and it is often also not known why this is the case. To research this the following main research question was constructed:

*How can Slimstock and the Big Benelux DIY company ensure that the desired service performance is attained while minimizing inventory by getting insight into the achieved service performance per product and optimizing parameters in the ordering policy model such that they better correspond to the reality for their 4800 products?*

The research started by analyzing the current situation, a closer look at the inventory model of Slimstock (Slim4) was taken. When taking a closer look at the current situation a lot of things that needed further understanding were found. This led to the construction of the literature review.

During the literature review, concepts, methods, and formulas were found that helped to get an understanding of and made it possible to improve demand forecasting and the inventory model of Slimstock which was in place at the DIY company.

After and during the literature review the knowledge which was found was linked to the current situation. Understanding the concepts of inventory management enabled the understanding of Slim4. It is determined that Slim4 works according to a Periodic-Review, Order-Up-to-Level (R, S) control policy. For this control policy the variables on which inventory decisions depend were determined. These variables are the base forecast, buffer stock (and the variables on which the bufferstock depends), order quantities, review time, and lead time. Then there was looked into how the actual ordering process goes. The parameters that have to be filled in by hand were determined. And in the end, because the year in which this research is conducted is a special year due to COVID-19, container cost and thus transport cost rised significantly and demand was unpredictable due to unexpected shop closures. The impact of this on the supplychain was determined.

When the current situation was clear, a dashboard is constructed to determine the achieved service performance over the past 54 weeks and this has been compared to the target service performance. It was found out that the target service performance is determined with a target fill rate, which assumes total backorders, and that the indication of the attained fill rate on an aggregated level assumes total lost sales. This means that these two variables are not completely comparable. The target fill rate and attained fill rates are both recalculated to KPIs which take the same amount of backorders into account. The dashboard constructed is split into an underperformers part for products that performed below the target fill rate and an overperformers part for products that performed above the target fill rate. It was estimated that the DIY company missed €492.470,82 due to not reaching the target fill rate and gained €243.807,90 by overperforming the target fill rate over 54 weeks ending in April 2021, assuming a profit margin of 10% over the purchase price of the products. Another interesting finding is that the average inventory cost over 54 weeks per product was €1.047,28 for an underperformer and € 1.630,87 for an overperformer.

After having a full picture of the current situation, we selected six products with outstanding KPIs to perform a in-depth analysis. For these products, the parameters within the model were compared with reality. In order to say something about the lead times, the DIY company should save the date on which an order is placed. In order to say something about the review time, the past order levels should be known. Both these things were not the case, such that only the MOQ could be compared with reality. For product 1, a deviating MOQ could be found. For three products, indications were found that the demand was higher than anticipated, however, this could not be checked because the past forecasts were not saved.

It is shown how the order levels of April 2021 are calculated. We showed that the buffer stock needs to rise by 79% when the real MOQ was filled in for product 1, this leads to an extra stock cost needed of €78,13 for the month of April 2021. We also showed that for two of the selected six products it is possible to order the EOQ and what the impact of this is on the buffer stock needed to attain the same fill rate. Because of a reduction in buffer stock which results from ordering the EOQ we showed that in the month of April 2021 for product 2 and product 4, €5,42 and €48,07 could be saved in stock cost respectively.

Lastly, the result of implementing a review/lead time ratio of 0,25 on the order levels of the six products is shown. For products with a huge review time compared to the lead time a significant reduction in orderlevel and stockcost for the month of April 2021 can be seen. The result depends on the chosen Review/lead time ratio, but the Review/lead time ratio makes sure that there is a constant ratio between the inventory caused by lead time and the inventory cause by review time. Because the review time for most products is set on one month this is especially useful in products with really short lead times (for example a few days).

When looking at the main research question, it can be concluded that during this research certain ways to decrease inventory level, while attaining the same target fill rate, were found or it is shown that in reality more inventory was needed to attain the same target fill rate, without changing the desired service performance. It was difficult to compare the reality with the parameters filled in Slim4 due to a lack of data. However therefore the impact of implementing the EOQ and implementing a Review/lead time ratio on the safety stock needed to attain the same target fill rateis shown and are the corresponding changes in stock cost for April 2021 calculated.

# Inhoudsopgave

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# Readers guide

**Chapter 1 – Introduction**

In chapter one, the introduction to the thesis is given. It contains the introduction of the company and the problem context. Based on this the problem-solving approach is mentioned and further elaborations on why and how the research is done are made.

**Chapter 2 – Literature review**

This chapter contains literature research about concepts, methods, and formulas of inventory management. This chapter contains the literature needed to understand the inventory solution module of Slimstock.

**Chapter 3 – Current situation analysis**

In this chapter, the literature found in chapter two is linked to the current situation of Slimstock and the DIY company. Their order policy and the relation with Slim4 are discussed.

**Chapter 4 – Dashboard**

In Chapter four the dashboard which is constructed in order to show the achieved service performance over 54 weeks is discussed. In this chapter, all KPIs used in the dashboard and the overall findings of the dashboard are discussed.

**Chapter 5 – Analysis of selected products**

In this chapter, further elaboration will be done about products that are selected based on outstanding KPIs constructed in chapter four. The parameters that are filled in for these products are compared with reality.

**Chapter 6 – Result of parameter discrepancy**

In this chapter, it will be shown how the order levels for April 2021 are calculated and the results of the parameter discrepancy on these order levels will be shown. Also, there will be shown what the result on the buffer stock is of ordering EOQs for the products and there will be shown what the result is on the order level of implementing a review/lead time ratio.

**Chapter 7 – Conclusions and recommendations**

In this chapter, the conclusions and recommendations of this research will be presented. Also, a discussion will be made about the limitations of the research, and suggestions for further research will be mentioned.

# 1. Introduction

This chapter introduces the research. A description is provided of the company and the relevance of the research is discussed (Section 1.1). After that, the focus will be on describing the problem and identifying the core problem, this is the basis for this research. We will start with the management problem (Section 1.2) after which we will continue to the problem cluster (Section 1.3) which will dissect the management problem into multiple problems and shows their relation. Out of the problem cluster, we will extract the core problems (Section 1.4). The core problems can be expressed in a norm and reality. After that Section 1.5, we will elaborate on the scope and in Section 1.6 the chosen problem solving approach with corresponding research questions will be explained. After this, the limitations of the research (Section 1.7) and the validity and reliability (Section 1.8) of the research design will be discussed. To end in Section 1.9, the deliverables will be evaluated.

## 1.1 Slimstock and the Big Benelux DIY company

This research will be conducted at the company Slimstock. Founded in 1993, Slimstock has become Europe's leading inventory optimization specialist. Slimstock's inventory model is an integrated solution for forecasting, demand planning, and inventory control and is designed and built to help their customers get the right inventory to the right place at the right time.

Furthermore, this research will be conducted at a customer of Slimstock, a Big Benelux DIY company. This company serves a lot of people in the Benelux when it comes to do-it-yourself equipment and other equipment for in and around the house. This company has a central distribution centre (DC). Suppliers deliver to this distribution centre and the company delivers to their retailers and webshop out of this DC.

## 1.2 Management problem

The models of Slimstock use a certain desired service level as input of the safety stock calculations for their customer's supply chain. This desired service level is seen as a benchmark for service performance for supply chain managers who use the software of Slimstock. This benchmark determines the amount of inventory that is expected to be delivered directly out of inventory. In the literature, this service level is called a target fill rate.

Based on the desired service level a certain safety stock is determined. This safety stock should be able to catch volatilities in demand and lead time and therefore prevent stock-outs. By choosing a certain service level, the supply chain manager determines to which extent stock-outs should be tolerated, while not having too high inventory cost. Figure 2.1 shows how safety stock prevents stock-outs.

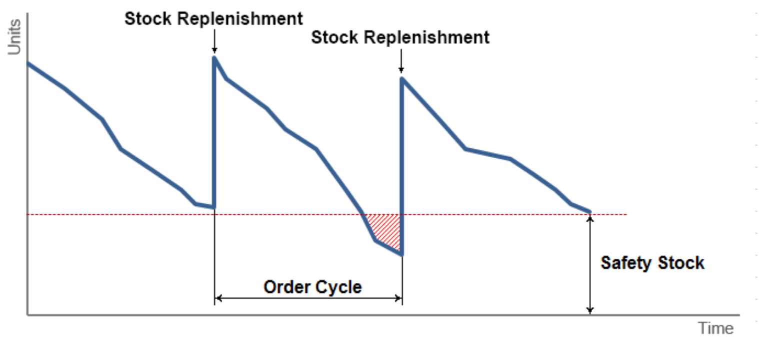


*Figure 1.2: Stock levels over time. (Reprinted from Smirnov, 2020)*

A customer of Slimstock, a DIY company, has a central DC out of which they deliver products to their retailers. Slimstock helps the DIY company with inventory management for 4800 products in the central DC but in reality, there are more products in stock in the warehouse.

When doing this they strive for a certain desired service level as mentioned above. However, they lack insight into the achieved service level per product. When the achieved service performance is different from the desired service performance, this can be caused by a wrong amount of stock that is in place such that the desired service level cannot be achieved.

On aggregated level, this company has insight into their achieved service performance. This means that they have insight per product group. Because of this, they know that in some product groups there are problems with the achieved service level. However, the achieved service performance per product is unknown. On aggregated level this is done by estimating the missed demand for a group of products and dividing it by the real demand. This is fraction of missed demand, when you substract this amount from one you will get the fraction attained demand, the service level, on aggregated level as it is called by Slimstock.

The company wants to get insight into the achieved service level per product in order to better spot differences between desired and achieved service performance. This will hopefully help to spot issues causing these differences. These issues could be, for example, parameters put wrongly in the model of Slimstock or certain factors that are not accounted for when determining the stock levels.

Not all issues are unknown, for example for some suppliers it is known that they have not been able to deliver products on time or at all. In that case, it is clear what the cause is for the bad service performance. However unknown weak spots could be found when having a better insight into the achieved service performance. An example of a potential unknown weak spot could be a constant underestimation of lead times. It is easier to find a problem if you know there is one.

This results in the following management problem:

*Slimstock and the Big Benelux DIY company suspect that they do not meet their desired service performance for several products.*

## 1.3 Problem cluster

After defining the management problem the next step is to design a problem cluster based on the management problem. “A problem cluster is used to map all problems along with their connection. It serves to bring order to the problem context and to identify the core problem” (Heerkens & Van Winden 2017, p. 42) The problem cluster belonging to this management problem can be found in Figure 2.2.

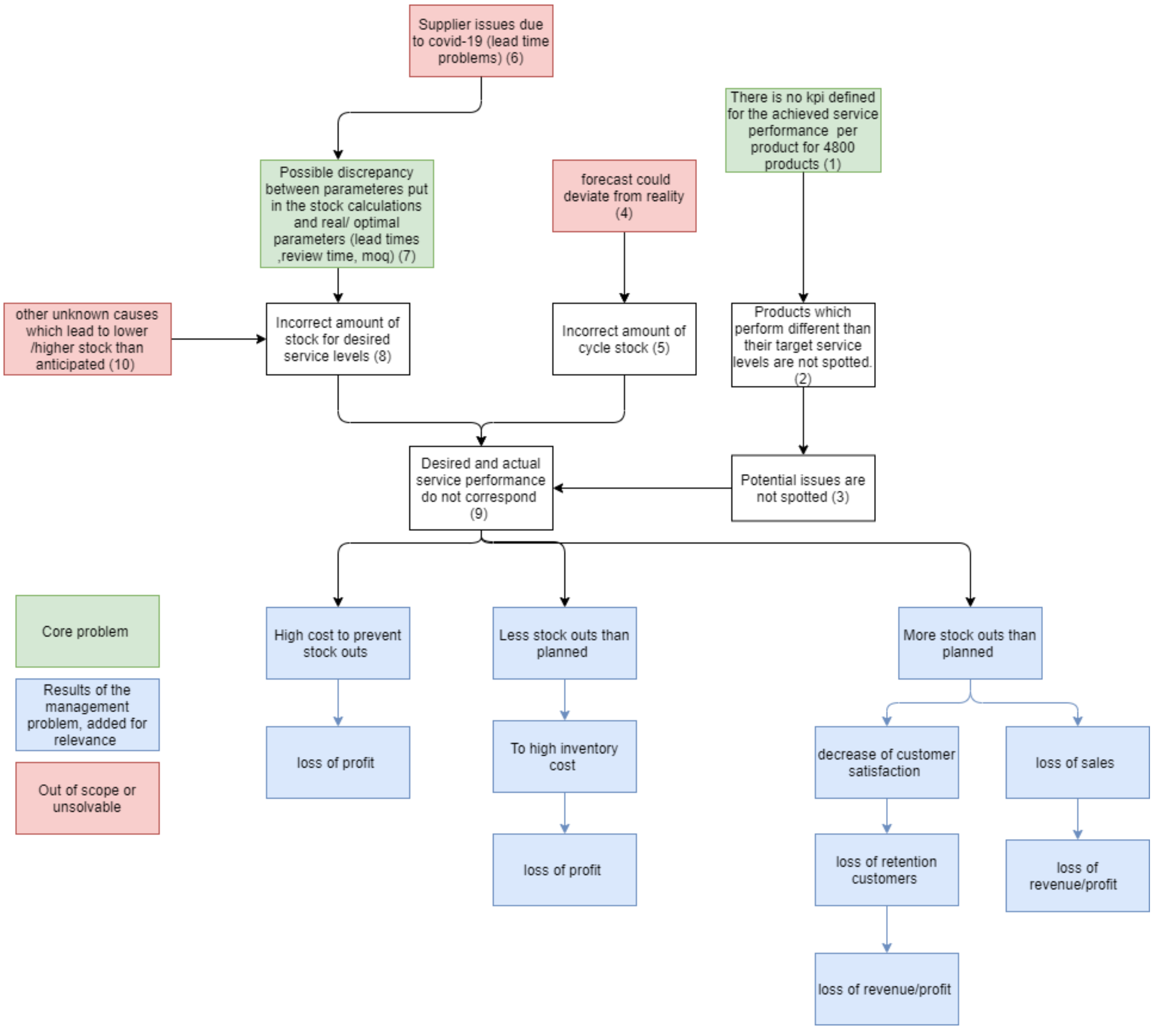


*Figure 1.2: Problem cluster.*

The management problem is that the desired and the actual service performance do not correspond (problem 9). Having a difference between the desired and actual service performance is caused by different problems. The first problem is that potential issues per product are not spotted (3) this in its turn is because it is unknown which products perform differently than their target service levels (2). This is not known because there is no KPI defined for the achieved service performance per product (1).

Another cause for a difference between desired and actual service performance is that there could be an incorrect amount of stock in place to reach the desired service levels. This can be due to the fact that there are parameters in the system which are not filled in correctly or optimally in comparison to reality (7). One problem that could cause this discrepancy is that suppliers do not deliver (on time) (6). This will cause the parameters filled in to not correspond with reality. When decisions are made for a lead time of 5 weeks by the system but in reality, the order comes after 10 weeks, the inventory model is suboptimal. However, it is out of the scope of this research to solve supplier issues due to COVID-19 because it is not solvable with the given materials.

Another problem that could cause the incorrect amount of stock is that there could be other unknown causes that can't be extracted out of the available data (10). This involves manual mistakes in the warehouse for example. This falls also out of the scope of this research and is therefore noted in red.

The last problem is that the forecast could deviate from reality (4). This will lead to an incorrect amount of cycle stock and therefore will lead to different attained service performance than targeted. This problem is unsolvable and falls therefore out of scope because the forecast is not saved in the data.

The blue problems are added for relevance in order to show the results of the desired and attained service performance not corresponding. And are therefore the results of the management problem.

## 1.4 Core problems

In order to select the core problem, we have to go back in the problem cluster to come to the problems which have no clear causes themselves. Also, problems that cannot be influenced cannot be a core problem. This leaves us with the following core problems:

*The achieved service performance per product for 4800 products is not measured.*

And

*There exists a possible discrepancy between parameters put in the stock calculations and real/optimal parameters such that the desired and actual service performance do not correspond.*

For the first problem Slimstock and the Big Benelux DIY company use service levels, put in their models, as the norm for their service performance. However, the reality is that this benchmark is not directly measurable per product and is only estimated on aggregated levels, per product group for example.

The norm for the second problem is that the parameters are filled in in the model as close to reality as possible. However in reality it is suspected that parameters are not filled in optimally and therefore suboptimal stock is taken to reach the desired service performance.

## 1.5 Scope

Because of a limitation in time a scope has to be determined for this research. The initial scope of this research will involve measuring the achieved service performance for all the 4800 products at the DC of the Big Benelux DIY company. However, when doing further analyses only the most interesting products or product(s)(groups) with generalizable insights will be picked. The number of products picked depends on the amount of time left and the results obtained in the previous phase. When coming on certain recommendations like switching suppliers, there will not be enough time to implement and evaluate. Therefore, this will not be part of the scope of this research.

## 1.6 Research questions and problem-solving approach

Based on the two core problems the following main research question is constructed for this research:

*How can Slimstock and the Big Benelux DIY company ensure that the desired service performance is attained while minimizing inventory by getting insight into the achieved service performance per product and optimizing parameters in the ordering policy model such that they better correspond to the reality for their 4800 products?*

In order to answer the main research question. A problem-solving approach with corresponding sub-questions is constructed. The sub-questions will be answered throughout the chapters.

Phase 1: Literature analysis (Chapter 2)

It is useful to look at the literature to get a better understanding of the subject. The theory will clarify the most relevant terms, theories, and formulas.

Sub-questions:

1. What is the role of inventory in a supply chain?
2. Which inventory control policies are described in the literature?
3. What are factors that can have an influence on service performance according to literature?
4. Which inventory performance KPIs exist in the literature?
5. What are methods to forecast demand according to the literature?

Phase 2: Research current situation (Chapter 3)

In this phase, the current situation at Slimstock and the Big Benelux DIY company is analysed. This will help to get a better understanding of the management problem. Researching the current situation will help get insight into the model of Slimstock. And we will look at which parameters influence the order policy and thus the service performance.

Sub-questions:

6. What is the current order policy at the DIY company with the model of Slimstock?
7. How is demand forecasted with the model of Slimstock?
8. Which parameters influence when, how and how much of a product is ordered in the model of Slimstock?

Phase 3: Construct KPIs and implement them in a dashboard with other product data (Chapter 4).

When having a good picture of the current situation at Slimstock and the DIY company and after providing an overview of the literature, the service performance KPIs can be constructed over a past time frame. These KPIs are needed to look into the problems which are not spotted because of the lack of insight into the achieved service performance. These KPIs will be constructed with the available data and determined for all 4800 products of the DIY company. After this, we will compare the values of these KPIs for the different products. A dashboard will be constructed in which products with outstanding values can be grouped. In this dashboard, other data should be visible as well, suppliers, lead times, and product groups for example. This way products can be grouped efficiently and service performance can be linked to relevant data that has an influence on service performance.

Sub-questions:

9. Which quantitative data concerning inventory management is available at the DIY company and Slimstock?
10. How can the data be made available as an input of the KPIs?
11. How does the target service level put in the model of Slimstock relate to achieved service performance?
12. What are the consequences on costs for the Big Benelux DIY company for too low/high service performance?

Phase 4: Analysis of selected products (Chapter 5)
It is out of the scope of this research to investigate all 4800 products, therefore, certain products will be selected based on KPIs that differ from the benchmarks of the DIY company. Further analysis will be done on these selected products. The current inventory situation of these selected will be determined and there will be looked at the real procurement order lines of these products. With the help of the real procurement order lines, the parameters filled in by the DIY company in de model of Slimstock will be compared to reality.

Sub-questions:

13. Which products are interesting to select for further analysis based on the constructed KPIs and the benchmarks of the DIY company?
14. What is the current inventory situation of the selected products?
15. Which data can be extracted out of the procurement order lines?
16. How do the parameters put in the model of Slimstock compare to the parameters found in the data?

Phase 5: Result on service performance of (possible) parameter discrepancy (Chapter 6)
After the analysis of the selected products, we will make calculations to analyse the result of the possible parameter discrepancy on the service performance of the selected products at the current order levels.

Sub-questions:

17. What are the formulas with which stock levels with a corresponding target service performance are determined?
18. What is the result of the service performance of parameters not corresponding with reality?
19. Can the achieved service performance be improved by adjusting parameters to reality?

Phase 6:Conclusions and recommendations (Chapter 7)
In the last phase, conclusions will be drawn and recommendations will be made based on the phases mentioned before.

## 1.7 Limitations research design

The limitations of a research design are shortcomings conditions or influences that place restrictions on its methodology and conclusions. The first limitation of this research is time, this research has to be conducted in 10 weeks, which is relatively a short amount of time for this type of research.

Another limitation present during this research is that the formulas used by the model of Slimstock have to remain confidential. Therefore the precise formulas used cannot be used in this bachelor thesis.

Something that also should be considered as a limitation is the possibility that contradicting information is retrieved or that no data at all can be retrieved. This will have a significant impact on the outcome of this research. For this research design, we expect that all necessary data is available. This is most likely the case, but due to certain unknown difficulties, some data might not be able to be retrieved.

## 1.8 Validity and reliability research design

According to Heerkens and Van Winden (2017) validity is about the extent to which is measured what was intended to measure. Validity can be split up into three types of validity, internal validity (Are your research design and your measuring instruments properly formulated?), external validity (Is your research applicable to other groups?) and construct validity (Are your concepts properly operationalized, logical related and were based on scientific knowledge?). This research should suffice to all these three types of validity. Regarding internal validity, it is assumed that the data provide by Slimstock and the

Big Benelux DIY company is correct. In this research, the data providers and the researcher have a common interest. In order to minimize bias, the finding will be written down and will be checked with the stakeholders at Slimstock and the Big Benelux DIY company. Also, it is important to notice that some of the formulas, KPIs, and definitions used in this research will differ from the ones used by Slimstock. It is important to have an understanding of all used terms to make sure all used formulas, KPI's and definitions are understandable for every party.

Concerning external there should be noted that there is worked with 4800 different products, no unjustifiable generalizations must be made. Construct validity is tackled by clearly defining constructs in this thesis.

Reliability is, according to Heerkens and Van Winden (2017), concerned with the stability of the research result. This is with the corona pandemic in mind and the damage this has done to supply chains everywhere a challenge. The Big Benelux DIY company has also been struck with the closure of retailers which led to big changes in demand and therefore to changes in service performance. It should therefore be mentioned that some conclusions and recommendations are only for the short term. A short-term conclusion can be for example that a supplier is unreliable due to COVID-19 which was never the case before the pandemic struck, therefore taking on a second supplier could be a short-term recommendation. A long-term conclusion can be that a supplier always has been unreliable, therefore a long-term recommendation could be switching suppliers altogether. This should be evaluated in the conclusions and recommendations.

## 1.9 Deliverables

- Analysis of literature.
- Overview of the current situation.
- Definitions of constructed KPI(s).
- Dashboard with explanation in which achieved service performance can be linked to several variables.
- Selected products with criteria.
- Inventory situation of selected products.
- Comparison parameters reality and model.
- Recommendations and conclusions on how to change parameters.
- Recommendations on further research.

# 2. Literature review

In this chapter, relevant theory to this research will be discussed. This literature focuses on inventory management. First, there will be discussed what inventory is and what its role is in a supply chain and we will elaborate on the different types of inventory (Section 2.1). After this we will look at lead time (Section 2.2.1) and review time (Section 2.2.2), inventory control policies (Section 2.3), inventory theory models(Section 2.4), economic, minimal, and incremental order quantity (Section 2.5), inventory performance indicators (Section 2.6), the relation between safety stock and cycle service level (Section 2.7), ABC-inventory qualification (Section 2.8) and forecasting demand (Section 2.9). This theory is needed to understand the current situation and construct further upon in this research.

## 2.1 Inventory

Before investigating the service performance of inventory, we discuss the concept of inventory, its role within the supply chain and the different types of inventory.

Inventory are items kept in storage. Inventory exists in the supply chain because of a mismatch between supply and demand. Sometimes this mismatch is intentional, for example when it is economical to produce in large lots or for a retail store that wants to prepare for an increase in demand. In these instances, inventory is held to reduce cost or increase the level of product availability. Inventory affects the assets held, the costs incurred, and responsiveness provided in the supply chain. High levels of inventory in an apparel supply chain improve responsiveness, but also leave the supply chain vulnerable to the need for markdowns, lowering profit margins. Higher inventory levels also facilitate a reduction in production and transportation costs, because of improved economies of scale in both functions. This choice, however, increases inventory holding costs. In general, managers should aim to reduce inventory in ways that do not increase the cost or reduce responsiveness (Chopra and Meindl, 2016).

Different types of inventory can be distinguished. These types of inventory are mentioned in the next subsections. The different types of inventory are noted because there can be different reasons why inventory is in place. To be able to make correct judgments about why inventory is in place it is useful to have an understanding of the types of inventory. The different types of inventory are mainly found in Silver et al. (2017), but are complemented with other literature like Chopra and Meindl (2016) Axsäter (2015) and Winston (2014).

### 2.1.1 Cycle inventory

Cycle inventory is the average amount of inventory used to satisfy demand between receipts of supplier shipments. (Chopra and Meindl, 2016). Cycle inventory is the result of an attempt to order or produce in batches instead of one unit at a time. The amount of inventory on hand, at any point, that results from these batches is called cycle stock. The amount of cycle stock in inventory is determined by management which makes a trade-off between holding and ordering costs (Silver et al., 2017).

### 2.1.2 Safety inventory

Safety stock is the amount of inventory kept on hand, on average, to allow for the uncertainty of demand and the uncertainty of supply in the short run. Safety stocks are not needed when the future rate of demand and the length of time it takes to get complete delivery of an order is known with certainty. The level of safety stock is controllable in the sense that this investment is directly related to the desired level of customer service (Silver et al., 2017). Safety stock acts as a buffer in case of a stock out. This does not mean that safety stock is meant to eliminate all stock-outs, just the majority of them (King, 2011), Figure 2.1 illustrates this.

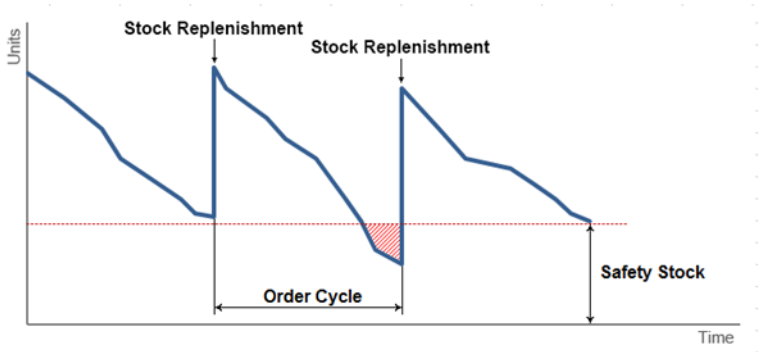


*Figure 2.1 – The role of safety stock in an inventory cycle (reprinted from Smirnov, 2020)*

When demand is forecasted, demand uncertainty is lowered as much as possible, meaning that safety stocks can be reduced. However, not all uncertainties can be taken away by trying to predict the future. Therefore, even when forecasting, safety stock is held; but only if the costs of understocking are higher than costs of overstocking. To determine this safety stock, it must be known how uncertain the forecast is, in other words, how large the forecast errors tend to be (Axsäter, 2006).

### 2.1.3 Congestion inventory

Congestion inventories are inventories arising due to items competing for limited capacity. When multiple items share the same production equipment, particularly when there are significant setup times, inventories of these items build up as they wait for the equipment to become available (Silver et al., 2017).

### 2.1.4 Anticipation inventory

Anticipation inventory consists of stock accumulated in advance of an expected peak in sales. When demand is regularly lower than average during some parts of the year, excess inventory (above cycle and safety stock) can be built up so that, during the period of high anticipated requirements, extra demand can be serviced from stock rather than from, for example, working overtime in the plant (Silver et al., 2017).

### 2.1.5 Pipeline inventory

Pipeline inventories include goods in transit (e.g., in physical pipelines, on trucks, or in railway cars) between levels of a multi-echelon distribution system or between adjacent work stations in a factory (Silver et al., 2017).

### 2.1.6 Decoupling inventory

Decoupling inventory is used in a multi-echelon situation to permit the separation of decision-making at the different echelons. For example, decoupling inventory allows decentralized decision-making at branch warehouses without every decision at a branch having an immediate impact on, say, the central warehouse or factory (Silver et al., 2017).

### 2.1.7 Strategic inventory

Strategic stock is the stock that is placed with a strategic reason, for example when the Brexit occurred this could have been a strategic reason to increase inventory (Dijk, Leeuw, Durlinger, 2017).

## 2.2 Lead time and review time

The time between an order that comes in and the next order to come in is the lead time plus the review time. In this section, there will be elaborated on these concepts.

### 2.2.1 Lead time

The lead time is the time from the ordering decision until the ordered amount is available on the shelf. It is not only the transit time from an external supplier or the production time in case of an internal order. It also includes, for example, order preparation time, transit time for the order, administrative time at the supplier, and time for inspection after receiving the order (Axsäter, 2015).

### 2.2.2 Review time

The review time is the time that elapses between two consecutive moments at which we look at the stock level. E.g., if we check stock levels once a month the review time is one month (Silver et al., 2017).

## 2.3 Inventory control policies

Inventory control policies are about the questions: “When should an order be placed and what quantity should be ordered?” (Silver et al., 2017, p242).

When talking about the stock situation, it is natural to think of the physical stock on hand. But an ordering decision cannot be based only on the stock on hand. We must also include the outstanding orders that have not yet arrived and backorders. In inventory control, the stock situation is therefore characterized by the inventory position (Axsäter, 2015).The inventory position is determined according to the following formula (Axsäter, 2015):

$$inventory\,position\ =\ stock\ on\ hand\ +\ outstanding\ orders - \ backorders \quad \text{(Equation 2.1)}$$

The answer to the problem of how often the inventory position should be determined is determined by the review interval (R). In periodic review, the stock status is only determined every R time units, for instance at the end of each day.In the case that there is continuous review, the stock status is always known. This means that in a continuous review the review interval R = 0 (Silver et al., 2017).The four most common inventory control policies are the (s, Q) policy, the (s, S) policy, the (R, s) policy, and the (R, s, S) policy ( Silver et al., 2017).In the next subsections, these policies will be explained.

### 2.3.1 Order-point, Order-Quantity (s, Q) System

The (s, Q) system is a continuous review system (i.e., R=0). In this system, a fixed quantity is ordered whenever the inventory drops to the reorder point s. The advantages of the fixed order-quantity (s, Q) system include that it is quite simple for the stock clerk to understand, that errors are less likely to occur and the production requirements for the supplier are more predictable. The primary disadvantage of an (s, Q) system is that in its unmodified form, it may not be able to effectively cope with the situation where individual transactions are large. If the transaction that triggers the replenishment in an (s, Q) system is large enough then the lot size Q will not even raise the inventory position above the reorder point (Silver et al., 2017).The reorder point of the (s, Q) System can be determined with the following formula (Bernard, 2015):

$$S = d * L \ + ss \qquad \text{(Equation 2.2)}$$

Where:

$S\ =\ Reorder\ point$

$d\ =\ average\ demand\ over\ a\ certain\ time\ period$

$L\ =\ Lead\ time$

$Ss\ =\ safetystock$

### 2.3.2 Order-Point, Order-Up-to-Level (s, S) System

This system again assumes continuous review and like the (s, Q) system, a replenishment is made whenever the inventory position drops to the order point s or lower. However, in contrast to the (s, Q) system, a variable replenishment quantity is used, ordering enough to raise the inventory position to the order-up-to-level S.

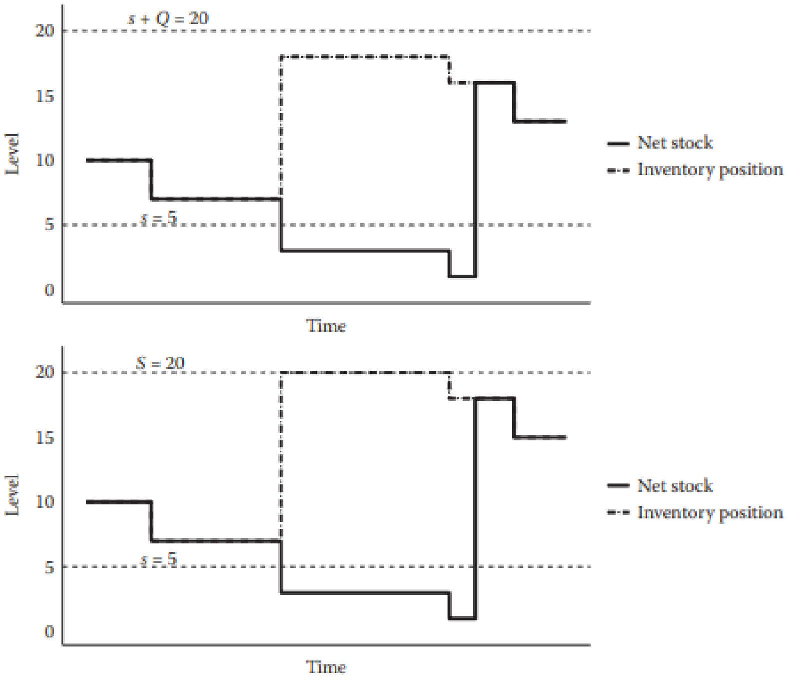


*Figure 2.2: the (s, Q) system (on top) and the (s, S) system below. (reprinted from Silver et al., 2017)*

### 2.3.3 Periodic-Review, Order-Up-to-Level (R, S) System

The control procedure of the periodic review, (R, S) system is that every R units of time enough is ordered to raise the inventory position to level S. Because of the periodic-review property, this system is much preferred to order point systems in terms of aggregating the replenishments of related items.
This enables a company to easier combine more products in one order. For example, when ordering from overseas, it is often necessary to fill a shipping container to keep shipping costs under control. The aggregated ordering afforded by a periodic review system can provide significant savings. Furthermore, the (R, S) system offers a regular opportunity (every R units of time) to adjust the order-up-to-level S, a desirable property if the demand pattern is changing with time (Silver et al., 2017). The order quantity needed to raise the inventory level to S can be calculated by the following formula (Bernard, 2015):

$$O = d * (R + L) + ss - I \qquad \text{(Equation 2.3)}$$

Where:
$O$ = *Order quantity needed to get up to the orderlevel*
$d$ = *average demand over a certain time period*
$R$ = *the review period*
$ss$ = *the amount of safety stock held for the item*
$I$ = *the amount of inventory on hand when the inventory level is check*ed

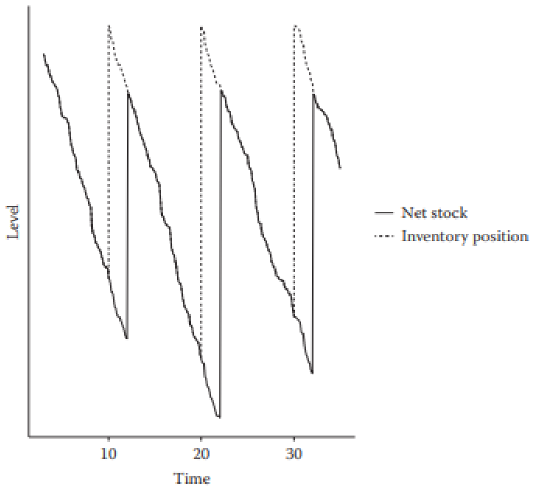


*Figure 2.3 The (R, S) system. Orders are placed every 10 periods with a lead time of 2 periods. (reprinted from Silver et al., 2017)*

### 2.3.4 The (R, s, S) system

This is a combination of (s, S) and (R, S) systems. The idea is that for every R units of time we check the inventory position. If it is at or below the reorder point s, we order enough to raise it to S. If the position is above s, nothing is done until at least the next review instant (Silver et al., 2017).

## 2.4 Demand models

In order to optimize supply chains, it is important to calculate the desired stock levels. However, in order to do that, inventory situations have to be modelled. There exists no universal model, with a wide range of factors affecting the inventory stock, and thus the situation here is closely related to the ability to predict the future consumption induced by future demand (Bartmann and Beckamann, 1992). The knowledge and character of demand are very important for the whole inventory management. This because the demand denotes at which rate the products leave the inventory. There are basically three demand modelling methods (Polanecký and Lukoszová, 2016).

### 2.4.1 Deterministic demand function as a model

One of the demand modelling methods is the deterministic demand model, where its explicit expression is known. The demand function may not only be a linear demand function, but also the polynomial of general degree n function, or any other known function. It merely depends on the real situation to be modelled (Lukáš, 2005).

### 2.4.2 Static stochastic demand description as a model

Stochastic inventory models differ from the deterministic ones only in the character of demand. Whilst demand is fixed in the deterministic models, demand in the former is of stochastic (probabilistic) nature, which means it is a random variable with a probability distribution. The stochastic models represent a certain demand, where its explicit expression is known. The demand function may include not only a linear function, but also a function with a polynomial of general degree n, or any other known function. It is merely dependent on the real situation to be modelled (Kořenář 2010).

As for static stochastic modelling, the main prerequisite here is the impossibility of further inventory replenishment. Therefore, these are situations, where over a certain period it is necessary to satisfy the needs from the stock that can be created only once. If the generated stock is lower than the actual need, certain costs from a shortage of stock will emerge. On the contrary, provided that the generated stock is higher than the actual need, some additional costs will be incurred again, for after the end of the period, the stock will not be usable (Polanecký and Lukoszová, 2016).

### 2.4.3 Dynamic stochastic demand description as a model

The most common assumption is that the demand distribution in a given period follows a normal distribution with a mean value (μQ) and a standard deviation (σQ). Likewise, demand during a particular lead time (L) is normally distributed with a mean value (μL) and a variance (σL). When a stochastic demand model is dynamic the probability function updates every once in a while.  This means in the situation mentioned above that the mean value and standard deviation updates. This is done by fore example forecasting on which is further elaborated in Section 2.10. When a demand model is dynamic the model can be adjusted for trend and seasonality (Polanecký and Lukoszová, 2016).

## 2.5 Economic, Minimal, and Incremental Order Quantity

When asking the question, how much should be ordered? There are a few different concepts that are useful to know about. These concepts are described in the this section.

### 2.5.1 Economic order quantity

When placing an order two questions are important.

1. How large should the order be?

2. When should the order be placed?

To answer these questions, companies often use the Economic Order Quantity model (EOQ).
The economic order quantity is the order amount for which the sum of the order cost and holding cost is minimal. Therefore this is the amount that can be ordered in order to minimize cost.

The formula for the economic order quantity is (Winston, 2004):

$$Q^* = \sqrt{\frac{2dk}{h}} \qquad \text{(Equation 2.5)}$$

Where:

$Q^* \;= Economic\ order\ quantity$

$d = Average\ demand\ over\ a\ certain\ timeframe$

$K = Order\ cost\ per\ order$

$h = Holding\ cost\ per\ unit\ over\ a\ certain\ time\ frame$

Holding cost (h)

This is the cost of carrying one unit of inventory for one time period. If the time period is a year, the carrying cost is usually expressed in euros per unit per year. The holding cost includes storage cost, insurance cost, taxes on inventory, and a cost due to the possibility of spoilage, theft, or obsolescence. However, the most significant component of holding cost is the opportunity cost incurred by tying up capital in inventory (Winston, 2004).

Order cost (K)

Many costs associated with placing an order or producing a good internally do not depend on the size of the order or on the production run. Costs of this type are referred to as the order cost (Winston, 2004).

From the perspective of a manager, the optimal lot size is one that minimizes the total cost to their company. The EOQ formula is used to find the minimum order cost plus the holding cost(Chopra and Meindl, 2016), Figure 2.4 shows this.

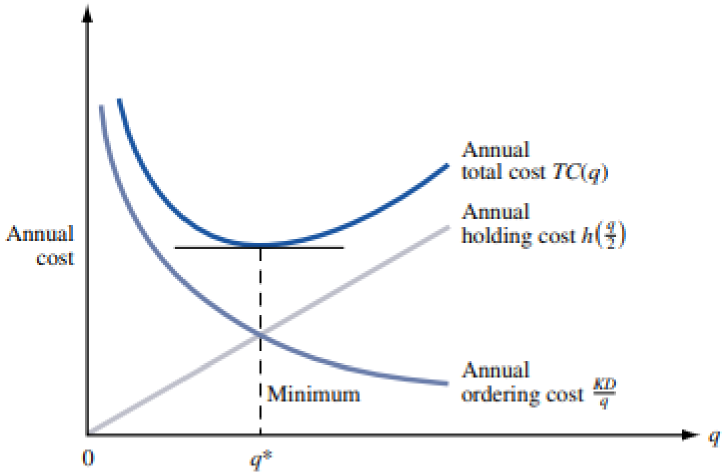


*Figure 2.4: Trade-off between ordering and holding cost (reprinted from Winston, 2004)*

For the EOQ-model to hold certain assumptions are required (Winston, 2004):

1. Demand is deterministically modelled and occurs at a constant rate.
2. If an order of any size is placed, an ordering and setup cost K is incurred.
3. The lead time for each order is zero.
4. No shortages are allowed.
5. The cost per unit-year of holding inventory is h.

### 2.5.2 Minimal Order Quantity (MOQ)

The minimum order quantity (MOQ) is the least amount of stock you can order from a supplier. If you cannot buy the MOQ of a product you need, the supplier will not sell it to you.

Items with high value tend to cost more to produce and are likely to have lower MOQs. Lower value items, on the other hand, are usually easy and inexpensive to produce and hence have higher MOQs. In the former case, your suppliers can make a profit even by selling smaller quantities. In the latter case, they're counting on numbers to make a profit, and thus need you to buy more as well (Hasita, 2019).

### 2.5.3 Incremental Order Quantity (IOQ)

The Incremental Order Quantity is the quantity the order rises if we order more than the MOQ. An example: A product is always sold per box and there are 4 pieces of the product in a box (Van den Pol, 2021).

## 2.6 Inventory performance indicators

Inventory performance indicators are indicators that show the performance of the inventory. As a supply chain manager, it is important to track these indicators in order to see how the decision-making influences the performance of the inventory. The indicators are often also used to make decisions upon. For example, an order policy can be determined with as goal striving for a certain cycle service level.

### 2.6.1 Cycle service level

The cycle service level (CSL) is the fraction of replenishment cycles that end with all thecustomer demand being met. A replenishment cycle is the interval between two successive replenishment deliveries. The CSL is equal to the probability of not having a stockout in a replenishment cycle. CSL should be measured over a specified number of replenishment cycles (Chopra and Meindl, 2016).

### 2.6.2 Fill rate

The fill rate measures the fraction of orders/demand that was met on time from inventory. Fill rate should be averaged not over time but over a specified number of units of demand or the amount of orders met. When talking about the amount of orders met we talk about the order fill rate and when we talk about the units of demand met we talk about the product fill rate (Chopra and Meindl, 2016).

### 2.6.3 Ready rate

The ready rate measures the fraction of time that a particular stock-keeping unit had zero inventory. This fraction can be used to estimate the lost sales during the stockout period (Chopra and Meindl, 2016).

### 2.6.4 Average inventory

The average inventory measures the average amount of inventory carried. Average inventory can be measured in units, days of demand, and financial value (Chopra and Meindl, 2016).

## 2.7 Safety stock and cycle service level, fill rate when demand is normal and backordering

When safety stock is known, the cycle service level can be calculated by filling in safety stock formulas, which can be seen in Figure 2.5. When safety stock and lot size are known the fill rate can also be determined. Cycle service level depends on the safety factor (z), but not on the lot size (Q) or on the demand during review time, while the fill rate does. These formulas can only be used when the demand for a product is normally distributed and backordering is assumed (Chopra and Meindl, 2016). Figure 2.5 shows these different formulas for a periodic or continuous review policy. The lead times can be fixed or there can be assumed that the lead times follow a normal distribution to take lead time variability into account (Wouter van Heeswijk, 2019).

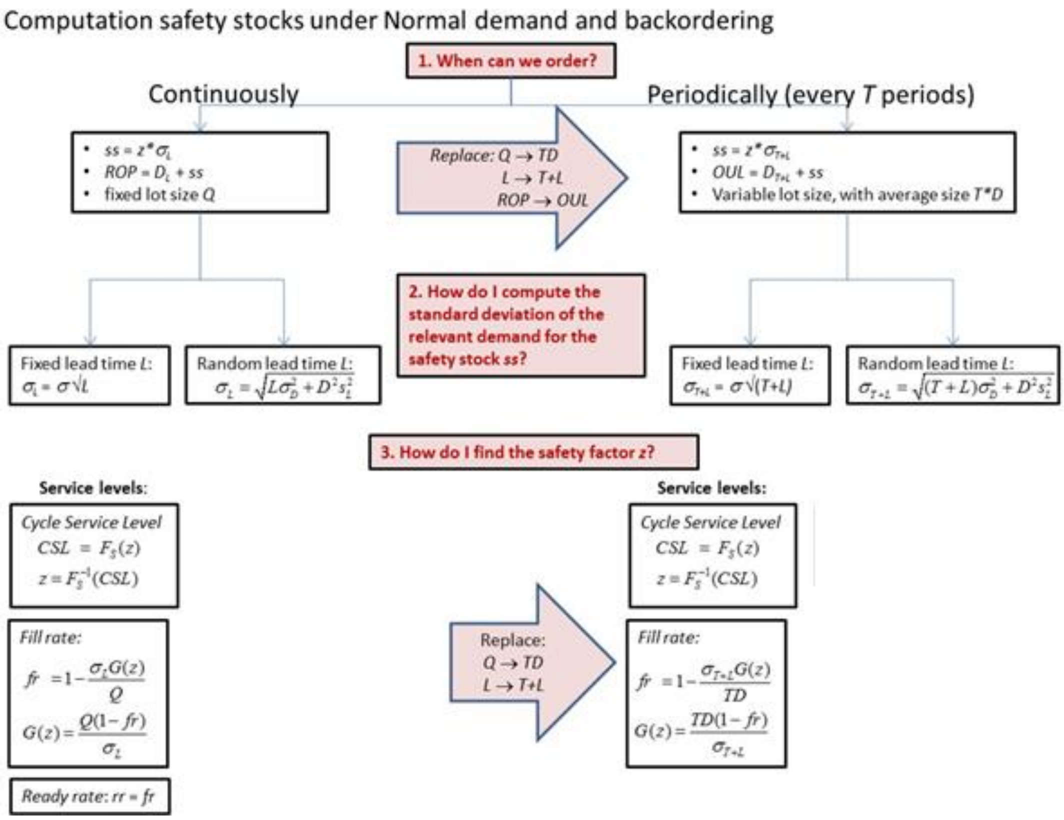


*Figure 2.5: Formulas for calculating safety stock, service level, and fill rate (adapted from Van Heeswijk, 2019)*

The higher the service level gets the more inventory needs to be held onto to increase the service level. Increasing the service level from 95 to 97% is vastly more expensive than increasing it from 85 to 87%. Figure 2.6 illustrates the relationship between the service level and the inventory level. (Schalit & Vermorel, 2014).

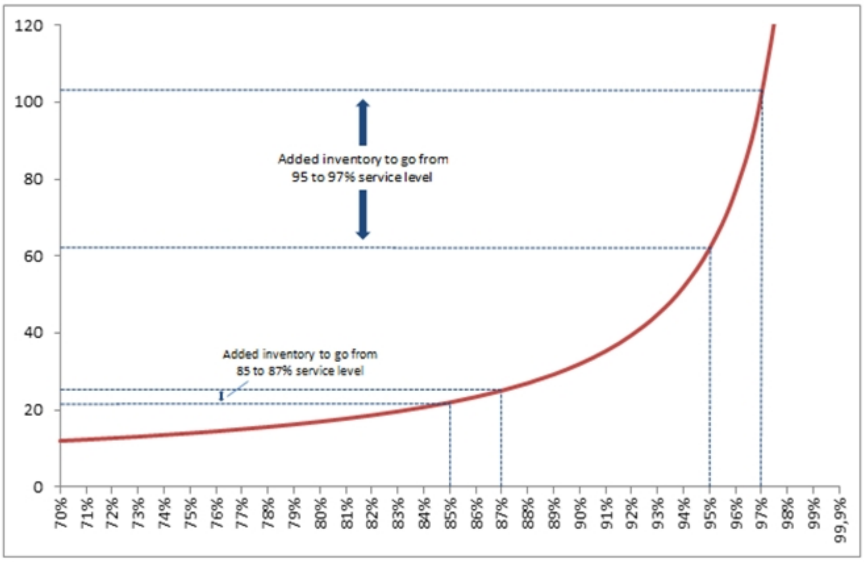


*Figure 2.6: Relationship between service level and inventory position (reprinted from Schalit & Vermorel, 2014).*

## 2.8 ABC-Inventory qualification

A type of grouping that is common in many companies is so-called ABC-inventory analysis. This means a grouping by dollar volume. Usually, a relatively small percentage of the items accounts for a large share of the total volume. Typically 20 per cent of the items can account for about 80 per cent of the dollar volume (Axsäter, 2015).

Items with a high volume are often more important for the company and it is, therefore, reasonable to expect that such items should require a more precise control and performance evaluation. Consequently, many companies initially group their items into three classes. A, B, and C. The A-class consists of items with a very high dollar volume. Typically the A class contains 10 per cent of the items. Likewise, about 30 per cent of the items with intermediate dollar volumes can be classified as class B items. Finally, the remaining 60 per cent of the items with low dollar volumes are referred to as the C class items (Axsäter, 2015).

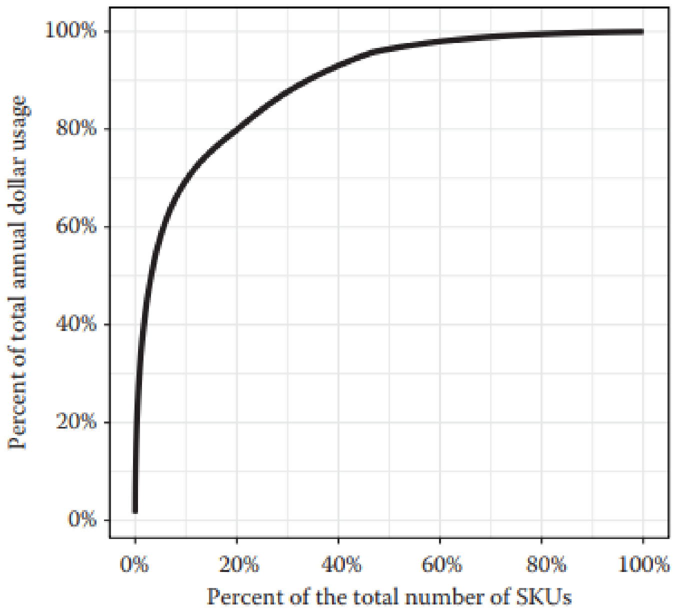


*Figure 2.7: Distribution of value of Stock keeping units (reprinted from Silver et al, 2017)*

## 2.9 Forecasting demand: Time series methods

As uncertainty continues to grow in its fame with rapid change becoming the new normal, practitioners need effective tools to navigate uncertainty. Forecasting is one such tool. Forecasting done well can serve as a steadying force—it can be seen as a stand-in or a proxy for reality (Sankaran et al., 2019).

There are essentially two basic types of forecasting: qualitative (reliance on judgmental factors) and quantitative (consisting of time series and causal methods). Quantitative methods are (and should be) steeped in science, whereas there is a heavy dose of art involved in qualitative methods. (Sankaran et al., 2019).

Time-series forecasting is a form of quantitative forecasting. Time-series forecasting methods use historical demand to make a forecast. They are based on the assumption that past demand history is a good indicator of future demand. These methods are most appropriate when the basic demand pattern does not vary significantly from one year to the next. These are the simplest methods to implement and can serve as a good starting point for a demand forecast (Chopra and Meindl, 2016).

In this chapter, we will elaborate on different types of time-series forecasting as these types of forecasting are used by Slimstock.

### 2.9.1 Single exponential smoothing (SES)

Single exponential smoothing is probably the most widely used time-series method for short-term forecasting (Silver et al., 2017).

In forecasting, in many cases, the most recent demand history or observations provide the best indication of what future demand will be. Therefore, it makes sense to create a weighting scheme that introduces decreasing weights as the observations get older. In other words, give more weight to the most current observations or recent demand periods (Chase, 2013). The relative weights depend on the smoothing constant used— called α, alpha (Sankaran et al., 2019).

The single exponential smoothing (SES) method essentially takes the forecast for the previous demand period and adjusts it using the forecast error. Then it makes the next forecast period (Chase, 2013).

The simple exponential smoothing forecast is computed by using the following formula (Chopra and Meindl, 2016):

$$F_{t+1} = \alpha D_t + (1 - \alpha)F_t \qquad \text{(Equation 2.6)}$$

Where:

$F_{t+1} = the\ forecast\ for\ the\ next\ period$
$D_t = actual\ demand\ in\ the\ present\ period$
$F_t = the\ previously\ determined\ forecast\ for\ the\ present\ period$
$\alpha = Smoothing\ constant\ between\ 0\ and\ 1$

An α close to 1 will have an adjustment value that is substantial, making the forecasts more sensitive to swings in past historical demand based on the previous period's error. The closer the α value is to 1, the more reactive the future forecast will be, based on past demand (Chase, 2013).

### 2.9.2 Croston method

When the demand for a product is sporadic, the exponential smoothing methods do perform quite poorly. Croston (1972) highlighted that single exponential smoothing produces very large forecasting errors. Thus, he proposed a forecasting method in which the updates of the demand estimations are performed only after a non-zero demand occurs (Sankaran, 2019).

In the case of positive demand, two averages are updated by exponential smoothing: the size of the positive demand, and the time between two periods with positive demand. This gives a more sTable forecast and also a better feeling for the structure of the demand (Axsäter, 2015).

### 2.9.3 Holt-Winters' Method

The simple exponential smoothing and Croston method presented in the previous subsections are based on models without a trend and therefore are inappropriate when the underlying demand pattern involves a significant trend. A somewhat more complicated smoothing procedure is needed under such circumstances. In 1957, Charles C. Holt expanded single exponential smoothing to include a linear trend component, enabling the ability to forecast data with trends (Chase, 2013).

If there are indications of seasonal patterns in the demand data set, Holt's method alone cannot handle the problem very well. Review of the SES model results and Holt's ability to improve on the SES method by accounting for the trend still indicates that there is an additional opportunity for improvement. In 1960, Peter R. Winters expanded on Holt's method by adding a seasonal component. The Holt-Winters method uses three equations to account for level, trend, and seasonality. Three complete years of historical demand are recommended to truly capture the effects of seasonality. However, you can capture seasonality with only two years (Chase, 2013).

# 3. Current situation analysis

In this chapter, the current situation will be discussed. First, we will give a brief introduction (Section 3.1) then there will be discussed how the order process goes with the help of the model of Slim4 (Section 3.2). In Section 3.3 there is elaborated on the parameters that have to be filled in manually. And finally, the impact of COVID-19 on the supply chain will be discussed (Section 3.4).

## 3.1 Introduction of the current situation

The DIY company currently holds a lot of items in a central warehouse which they source from all over the world. These products are distributed from the central warehouse to retailers all over the country. In order to optimize the inventory situation for some of their products in their central warehouse, the DIY company gets help from Slimstock. The software package of Slimstock, Slim4, is used to make order decisions in order to maintain optimal stock levels and reduce cost. Slim4 is used on 4800 products in their warehouse.

## 3.2 Order policy at the Big Benelux DIY company using Slim4

The Big Benelux DIY company uses the software platform of Slimstock which is called Slim4 to determine when to place an order and what to order. This system works with an (R,S) order policy in case there is no MOQ or EOQ in place. This means that in that case every review period (R) a variable amount is ordered to raise the inventory level up to the order level. When the MOQ is larger than the amount there needs to be ordered to raise the inventory level up to the order level the MOQ is ordered. This is because the MOQ is the smallest amount that can be ordered. There is no EOQ in place at the DIY company but if there was the EOQ is the amount that is ordered when the EOQ is bigger than the MOQ and the amount needed to raise inventory level up to the order level. The order level consists of the cycle stock, which is the expected demand during the lead time and review time plus the safety stock . In Slim4 the safety stock is called buffer stock and the cycle stock is called base forecast.

### 3.2.1 Base forecast

The base forecast is the expected demand during review time and lead time. The demand during lead time and review time is forecasted using different time-series methods (based on past demand). The forecasting method depends on the demand class of the item, there are 11 different demand classes and three different demand forecasting methods. Demand is forecasted using single exponential smoothing for the items with the most frequent demand. When there exist periods of zero demand the Croston method is applied. When demand is even more scarce the demand is forecasted using a Poisson distribution. For new products and products with a demand history of fewer than 2 months, a manual forecast is in place which should be filled in by the planners. When there exist two years of data the demand patterns will be tested for seasonality and trend. If there exists a trend and seasonality factors will be added to adjust the forecast for the found trend and seasonality. This is done with formulas inspired by the Holt-Winters' method. The demand is forecasted every month and is multiplied by the review and lead time which yields the base forecast. In case of a month with significant deviating demand in comparison to other months this month is excluded in the simple exponential smoothing calculation.

### 3.2.2 Buffer stock

The buffer stock is in place in order to catch up volatilities in demand. However, how much of the volatilities are caught by the buffer stock is decided by management. In Slim4 this is done by setting a target fill rate. The target fill rate assumes that there are no backorders. This means that the target fill rate is the percentage of items that are sold from inventory on time. For example, management determines that a product should have a 96% fill rate. This benchmark is filled in in Slim4 after which a corresponding buffer stock is determined such that 96% of demand is fulfilled on time out of inventory. The target fill rate is called service level in Slim4, this should not be confused with the cycle service level. The target fill rate in contrast to the cycle service level also takes the order quantity into account.

After all, the more time spend close to 0 zero stock (which is the case with a lower order quantity) the bigger the probability of missing demand and therefore the lower the fill rate.

To determine the target fill rates the ABC-qualification is in place  (Section 2.8). This means that products are divided into A, B, and C and that they got a target fill rate per letter. For A products the target fill rate is 96%, for B products this is 93% and for C products this is 85%.

The target fill rate that is filled in in Slim4 assumes total backorders, this means that it assumes that every demand that is missed due to a stock out will be ordered anyway later on.

### 3.2.3 Order quantities

Theoretically, the amount ordered is the forecasted demand during lead time and review time . When ordering the forecasted demand, the IOQ should be taken into account. Orders should always be placed in multiples of the IOQ.

If the MOQ is greater than the amount of forecasted demand during lead time and review time, this is the amount ordered if the inventory position is below the reorder level. The EOQ is not yet calculated for products of the Big Benelux DIY company, therefore this amount is not ordered. The EOQ uses the forecasted demand as input and is therefore updated each month.

### 3.2.4  Review Time

Currently, the planners of the Big Benelux DIY company have three different review periods for their products. Some of the products with high demand or products that have a low lead time are checked once a week and therefore have a review period (R) of 1 week. Then there are some products with a review period (R) of 2 weeks that have also high demand or have a lower lead time. The rest and the majority of the products have a review period (R) of 1 month.

### 3.2.5 Lead times

The Big Benelux DIY company currently does not save historical lead times. Therefore the lead times filled in in Slim4 are estimations based on agreements with suppliers plus estimations of the time needed to get an order on the shelf.

### 3.2.6 The actual ordering

When the planners look at the inventory level once a review period,  they create an order if the inventory position is below the order level. However in reality there are some more factors that should be taken into account. When sourcing out of Asia the Big Benelux DIY company orders in full containers. The containers are filled per supplier and are not aggregated in the harbour. Therefore, in a lot of orders, a surplus is ordered in order to fill off containers. This can lead to a higher order quantity than optimal for the given target fill rates. Another influence that should be taken into account is that sometimes the supplier decides to offer a discount when a specifically large amount is ordered. This sometimes also ‘sub-optimally’ inflates the order quantity.

## 3.3 List of parameters that should be filled in manually in Slim4

In Slim4, some parameters have to be filled in manually by the DIY company with which the model calculates the optimal order policy. The order policy that comes out of Slim4 is better when these parameters correspond closer with reality. The parameters that have to be filled in manually are to be found in Table 3.1.

| | |
|---|---|
| Lead time | Section 2.2.1 |
| Review time | Section 2.2.2 |
| MOQ | Section 2.5.2 |
| IOQ | Section 2.5.3 |
| EOQ (holding cost, order cost) | Section 2.5.1 |
| Target fill rate (based on ABC-qualification) | Section 2.6.1 / 2.7 (Section 2.8) |

*Table 3.1: Parameters that have to be filled in manually in slim4.*

## 3.4 COVID-19 and the impact on the supply chain

The data on which the dashboard is built is based on data ranging from 15 April 2020 up to 29 April 2021. In this time frame, supply chains all over the world were disrupted due to the COVID-19 virus and other supply chain disrupting factors like rising commodity prices and the Evergreen blocking the Suez canal for 6 days. In Figure 3.1, the Shanghai Containerized Freight Index can be seen, out of this figure, it can be noted that from the start of 2020 up till the eleventh of June the container prizes have more than quadrupled. This of course has a great impact on supply chains. Order costs raise significantly and therefore it becomes more optimal to order larger batch sizes. This leads to having more than average inventory in stock.

The Big Benelux DIY company experienced during the corona crisis certain periods of really high peak demand and periods of significantly lower demand. Due to lockdown a lot of people started working on their houses, which significantly increased demand. But due to shop closures, a lot of demand fell away, especially for items that are not purchasable in the web shop of the company. This led to difficulties in demand forecasting.

Another issue that was caused by the corona crisis was that a lot of suppliers could not get their hands on commodities or could not keep up with demand. Therefore there were a lot of supply issues during the past year. When a supplier does not deliver, it is difficult to make sure the item is sufficiently on stock and therefore it is difficult to reach the desired service performance.

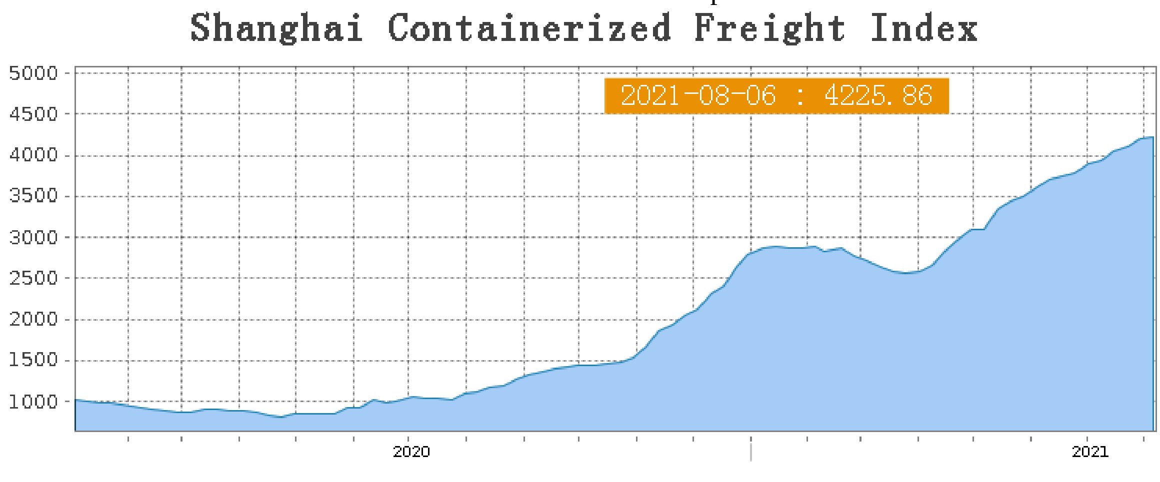


*Figure 3.1: Shanghai Containerized Freight Index (reprinted from Shanghai Shipping Exchange , 2021)*

# 4. Dashboard

In order to get insight into the service performance of the 4800 products of the Big Benelux DIY company, a dashboard has been constructed. The dashboard has been built with the data extracted out of Slim4. This data set contains the stock levels and achieved demand over a past time frame of 54 weeks up till April the 22nd. The data also contains the settings at which the product is currently set. This dashboard is aimed at spotting products that performed differently from their service objectives of the Big Benelux DIY company over the past 54 weeks. In this chapter, we will evaluate this dashboard. This will be done by firstly discussing which KPIs are used in the dashboard (Section 4.1). After this, a separation in underperformers and overperformers to compare their target service performance will be made (Section 4.2). Then the benchmarks that are currently in place at the DIY company will be discussed (Section 4.3). We will conclude with some overall findings of the dashboard (Section 4.4).

## 4.1 KPIs

In order to get insight into the service achievement per product of the Big Benelux DIY company over the past 54 weeks, 17 KPIs are constructed with the available data. In thissection, there will be elaborated on these KPIs. Table 4.1 shows the abbreviations for KPIs that are used in the formulas.

| Abbreviation | KPI |
|---|---|
| **AD54** | Achieved demand in 54 weeks |
| **0stock** | Days of 0 stock on hand in 54 weeks |
| **RD54W** | Real demand 54 weeks without backorders |
| **RD54BO** | Real demand 54 weeks with backorders |
| **TFR** | Target fill rate |
| **FR** | Fill rate |
| **TPDF** | Target Percentage demand fulfilled |
| **PDF** | Percentage demand fulfilled |
| **DTPDF** | Difference percentage target demand fulfilled and percentage demand fulfilled |
| **MD54** | Missed demand 54 weeks |
| **€M** | Euro’s missed compared to the target |
| **%CRRB** | Contribution revenue % real demand with backorders |
| **AS** | Average stock |
| **IC54** | Inventory cost 54 weeks |
| **AIV54** | Average inventory Value 54 |
| **ATTW** | Average throughput time in weeks |
| **A,MOQ** | Average order quantity or MOQ |

*Table 4.1: Abbreviations for KPIs.*

### *Achieved demand in 54 weeks*

This KPI is extracted straight from the data. Because the demand per product per week is given in the data set presented by the Big Benelux DIY company, the achieved demand for 54 weeks (AD54) could be easily determined. This KPI is important because it is the input for other KPIs mentioned below.

### *Days of 0 stock on hand  in 54 weeks*

This is a KPI that is also extracted straight from the data, the days of zero stock (0stock) are given per week. Therefore the number of total days of zero stock on hand could also be determined. This KPI is also an input for other KPIs mentioned below.

### *Real demand 54 weeks without backorders*

The achieved demand- and the days of 0 stock on hand in 54 weeks together can be used to determine the real demand in 54 weeks without backorders (RD54W). However in order to do that the following assumption must be made: In the days that there was 0 demand, the average demand per day over the days that there was stock in place would have been in place. This KPI does not take back orders into account. Therefore to construct this KPI the days of zero demand are multiplied with the average demand per day over the days that there was stock. This amount is then added to the achieved demand to create the real demand in 54 weeks without backorders. The real demand of 54 weeks without backorders is determined according to the following formula:

$$RD54W = AD54 + \frac{AD54W}{(378 - 0stock)} * 0stock \qquad \text{(Equation 3.1)}$$

*Real demand 54 weeks with backorders*

In reality, it is unlikely that there are no backorders. Therefore a new KPI was constructed, the real demand 54 weeks with partial backorders (RD54BO) which takes into account a percentage of backorders (%BO). In consultation with the management of the big Benelux DIY company, there was decided that probably 15% of the demand missed would be registered in the achieved demand. This is due to the fact that when an item is out of stock it is sometimes still ordered at a later moment. The assumption of 15% backorders changes the real demand achieved in 54 weeks. Now instead of adding the average amount of demand during days of 0 stock, only 85% of this amount has to be added. Hence 15% of demand was fulfilled when the product becomes stocked again. Because this KPI is closer to reality than the real demand without backorders, this KPI is the demand that is used as input for other KPIs.

$$RD54BO = AD54 + (1 - \%BO)\frac{AD54}{(378 - 0stock)} * 0\text{stock} \qquad \text{(Equation 3.2)}$$

*Target fill rate*

Each product has a target fill rate (TFR) dependent on its demand class. This target fill rate determines the percentage of demand that should be filled on time and directly out of stock. The target fill rate assumes that all demand missed is considered as backorder, it should be noted that in reality that is not the case. Therefore this KPI indicates how much of the demand should be met on time. This KPI used as a service objective for the products. The target fill rate is directly extracted out of the data.

*Fill rate*

The actual fill rate (FR) is difficult to determine out of the available data, since it is impossible to determine which demand was met on time and which demand was met as a backorder. Therefore, when determining the achieved fill rate KPI, backorders are neglected and the average demand of the days of zero demand is added to the real demand. Slimstock uses this KPI to determine the achieved fill rate and thus to compare the service objective with the service performance. However, because of the difference in backorder assumption, these are not completely equal. This KPI is determined using the following formula:

$$FR = 1 - \frac{\frac{AD54}{378 - 0stock} * 0stock}{RD54W} \qquad \text{(Equation 3.3)}$$

*Target percentage demand fulfilled*

In order to determine the target of the percentage of the demand that is actually fulfilled (TPDF) this KPI is constructed. In order to determine this percentage, the percentage of backorders need to be known. As mentioned before it is assumed that this percentage is 15%. The target fill rate indicates the amount that is served on time. This KPI assumes that of the amount not met on-time 15% is still sold and the other 85% is lost sales. Therefore this KPI is determined using the following formula:

$$TPDF = 1 - (1 - TFR) * (1 - \%BO) \qquad \text{(Equation 3.4)}$$

*Percentage demand fulfilled*

In order to determine the percentage of the demand actually met this KPI, the percentage demand fulfilled (PDF) is constructed. This is done by dividing the real demand by the achieved demand. The target fill rate determines how much of the demand should be met on time (assuming total backorders), this KPI determines how much of the demand is met at all. This KPI is determined using the following formula:

$$PDF = \frac{AD54}{RD54BO} \quad \text{(Equation 3.5)}$$

*Difference percentage target demand fulfilled and percentage demand fulfilled*

The difference between the percentage target demand fulfilled and percentage demand (DTPDF) fulfilled says something about the demand that is not sold compared to the target level set by the target fill rate. This KPI is determined using the following formula:

$$DTPDF = TPDF - PDF \quad \text{(Equation 3.6)}$$

*Missed demand 54 weeks*

When knowing the difference between the target of the demand fulfilled and the percentage of demand actual fulfilled the demand missed over 54 weeks (MD54) can be determined. This is done with the following formula

$$MD54 = DTPDF * AD54 \quad \text{(Equation 3.7)}$$

*Euros missed compared to target*

When the amount of missed demand is known the amount of Euros missed compared to the target can be determined. To do this, the unit price (UP) and the profit margin (PM) should be known. Out of the available data we can extract the purchase price for almost all products. For some products there was no purchase price defined in order to get an approximation for the purchase price of these products, the price was taken from the internet and divided by 2.5 as this was the case for products for which the purchase price was defined. The profit margin on the purchase price had to be assumed, this amount is assumed to be 10%, but can be changed in the dashboard. This KPI is determined with the following formula:

$$€M = MD54 * UP * PM \quad \text{(Equation 3.8)}$$

*Contribution revenue % real demand with backorders*

In order to determine how important a product is for the company, the contribution of the product to the revenue (%CRRB) is constructed. The higher the contribution to revenue the more the company should focus on improving service performance. If a product has been long out of stock it is logical that the contribution to the revenue is smaller than if the product has not been out of stock. To balance for this and show the real importance of a product for the company the real demand over 54 weeks with backorders is taken (RD54BO) and multiplied by the unit price. Assuming that the profit margin per product on the purchase price is equal this KPI gives a good indication of the contribution % to the revenue. This results in the following formula:

$$\%CRRB = \frac{RD54BO*UP}{\sum_{products} RD54BO*UP} \quad \text{(Equation 3.9)}$$

*Average stock*

The average stock (AS) over a past timeframe is important to determine the holding cost attained over a past timeframe. The average stock can also be used to spot certain really high or low average stock levels. This KPI is constructed in the following way: Out of the data, the max and min stock per week could be extracted. The average of the max stock (AMXS) and the min stock (AMNS) is then taken over the period of 54 weeks. These average are added and divided by 2. This means that the assumption is made that the demand was divided equally over a week and incoming orders come in always at the same moment in time. This results in the following formula:

$$AS = \frac{AMXS+AMNs}{2} \quad \text{(Equation 3.10)}$$

*Inventory cost 54 weeks*

The inventory cost over 54 weeks (IC54) is a KPI that denotes how much it has cost to have kept a product in inventory for a year. This is KPI is especially useful for products that perform better than the target fill rate / target percentage demand full filled. This because being better than your goal and having high inventory costs could be a good indication of having had too much stock in inventory and the costs this involved. To determine this KPI an assumption has been made. The assumption that has been made is that the holding cost for a product is 25% of the purchase price per year. The percentage is then determined for 54 weeks and multiplied with the unit price (UP). This holding cost is multiplied by the average stock (AS) over 54 weeks to give a good indication of the inventory cost over 54 weeks.

$$IC54 = \frac{25\%}{52} * 54 \ * UP * AS \qquad \text{(Equation 3.11)}$$

*Average inventory value 54 weeks*

The average inventory value over 54 weeks (AIV54) indicates how much the average value was of the inventory in stock. To determine this, the purchase price (UP) was multiplied by the average stock (As).

$$AIV54 \ = UP * AS \qquad \text{(Equation 3.12)}$$

*Average throughput time in weeks*

The average throughput time in weeks (ATTW) is the number of weeks it took on average to sell the inventory. This tells something about how many weeks of stock there was in stock on average. A high throughput time indicates that there has been ordered too much. This KPI is calculated by dividing the average stock (AS) by the average demand per week (ADW).

$$ATTW = \frac{AS}{ADW} \qquad \text{(Equation 3.13)}$$

*Average order quantity or MOQ*

This KPI, the average order quantity or MOQ (A,MOQ), determines how much the DIY company ordered on average. This KPI is introduced because the DIY company does not always order a constant amount. They order up to the orderlevel when the amount needed to get to the orderlevel (AOQ) is larger than the MOQ but when the MOQ is larger the MOQ is ordered. The big Benelux DIY company does not calculate an EOQ, therefore, the order quantity can be 2 factors, the average order quantity (AOQ) or the MOQ. The average order quantity is the average demand during review time in multiples of the incremental order quantity. This amount is ordered, because stock levels should be ordered every review time up to the order level. If the MOQ is bigger than the average order quantity this amount is ordered. The MOQ is extracted out of the data directly and the average order quantity is calculated using the following formula:

$$A, MOQ = \begin{cases} AWD * \ T \ \ (multiples\ IOQ) & If\ AWD * T \ > MOQ \\ MOQ & If\ AWD * T \ \leq MOQ \end{cases} \qquad \text{(Equation 3.14)}$$

Where :

$Awd \ = \ Average\ week\ demand$

$T \ = \ review\ time\ in\ weeks$

$MOQ \ = \ minimal\ order\ quantity$

## 4.2 Overperformers and underperformers

When comparing the target fill rate and the attained fill rate, it comes to light that some products performed better than the goal and some products performed worse than the goal. Performing lower than the goal, underperforming, is not desirable. This because fewer products are sold (on time) than targeted and, therefore, profit margin and also service towards customers is lost.

Performing better than the goal, overperforming, is also not desirable. Overperforming means that it is highly likely that more stock has been kept than was needed for the target. Therefore high stock costs could have been experienced. However overperforming also yield the profit of selling more than targeted.

In order to be able to get the right averages in the dashboard, the dashboard is split into two pieces, one for overperformers and one for underperformers. This is done because when there are a lot of overperformers and a lot of underperformers the averages can show no clear differentiations from the target. However in reality there are a lot of products that do not correspond with their target. Another reason to split the dashboard is that it is easier to compare certain KPIs. For example, for overperformers, it is interesting to sort the difference percentage target demand fulfilled from low to high and for overperformers it is interesting to sort them from high to low. The few products that perform on target are in the overperformers part of the dashboard.

## 4.3 Benchmarks for KPIs  of the Big Benelux DIY company

The Big Benelux DIY company has benchmarks for some KPIs when it comes to their inventory management. These benchmarks are used to set goals for inventory management over time.

The first KPI that is a clear benchmark is the target fill rate which is filled in in the system of Slim4. This benchmark is for the service performance of the inventory system. As mentioned before, the target fill rate assumes total backorders and the attained fill rate assumes total lost sales. This means that the target fill rate is not really comparable with the attained fill rate. This is why the KPIs target percentage demand fulfilled and percentage demand fulfilled are added. These benchmarks assume a certain percentage of backorders and are therefore made comparable. The benchmark of the Big Benelux DIY company for the service performance per product is therefore expressed in the target percentage demand fulfilled KPI. The benchmark per product can be found in the data.

The next KPI with a benchmark is the average throughput time in weeks. This benchmark is important especially in products that perform better than their service objective because it can indicate significant overstocking. This benchmark gives the desired period to sell the average stock on hand. The benchmark for this KPI is four and a half weeks.

The last KPI with a benchmark is the average inventory value. This KPI indicates how much capital is locked in inventory. The benchmark for this KPI is 25 million euros in capital locked in in inventory. However, not the whole inventory uses Slim4, therefore, the real value  cannot be compared with the benchmark. It is known that the Big Benelux DIY company is focussing on decreasing the capital locked in inventory, therefore this benchmark is still mentioned.

## 4.4 Findings dashboard overall situation

When constructing this dashboard, KPIs are constructed to get insight into the total inventory situation. This became interesting, because a way is found to implement backorders in our KPIs, with which we have been able to approximate the real demand. In order to do this, a few assumptions had to be made. These assumptions can be found in Table 4.1. The first two assumptions have been made in consultation with the management of the DIY company and the last assumption is a standard assumption which is made by Slim4.

| | |
|---|---|
| Profit margin over purchase price | 10% |
| Percentage of backorders | 15% |
| Holding cost per year as percentage of the purchase price | 25% |

*Table 4.1: Assumptions Dashboard.*

The total average value of the inventory which is forecasted by Slim4 is € 14.515.390,55. This value is the average amount of euros that was in stock during the year for all products that are forecasted by Slim4. This value cannot be compared to the benchmark, because this value does not represent the whole inventory. For the next subsections, we will split the KPIs into underperformers and overperformers for the reasons mentioned in Section 4.2.

### 4.4.1 Underperformers

In Table 4.2, the KPIs of the underperformers can be seen. These KPIs are constructed with the assumptions mentioned in Table 4.1. As can be seen in Table 4.2, during the past 54 weeks up to April 2021 the amount of €492.470,82 was missed due to the missing of the target fill rate on 1340 products. The average throughput time in weeks is 35,32 weeks which is way higher than the benchmark of 4,5 weeks.

| | |
|---|---|
| Number of underperformers (products) | 1340 |
| Amount of demand missed compared to target (units) | 2.492.753 |
| Average target fill rate | 0,906 |
| Average attained fill rate | 0,783 |
| Average target ratio demand fulfilled | 0,920 |
| Average ratio demand fulfilled | 0,810 |
| Lost sales in euros compared to target | €492.470,82 |
| Average actual ordered quantity (units) | 3672 |
| Average standard deviation during lead time and review time (units) | 870,05 |
| Average lead time (weeks) | 15,47 |
| Average review time (weeks) | 3,57 |
| Inventory cost 54 weeks all products | € 1.402.897,11 |
| Average inventory cost 54 weeks per product | €1.047,28 |
| Average inventory value underperformers | € 5.403.751,84 |
| Average of the average throughput time (weeks) | 35,23 |

*Table 4.2: KPIs dashboard overall situation underperformers.*

Figure 4.1 shows how the difference percentage demand fulfilled (PDF) of the 1340 (Table 4.3) underperformers is distributed per product. It is noticeable that the majority of the underperformers has a difference which is greater then 0,1 which a significantly miss of the target percentage demand fulfilled.

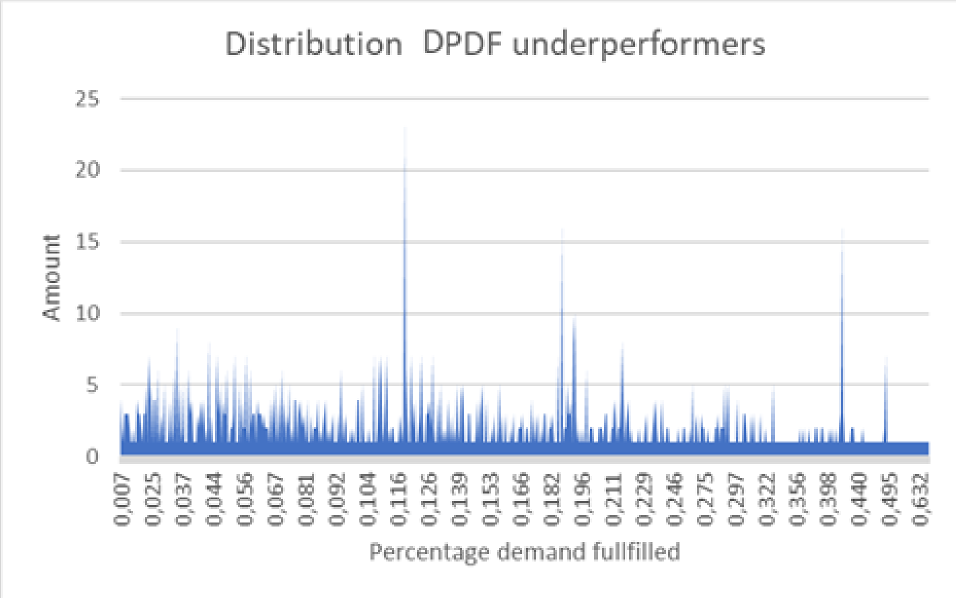


*Figure 4.1: Distribution difference percentage demand fulfilled underperformers.*

### 4.4.2 Overperformers

In Table 4.3 the KPIs of the overperformers can be seen. These KPIs are constructed with the assumptions mentioned in Table 4.1. What is noticeable is that there are more products overperforming than underperforming. The profit that is made extra due to overperforming is €243.807,90, this is lower than the amount lost for the underperformers. Something that also stands out is that the average inventory cost per product over 54 weeks is way higher for the overperformers than for the underperformers (€ 1.630,87 versus €1.047,28 respectively). Moreover, the average throughput time in weeks is also twice as high for the overperformers and way higher than the benchmark (35,23 versus 72,42). For example this could be due to the fact that demand is lower than expacted for overperformers or due to high MOQs. This indicates that way more stock is in place for overperformers than for underperformers. Something that can be concluded is that the inventory cost for overperformers is way higher than for underperformers however overperforming in itself leads to more sales and thus also to more profit.

| | |
|---|---|
| Number of overperformers (products) | 1787 |
| Amount of Demand extra met compared to the target (units) | 457.522 |
| Average target fill rate | 0,87 |
| Average Attained Fill rate | 0,982 |
| Average target ratio demand fulfilled | 0,893 |
| Average ratio demand fulfilled | 0,985 |
| Profit extra sales in euro's compared to target | €243.807,90 |
| Average actual ordered Quantity | 839 |
| Average standard deviation during lead time and review time | 269 |
| Average Lead time (weeks) | 12,21 |
| Average review time (weeks) | 3,89 |
| Inventory cost weeks | € 2.914.360.16 |
| Average inventory cost 54 weeks per product | € 1.630,87 |
| Average inventory value underperformers | € 9.111.638,71 |
| Average of the average throughput time (weeks) | 72,42 |

*Table 4.3: KPIs dashboard overall situation overperformers*

Figure 4.2 shows how the Differrence percentage demand fulfilled (DPDF) of the 1787 (Table 4.3) overperformers is distributed per product. It shows that the differences lay among the same numbers, this is declarable because most of te overperformers attained al there demand so they had a ratio of 1 for the percentage of the demand fulfilled and the different differences can be declared due to the different targets determined by the ABC-qualification.

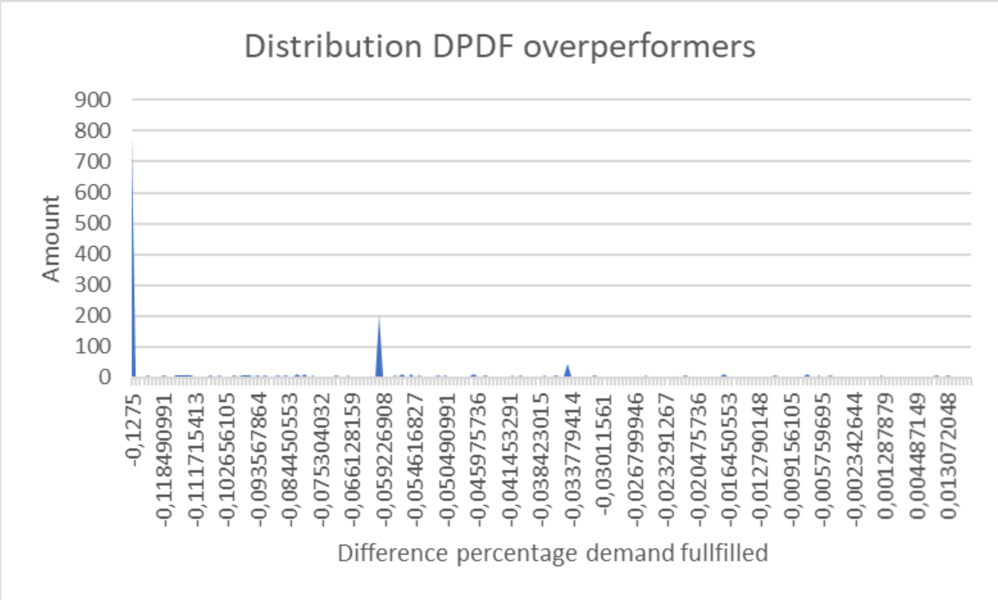


*Figure 4.2: Distribution percentage demand fulfilled overperformers.*

Out of the dashboard, data per supplier and per product group can also be extracted. However, it is decided in consultation with the management of the DIY company to not include this data in this research, because there are insufficient resources to dive deeper into suppliers and common factors of product groups.

In this chapter we have defined KPIs to show the achieved service performance over a past time frame and what this ment for the company for 54 weeks uptil April 2021. A way was found to conclude backorders into the achieved service performance which enabled the percentage of the demand fulfilled to be estimated. A dashboard was constructed which was split in underperformers and overperformers, overall average KPIs were found an mentioned. It can be concluded that the overperformers had a lot higher inventory cost than underperformers. Due to missing the target service performance underperformers missed an estimated amount of €492.470,82 of profits and overperformers gained €243.807,90 due to performing better than their target.

# 5. Analysis of selected products

In this chapter, products that will be further analysed are selected. Section 5.1 will elaborate on what criteria were used to select certain products. Then the inventory situation of these products over the past 54 weeks will be shown. To end this chapter, further analysis on the procurement order lines of the selected will be done and there will be looked at if the parameters of these products correspond to reality (Section 5.2).

## 5.1 Selected products

There will be not enough time to investigate all 4800 products, therefore, products with the criteria mentioned below will be further analysed. For these products, a further dive into the procurement orderliness will be done. A criterion that counts for all of the selected products is that their demand is tested for normality and is normally distributed. The selected products are divided into overperformers and underperformers. The inventory situation over the past 54 weeks of the selected products is determined with the help of the following KPIs: Real demand 54 week with backorders (RD54BO), target percentage demand fulfilled (TPDF), percentage demand fulfilled (PDF), difference percentage demand fulfilled (DTPFD), euros missed compared to target (€M), average throughput time in weeks (ATTW), average order quantity or MOQ (A,Moq), lead time in months (L(M)), review time in months (T(M)), contribution revenue % real demand with backorders (%CRRB), average inventory value 54 weeks (AIV54), and inventory cost 54 weeks (IC54).

### 5.1.1 Underperformers

Three underperforming products are selected. These products are selected based on the following criteria. In this section, the inventory situation of the selected products over the past 54 weeks is described.

*High € Loss*

This product is selected based on the KPI: Euro's missed compared to target (Section 3.3.1).

Product 1: This product is selected because it is the product with the highest amount of euros missed compared to their target (€ 9.728,85).

*A-article with a lot of demand with a big difference between percentage demand fulfilled and target demand fulfilled*

Product 2: This product is selected because it is an A-product with a lot of demand (118.055) Also there is a significant difference between the target percentage (0,966) and the attained percentage (0,736).

*An item with currently 0 buffer stock and highest loss or highest demand*

Product 3: This product is selected because it has 0 buffer stock, but attained a really high demand over the past year (40.856).

Table 5.1 shows the KPIs for the selected underperformers over the past 54 weeks up to April. Something that stands out is the high lead time (L (M)) of the first product. This makes this product less responsive to possible shortages. All of these products quite severely missed their target of percentage demand fulfilled.

| Product | RD54BO | TPDF | PDF | DTPFD | €M | ATTW | A,MOQ | L (M) | T (M) | %CRRB | AIV54 | IC54 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 26.421 | 0,966 | 0,554 | 0,412 | €9.728,85 | 6,99 | 4272 | 5,62 | 1,00 | 0,35 % | €16.315,59 | €4.234,78 |
| **2** | 118.055 | 0,966 | 0,736 | 0,230 | €1.029,86 | 2,11 | 8000 | 3,22 | 0,99 | 0,01 % | €1.245,69 | €323,40 |
| **3** | 40.856 | 0,966 | 0,608 | 0,358 | €292,43 | 10,31 | 6000 | 3,16 | 0,99 | 0,01 % | €914,69 | €237,47 |

*Table 5.1: Inventory situation underperformers 54 weeks.*

### 5.1.2 Overperformers

Three underperforming products are selected. These products are selected based on the following criteria.

*Really high MOQ and high throughput time*

Product 4: This is also a product with a high MOQ (7776) and a throughput time above the benchmark of 4,5 (12,35) the yearly stock cost of this product is also high (€ 23.690,68).

*Product with high buffer stock compared to the total stock*

Product 5: This product is selected because the buffer stock (12.647) is one-third of the total stock (35.977) which is really high.

*A-article with a high throughput time*

Product 6: This product is selected because it is an A article with a high throughput time (29,16 weeks). The throughput time for A products is normally lower than average, therefore, this is still a high throughput time for an A product but not compared to the overall average of the dashboard.

Table 5.2 shows that the KPIs for the overperformers of the dashboard over the past 54 weeks up to April. Something that stands out for the overperformers is the first product in Table 5.2 has a high average inventory and average throughput time compared to the contribution to revenue. Something that also stands out is that for the first and the fourth product the lead time is almost as long as the review time. This means, depending on the MOQ and the order cost, that it could be the case that half of the stock is caused by the review time. This is excessive because the review time can be reduced by management. In Section 6.4, we will discuss implementing a review/lead time ratio which will make sure that the review time is always a certain percentage of the lead time. Something that also stands out that for all of the products the average throughput time in weeks is way higher than for the underperformers and all largely above the benchmark.

| Article code | RD54BO | TPDF | PDF | DTPFD | €M | ATTW | A,MOQ | L (M) | T (M) | %CRRB | AIV54 | IC54 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **4** | 227.160 | 0,966 | 1,000 | -0,034 | -€1.459,73 | 12,36 | 23328 | 0,526 | 1,00 | 0,63% | €94,672,71 | €23.690,68 |
| **5** | 34.452 | 0,966 | 1,000 | -0,034 | -€97,22 | 16,50 | 4622 | 3,78 | 0,99 | 0,04% | €8.424,64 | €2.106,16 |
| **6** | 28.908 | 0,966 | 1,000 | -0,034 | -€78,63 | 29,16 | 5400 | 3,45 | 1,00 | 0,03% | €12.044,06 | €3.011,01 |

*Table 5.2: Inventory situation overperformers 54*

## 5.2 Reality versus Model

In this section, the data of the procurement orderliness is investigated in order to spot discrepancies between the parameters and the actions placed by the company. After this, the demand and stock levels over time are analysed in order to spot indications of forecast errors or other indications of bad corresponding with the model. The availabe categories of data are the amount ordered, the amount that is delivered, the delivery date and stock, and the demand development over time. Since only the delivery date is known, nothing can be deduced about the lead time and the review time For the lead times this is the case because the order date is unkown. Nothing about the review time can be said even not when assuming constant lead times. This is because the (forecasted) demand is not constant and differs each month. In this year there were extra demand fluctuations because of the closure of shops. Because the past demand forecasts are not saved, the past order levels cannot be determined. Therefore it cannot be seen if every review time there was ordered when inventory levels were below the order level. This is made extra difficult by the fact that the DIY company has high MOQs, which means that not every review time there has to be ordered.

Because the date an order is delivered is known, it is necessary to save the date on which the order is placed to be able to compare the actual lead times with the lead times in the model. To be able to also compare the review time with reality, the order levels over time are needed to be known. In order to determine these, the past forecasts need to be saved.

Hence, the only possible comparisions between reality and the model are the MOQ and the IOQ. The EOQ is not calculated by the DIY company, so this amount cannot be compared with the model. However, the EOQ is calculated in Section 6.3 and the result of ordering the EOQ is shown.

The most relevant findings for this research are discussed in Section 5.2.1 for the rest of the analyses can be found in Appendix C.

### 5.2.1 Findings reality versus model

In this section the most important findings of the comparison of the data of the procurement orderliness are discussed. This is done for the products selected based on the criteria mentioned in Section 5.1.1 and 5.1.2. Only for product 1 significant findings could be done, the analyses of the rest of the products can be found in Appendix C.

*Product 1*

Figure 5.1 shows the demand per week and Figure 5.2 shows the stock development of the average stock per week for product 1. Something that is noticeable when looking at Figures 5.1 and 5.2 is that there was a period of no stock while there was demand. This indicates an error in data submission. According to the ERP of the DIY company, this product is out of stock since 11/12/2020 up till now. While according to the data extracted out of Slim4, this product is in inventory again since 28/12/2020 and was out of stock a period before this date, as can be seen in Figure 5.2.

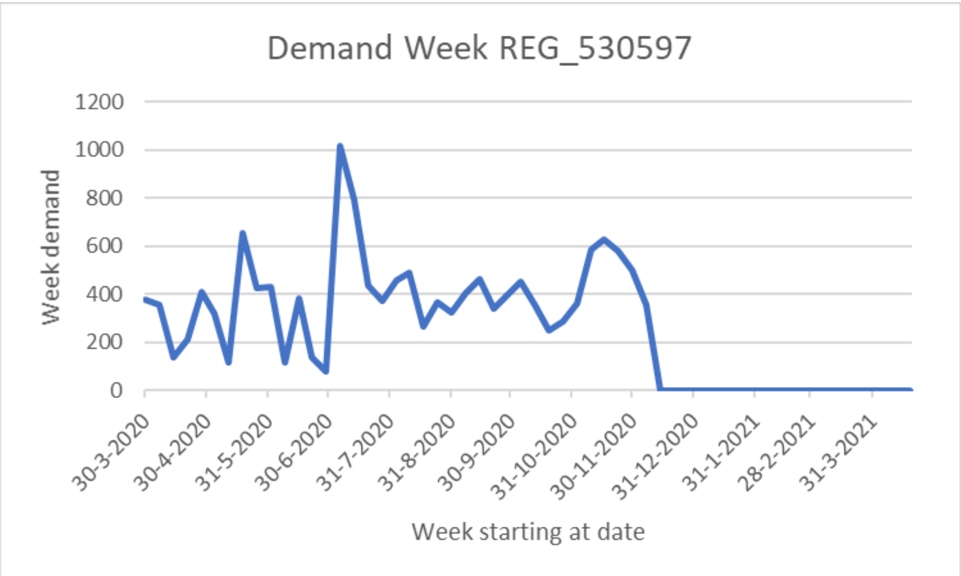

*Figure 5.1: Demand per week for product 1 extracted out of Slim4.*

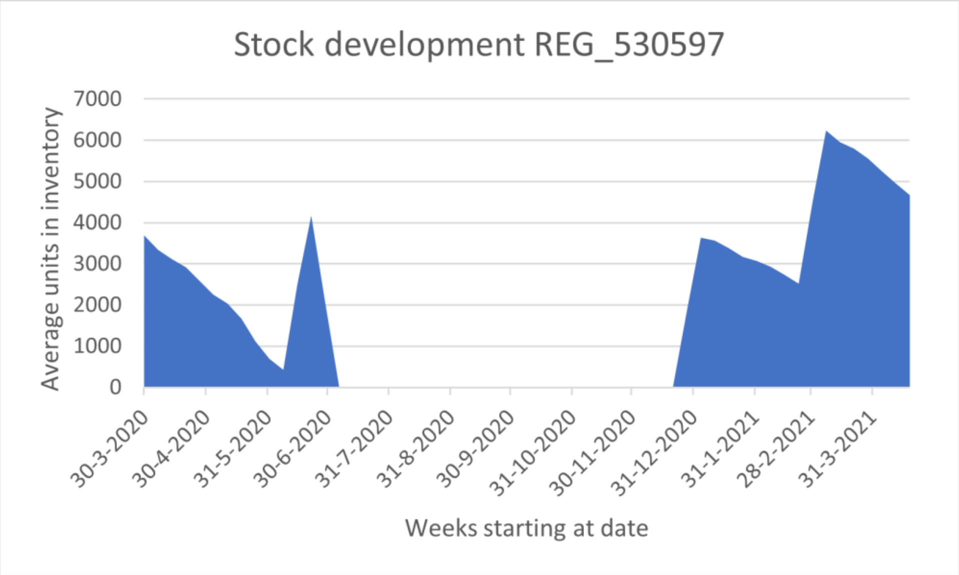


*Figure 5.2: Stock development per week for product 1 extracted out of Slim4.*

Table 5.3 shows the delivery scheme for the product. Something that is noticeable is that in the first few orders the MOQ is ordered. However, later the amounts ordered started differing. Also, the time between delivery is fluctuating a lot. When looking at the stock levels provided by Slim4, the orders of 19/08/2020 or 28/09/2020 are not visible, while in the ERP data of the DIY company they are present. We should therefore note that the data which is saved by Slim4 is not correct. However, it is clear for this product that it performed worse than targeted, because it has been out of stock since 11/12/2020 until 21/4/2021 according to the DIY company's ERP data.

| Delivery date | Amount ordered | Amount delivered | Days between order delivery | Months between delivery |
|---|---|---|---|---|
| **14/02/2020** | 4272 | 4272 | | |
| **15/06/2020** | 4272 | 4272 | 122 | 4,47 |
| **19/08/2020** | 4272 | 4272 | 65 | 2,38 |
| **28/09/2020** | 1980 | 1980 | 40 | 1,47 |
| **04/06/2021** | 4668 | 4668 | 249 | 9,12 |

*Table 5.3: procurement orderliness of product 1.*

When we compare the MOQ and the IOQ with the amount ordered, it is noticeably possible for this company to order less than the MOQ filled in in Slim4. An amount of 1980 is ordered on 28/09/2020. The amount ordered is always a multiple of 6 so the IOQ seems to be correct.

| Parameters | Value parameter according to Slim4 |
|---|---|
| **MOQ** | 4272 |
| **IOQ** | 6 |

*Table 5.4: Parameters as they are currently filled in in Slim4.*

Appendix C shows that for the other products we have seen some indications of higher demand than anticipated for which sometimes could be confirmed by the DIY company. Furthermore, we have tried to find parameter discrepancy by looking at the real procurement orderliness. However, only a closer look at the MOQ and IOQ could be taken due to a lack of data. One deviant MOQ was found for product 1 this product had an MOQ of 4272 but an amount of 1980 was ordered during the last year. In the next chapter there will be looked what this has for result on the safety stock needed to attain the fill rate for this product.

# 6. Result of parameter discrepancy

In the previous chapters, the inventory situation over the last 54 weeks is described and the parameters in the model are compared with reality. This chapter describes how the order levels on April 2021 are calculated (Section 6.1). After this, we will take a look at how the buffer stock needed will differ for the order level if the MOQ of product 1 is filled in closer to reality (Section 6.2). In Section 6.3 it is looked if it is possible to order the EOQ and what the result of ordering the EOQ is on the buffer stock needed to attain the same fill rate. To end in Section 6.4 there is elaborated on what the result of implementing a review/ lead time ratio is .

## 6.1 Current situation

As mentioned before the order level consists of the base forecast plus the buffer stock (Section 3.2). The buffer stock is calculated with the following formula, which can also be found in Figure 2.5 (assuming total backorders and normally distributed demand):

$$ss = z * \sigma_m * \left(\sqrt{T+L}\right) \qquad \text{(Equation 6.1)}$$

Where:

$ss = bufferstock$
$z = safety\ factor = F_S^{-1}(Csl)$
$\sigma_m = Standard\ deviation\ monthly\ demand$
$T = review\ time\ in\ months$
$L = lead\ time\ in\ months$

In this case the bufferstock depends on safety factor z which is unknown. The safety factor (z) often depends on the cycle service level (CSL). However, In the models of Slimstock the target fill rate is used to determine corresponding buffer stock levels. The fill rate in comparison to the cycle service level also takes lot size into account. The safety factor can be determined with the help of the normal loss function of z (G(z)). When G(z) is known the z corresponding to the chosen fill rate can be determined with the help of the table in Appendix A. To come to the G(z) corresponding to the chosen fill rate the following equation is used (assuming total backorders and normally distributed demand):

$$Fr = 1 - \frac{\sigma_m * \left(\sqrt{T+L}\right) * G(z)}{A, Moq} \qquad \text{(Equation 6.2)}$$

Where:

$Fr = fill\ rate$
$\sigma_m = Standard\ deviation\ monthly\ demand$

$T = review\ time\ in\ months$
$L = lead\ time\ in\ months$
$G(z) = F_S(z) - z * [1 - F_S(z)] = normal\ loss\ function\ z$
$A, moq = Average\ demand\ during\ review\ time\ or\ minimal\ order\ quantity$ (Equation 3.14)

The base forecast is determined with the forecasting methods mentioned in Section 3.2.1. Every month the forecast updates and this is then multiplied with the review and lead time. The order level is the sum of the base forecast and the safety stock. This results in the following formula for the order level:

$$S = D_f * (T+L) + SS \qquad \text{(Equation 6.3)}$$

Where:

$S = Order\ level$
$D_f = demand\ forecasted\ per\ month$

$T = review\ time\ in\ months$
$L = Lead\ time\ in\ months$
$SS = bufferstock$

In Tables 6.1 and 6.2 the current parameters as determined by the formulas mentioned above are shown.

| Product | $D_f$ *(T+L) | L(m) | T | $\sigma_m$ | S | SS | A,MOQ | Z | CSL | G(z) | Fr |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 10600 | 5,62 | 1,00 | 369.68 | 11132 | 532 | 4272 | 0,559 | 0,712 | 0,180 | 0,960 (0,96) |
| **2** | 39299 | 3,22 | 0,99 | 1979,52 | 43518 | 4219 | 8000 | 0,962 | 0,832 | 0,077 | 0,960 (0,96) |
| **3** | 10958 | 3,16 | 0,99 | 83,44 | 10958 | 0 | 6000 | 0,000 | 0,5 | 0,399 | 0,989 (0,96) |

*Table 6.1: Table with the parameters filled for the underperformers.*

| Product | $D_f$ * (T+L) | L(m) | T | $\sigma_m$ | S | SS | A,MOQ | Z | CSL | G(z) | Fr |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **4** | 125843 | 0,526 | 1,00 | 4164,84 | 128485 | 2642 | 23328 | 0,513 | 0,696 | 0,194 | 0,960 (0,96) |
| **5** | 23330 | 3,78 | 0,99 | 3614,36 | 35977 | 12647 | 4622 | 1,607 | 0,959 | 0,023 | 0,960 (0,96) |
| **6** | 13342 | 3,45 | 1,00 | 324,81 | 13465 | 123 | 5400 | 0,180 | 0,571 | 0,316 | 0,96 (0,96) |

*Table 6.2: Table with the parameters filled in for the overperformers.*

Between brackets in the last column of these tables, we see the target fill rate with which the desired amount of safety stock is determined. The fill rate for product 3 is higher than the target because the buffer stock is zero. The amount of bufferstock is determined by the target fill rate but because of a high A,MOQ the fill rate is already larger without buffer stock. Therefore the buffer stock is 0.

## 6.2 Result on buffer stock needed with new MOQ for product 1

For product 1, we found a deviating MOQ compared to the MOQ filled in in Slim4. In this section, the result of ordering the new MOQ on the bufferstock for the month of April 2021 is calculated. The buffer stock needed for the month of April 2021 to attain the same fill rate with a lower MOQ (as seen in Section 5.3) is calculated for product 1. The forecasted demand during review time for product 1 is still lower than the MOQ, therefore, this is the amount that should be filled in in Equation 6.2. The parameters are filled in in Equation 6.2 to determine the G(z) value. With the help of the normal loss function table in Appendix A, the corresponding z value to the G(z) value is found. And this is then again used to calculate the new buffer stock needed for the new MOQ. In the second to last column the percentage with which the buffer stock changes is mentioned. And in the last column the extra stock cost this enhances for the month of April are mentioned this is calculated with the assumption that the holding cost is 25% of the unit price per year and the assumption that the bufferstock is on stock for the whole month of April. Also we use the assumptions mentioned in Appendix B. The baseforecast does not change with ordering a new MOQ therefore when filling in the formula mentioned in Appendix B we can calculate the change in stock cost. Having a new MOQ means that with the new MOQ 79% more bufferstock is needed to attain te same fill rate This lead to an extra stock cost of €78,13 that must be made for the month of April 2021 to hold the extra bufferstock. With a lower MOQ more often can be ordered, depending on the demand forecast therefore the decrease in stock cost is independent of the ordering cost. The change in ordercost cannot be determined because forecasts in the future are not known and not every review time there has to be ordered. In order to determine the optimal ratio between ordering and holding cost the EOQ should be calculated for every moment that the next forecast is known. For other months the stock cost as a result of the lower MOQ will be higher as well but the exact amounts cannot yet be determined due to the fact that the forecasted demand for these months is still unknown. There can be less cost due to the amount of stock that the inventory level rises less above the order level due to ordering the new MOQ instead of the old MOQ. This cannot be determined because future forecasts are not known and it is not known when there should be ordered.

| Product | L(m) | T | $\sigma_m$ | Old A,MOQ | New A,MOQ | Fr | SS Old | SS new | % change | Mutation stock cost April 2021 |
|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 5,62 | 1,00 | 369.68 | 4272 | 1980 | 0,96 | 532 | 952 | + 79% | +€78,13 |

*Table 6.3: Result on buffer stock needed with new MOQ for product 1*

## 6.3 Economic order quantity

The DIY company does not calculate EOQs for their products because they assume that their MOQs in reality will be higher. For this research, we calculated the EOQ with the help of Equation 2.5. In order to do this, a few extra assumptions were needed next to the assumptions mentioned in section 2.6.1. These assumptions are extracted out of Slim4. We used the following assumptions:

1. The holding cost is 25% of the unit price per year, calculated per month.
2. The order cost amount €50,- per order.
3. The demand used in the formula is the forecasted demand which is also used to determine the current order level.
4. The cost of inventory rising above the order level due to ordering more (EOQ, MOQ) than the average demand during review time are neglected.

Table 6.4 and 6.5 show the results of the EOQ calculations. If the EOQ is larger than the Average demand during review time and the MOQ and thus can be ordered, the effect on the fill rate by changing the A,MOQ to the EOQ will be shown. It should be noted that the CSL will not change when a different amount is ordered because only the fill rate is dependent on the order size. The last column of Table 6.4 and 6.5 show the results on the stock cost for the month of April 2021 on ordering the EOQ while maintaining the same target fill rate. These calculations are made with the help of assumption 1 and Also we use the assumptions mentioned in Appendix B. The baseforecast does not change with ordering a new MOQ therefore when filling in the formula mentioned in Appendix B we can calculate the change in stock cost. The amount of stock that the inventory level rises above the order level due to ordering EOQ instead of the average demand during lead time will lead to extra inventory cost. If this happens and how much these costs are can not be determined because the future forecasts are not known and it is not known when there should be ordered. However it should be noted that it is always more optimal to order the EOQ due to the fact that EOQ minimizes holding cost plus order cost. Therefore we neglect these cost in this thesis.

| Product | A,MOQ | Fr | EOQ | EOQ > A,MOQ | Buffer stock with A,MOQ | Buffer stock with EOQ | % change of bufferstock | Unit price | Mutation stock cost April 2021 |
|---|---|---|---|---|---|---|---|---|---|
| **1** | 1980 | 0,960 | 928 | No | 952 | - | - | €8,93 | |
| **2** | 8000 | 0,960 | 10861 | Yes | 4219 | 3534 | -16,2% | €0,38 | - €5,42 |
| **3** | 6000 | 0,989 | 7968 | Yes | 0 | 0 | - | €0,2 | |

*Table 6.4 EOQ for underperformers and their result on the bufferstock while attaining the same fill rate.*

| Product | A,MOQ | Fr | EOQ | EOQ > A,MOQ | Buffer stock with A,MOQ | Buffer stock with EOQ | % change of bufferstock | Unit price | Mutation stock cost April 2021 |
|---|---|---|---|---|---|---|---|---|---|
| **4** | 23328 | 0,960 | 7145 | No | 2642 | - | - | €1,89 | |
| **5** | 4622 | 0,960 | 9944 | yes | 12647 | 9867 | -21.9% | €0,83 | -€ 48,07 |
| **6** | 5400 | 0,960 | 4240 | No | 123 | - | - | €0,80 | |

*Table 6.5 EOQ for overperformers and their result on the bufferstock while attaining the same fill rate*

We can see that switching to the EOQ for the products for which the EOQ is larger than the A,MOQ results in a lower safety stock for attaining the same fill rate. This lower safety stock result in reduction of stock cost for both product 2 and 5 for the month of April 2021. The stock cost for product 2 is reduced by €5,42 and for product 5 this is reduced by €48,07 for the month of April 2021. Another beneficial effect is that the sum of the ordering costs and holding costs are now minimized if all assumptions and forecasts are correct. Therefore it is advantageous for the DIY company to calculate their EOQs and implement them where possible (EOQ > A,MOQ).

Something that also should be noted is that the assumption that the MOQs are larger than their EOQ is not correct for a lot of products. In order to further improve EOQ calculations, the holding cost and ordering cost can be determined more extensively.

## 6.4 Implementing a review/ lead time ratio

To make sure that for every product the review time consists out of the same percentage of stock in comparison to the lead time a new ratio is constructed. The review/lead time ratio decides after how many lead times the inventory should be evaluated. For products that have stock for a lead time of 2 weeks and for a review time of 1 month, a lot of the stock which is in place for this product is the result of the long review time. Therefore the review/lead time ratio is especially useful to lower the needed stock levels for products with a low lead time (depending on the ratio). Currently the review time for the most products is set on one month (Section 3.2.4), this is chosen out of convenience.

The benchmark for the review/ lead time ratio is determinable by the management of a supply chain and can be set dependent on the order cost of a company. If a company endures high order costs, it can be useful to order less frequent and therefore check the inventory level less frequent.

For this research, we will show the result on the selected products with a review lead time ratio of 0,25. This means that every one-fourth of the lead time the inventory level of a product should be checked. The new order level for April 2021 with the new review time will be calculated. When the review time changes both the base forecast (expected demand during review time plus lead time) and the buffer stock change as well. For the old situation, the situation mentioned in Section 6.1. will be used.

The new base forecast is calculated by multiplying the demand forecasted per month with the lead time plus new review time. The new buffer stock is calculated by filling in Equations 6.1 and 6.2 (with the help of the standard normal loss function table in Appendix A) with the new review time. Furthermore, the buffer stock and base forecast are added to determine the new order level and the percentage of change of the old order level will be shown. Lastly, the result on the stock cost of the change of the order level for the month of April 2021 will be shown. This will be done while using the following assumptions: The buffer stock is on stock for the whole month of April. On average half of the base forecast is on stock during the month of April. More details on these calculations can be found in Appendix B. We can not determine the order cost because only the forecasted demand for one month is known it is therefore not known if every review time there should be ordered.

| Product | Old Base forecast | Old SS | Old order level | L(m) | Old T | New T | New base forecast | New SS | New order level | % change order level | Unit price | Mutation stock cost April 2021 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 10600 | 532 | 11132 | 5,62 | 1,00 | 1,41 | 11821 | 569 | 12390 | + 11,3% | €8,93 | +€173,20 |
| 2 | 39299 | 4219 | 43518 | 3,22 | 0,99 | 0,81 | 37619 | 4053 | 41672 | -4,24% | €0,38 | -€8,62 |
| 3 | 10958 | 0 | 10958 | 3,16 | 0,99 | 0,79 | 10429 | 0 | 10429 | -4,83% | €0,2 | -€1,10 |

*Table 6.6: Result on order level of implementing a review/ lead time ratio underperformers.*

| Product | Old Base forecast | Old SS | Old order level | L(m) | Old T | New T | New base forecast | New SS | New order level | % change order level | Unit price | Mutation stock cost April 2021 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 | 125843 | 2642 | 128485 | 0,526 | 1,00 | 0,13 | 54221 | 929 | 55150 | -57,1% | €1,89 | -€1477,51 |
| 5 | 23330 | 12647 | 35977 | 3,78 | 0,99 | 0,95 | 23110 | 12531 | 35641 | -0,9% | €0,83 | -€3,91 |
| 6 | 13342 | 123 | 13465 | 3,45 | 1,00 | 0,86 | 12930 | 115 | 13045 | -3,9% | €0,80 | -€3,57 |

*Table 6.7: Result on order level of implementing a review/ lead time ratio overperformers.*

When looking at the percentages the order levels changed there can be noticed that for a lot of products the impact is not big. This is because the review time was already close to one-fourth of the lead time. The same changes in the mutation of the stock cost can be seen, however, here the unit price plays a bigger role. When looking at product 1 a severe reduction in the order level can be seen. This is due to the fact that a lot of inventory was caused by the long review time in comparison to the lead time. When implementing the review/lead time ratio of 0,25 the order level is significantly reduced while the only thing that has to be done to realise this is to check the inventory level more often. Section 5.2.1 presented that this product had an inventory cost over 54 weeks of €23.690,68, this is a high amount compared to other products. By implementing a review/lead time ratio €1477,51 can be saved for the month of April 2021 alone. And that is just for one product, by looking at figure 6.1 we can see that there exist more products with a low review/lead time ratio. By implementing the review/lead time ratio to more products with a high review time compared to the lead time more costs can be saved. Figure 6.1 shows the distribution for the current review/lead time ratio. In this figure can be seen that the majority of products have a higher review/lead time ratio than our chosen value of 0,25. There are even some products wih a review/lead time ratio of 12,5 on these products it can be expected that a lot of stock cost could be saved by lowering the review time. There are of course extra costs of checking the inventory more often and when implementing a standard ratio, for some products, the review time should be raised as well (depending on the chosen ratio). To fully determine this a further cost analysis could be done to determine the financial result of implementing a review/lead time ratio on all products. However it can be concluded that implementing a review/lead time ratio could be a useful tool to lower the stock while still attaining the desired fill rate.

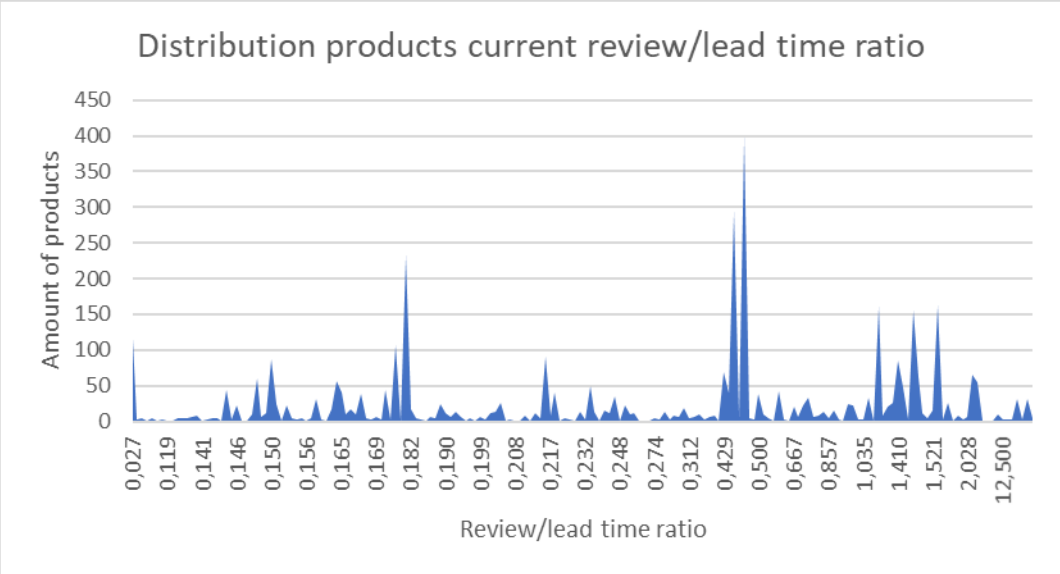


*figure 6.1: Distribution of the current review/lead time ratio for the products at the DIY company.*

# 7. Conclusion and recommendations

In this chapter, the conclusions and recommendations of this research will be presented. Also subjects that are interesting for further research will be mentioned and lastly, assumptions and limitations for this research will be discussed.

## 7.1 Conclusion

During this research the following main research question was in place:

*How can Slimstock and the Big Benelux DIY company ensure that the desired service performance is attained while minimizing inventory by getting insight into the achieved service performance per product and optimizing parameters in the ordering policy model such that they better correspond to the reality for their 4800 products?*

This research question consists out of two parts, getting insight into the achieved service performance per product and optimizing parameters in the order policy such that they better correspond to reality. Therefore the conclusion is split into two parts.

### 7.1.1 Getting insight into achieved service performance

During this research, a dashboard was built to get insight into the achieved service performance. In this dashboard, the KPIs mentioned in Section 4.1 were implemented. When constructing this dashboard the following findings were made.

- Slimstock uses as service level the fill rate (according to the definition in literature), with which Slimstock calculates the safety stocks required to achieve this fill rate.
- The target fill rate assumes total backorders and the KPI that Slimstock uses to get insight into the achieved service level on an aggregated level (not per product) assumes that every demand missed is lost and thus that there are no backorders. Therefore in order to get a real insight into the achieved service performance in comparison with the target service performance a new KPI had to be constructed that takes backorders into account.
- The KPIs target percentage demand fulfilled and percentage demand fulfilled are constructed in order to be able to compare the target fill rate and the attained fill rate.
- When the difference between the target percentage of demand fulfilled and the demand fulfilled is known, the amount of demand missed or gained in comparison to the target can be determined. This leads to the possibility of determining how much money was lost or earned due to not meeting the target percentages demand fulfilled.
- Of the 4800 products in total, 1340 products performed below their target percentage demand fulfilled and 1787 products performed better than their target percentage demand fulfilled. This means that the suspection of the DIY company that they do not meet there target service performance for some of there products is true. The amount of products that does not meet the target service performance is quite high and higher than expected.
- For the underperformers, an amount of €492.470,82 was lost due to not meeting the target percentages demand fulfilled. For the overperformers, an amount of €243.807,90 was saved by overperforming in comparison to the target percentage demand fulfilled.
- The average inventory cost per product over 54 weeks for underperformers was €1.047,28 while for overperformers this was an amount of € 1.630,87. This means that while there was saved €243.807,90 because there were more products sold due to overperforming there were also significant extra inventory cost due to having excess inventory on stock.
- The average throughput time in weeks is twice as high for the overperformers than for the underperformers and way higher than the benchmark of 4,5 weeks (35,23 versus 72,42). This also indicates that for the overperformers excess stock was in place.

### 7.1.2 Optimizing parameters in the order policy model

In this research, products that had outstanding KPIs that stood out in the dashboard were selected. Then a further analysis on these products was done in order to optimize the parameters filled in in Slim4. The following findings were made:

- In order to compare the attained lead times with the lead times filled in in Slim4, the DIY company should save the date on which an order is placed.
- In order to compare the review time with the review time filled in in Slim4, the order levels over the past should be saved. The order levels can be compared with the stock levels and then there can be seen if an order is placed every review time the order levels drop below the stock level.
- For multiple products, there were indications of more demand than indicated and therefore an incorrect forecast. This was probably caused by unpredictable demand patterns due to COVID-19.
- For product 1, the data extracted out of Slim4 of the stock levels was incorrect and did not correspond with the data extracted out the ERP system of the DIY company.
- For product 1, a MOQ that did not correspond with reality was found. In order to attain the same fill rate for this product with the new MOQ, 79% more safety stock needs to be in place calculated for April 2021. This leads to an extra stock cost of €78,13 for the month of April 2021.
- For all of the selected products, an EOQ was calculated. Out of the six selected products, 2 products had a higher EOQ than MOQ and therefore for these products the EOQ could be ordered.
- When ordering the EOQ, significant savings can be made on the buffer stock which needs to be in place to reach the same target fill rate. For product 2 ordering the EOQ led to a decrease of €5,42 and for product 4 of €48,07 in stock cost for the month of April 2021.
- When implementing a review/lead time ratio the percentage of stock which exists out of lead time will be linked with a constant ratio to the percentage of stock which exists out of review time.
- When calculating the order levels for the six selected products with the new review time corresponding to the review/lead time ratio (0,25) we can see that the order level is lowered a lot for the product with the lowest lead time. This resulted in lower inventory costs for most products for the month of April 2021.

When looking at the main research question it can be concluded that during this research certain ways to decrease inventory level while attaining the same target fill rate were found or it is shown that in reality more inventory was needed to attain the same target fill rate without changing the desired service performance. It was difficult to compare the reality with the parameters filled in Slim4 due to a lack of data. However therefore the impact of implementing the EOQ and implementing a review/lead time ratio on the safety stock needed to attain the same target fill rateis shown and are the corresponding changes in stock cost for April 2021 calculated.

## 7.2 Recommendations

Based on the insights developed during this research, several recommendations can be made to the DIY company and Slimstock. The recommendations are mentioned per company.

### 7.2.1 DIY company

During this research, we found the following recommendations for the DIY company.

- The first recommendation is that it is useful to calculate the EOQ for all the 4800 products forecasted with the help of Slim4. It is useful to implement this EOQ where the EOQ is bigger than the demand during review time and MOQ.
- It should be checked that if an MOQ is filled in, this is also the amount ordered when demand during review time is smaller than the MOQ. The MOQ has a big impact on the fill rate when larger than the demand during review time. When less than the MOQ is ordered, a lower fill rate will be achieved with the amount of safety stock that is calculated for the higher MOQ.
- Start saving the date on which an order is placed in the ERP system of the DIY company. This enables the DIY company to compare lead times filled in in Slim4 with reality. This will also enable the DIY company to implement the lead time variability module which is optional in Slim4.
- Implement a review/lead time ratio in order to lower review time for products with a low lead time.

### 7.2.2 Slimstock

During this research, we found the following recommendation for Slimstock.

- Start saving past forecasts in order to be able to determine what is the cause of not reaching the target service performance. This will help indicate if missing target service performance is due to missing of the forecast or due to the customer not handling the system well (wrong parameters for example).
- Start saving the forecast error in order to dynamically adjust the smoothing factor of the forecasting. This enhances that when the forecast errors are high the last months get a higher weight compared to months longer ago in order to determine the next forecast. Saving the past forecasts will also enable comparing the past demand during review time and lead time to see if the right amount is ordered.
- Look into implementing KPIs in the Power BI tool (dashboard over the past period in development by Slimstock) which take backorders into account because currently the target fill rate cannot be compared with the achieved fill rate. This can be done for example by implementing Target percentage demand fulfilled and percentage demand fulfilled mentioned in section 4.1. This will also enable Slimstock to express missing the target fill rate in euros. This shows the impact of missing the target fill rate, this leads to being able to decide on which products to focus when trying to fix missing the target fill rate.
- When past forecasts are saved, the real demand achieved over a past period can be approximated more realistically, because trend and seasonality can be taken into account. This is because you can adjust the past average demand with the saved trend and seasonality facotrs.

## 7.3 Assumptions and limitations

In this section, the most important assumptions and limitations that came along during this research are discussed.

- The exact formulas used by Slimstock could not be used during this research due to confidentiality. Therefore formulas out of the literature were used with which we came approximately to the same results. This also resulted in the inability to say something about the exact formulas used in the forecast because these formulas were adjusted to practice by Slimstock in the years they used them.
- For about 300 products in the data of the DIY company, there was no unit price defined. In order to come to better estimations, the price was taken of internet and divided by 2,5 because this resulted in the unit price for a lot of comparable items for which the unit price was filled in. It should be noted that for EOQ calculations (Section 6.3.1) it is also important that the unit price is filled in.
- For the EOQ calculations (Section 6.3.1), assumptions were based on the values in Slim4. In order to get to EOQs which better correspond with reality, it is useful to approximate these numbers more precisely.
- Because the forecast, review time and lead time all interact with each other, it is important to save data for all of these parameters to be able to precisely compare the model with reality.
- Because the season and trend factors are not saved in the data, the real (past) demand cannot be adjusted for season and trend. Therefore the real demand is calculated with the average demand on days that there is no stock.
- The supply chain of the DIY company was influenced by COVID-19. This meant that demand was way more unpredictable than expacted and there were lots of supply issues. This can be an explanation for lower achieved service performance than normal. The exact impact of COVID-19 was not determined in this research.
- The holding cost is assumed to be 25% of the purchase price per year. In order to come to better EOQ and cost calculations.
- The warehouse situation of the DIY company is not taken into account, because it was not possible to visit the warehouse and it was not possible to speak with people which operated the warehouse. Therefore it is not tested if inventory changes fit in the warehouse.
- Political influences, pandemic influences and higher chances of supply chain disrupting events are not taken into account for this research.
- The effect of ordering more to fill of containers is not taken into account for the EOQ and order level calculations.

## 7.4 Contribution to practice

The main goal of this research was to make sure that the desired service performance can be attained while minimizing inventory. In this research, the current ordering and the model of slim4 have been analysed. Then the inventory situation over the past 54 weeks was determined. Products were selected based on certain outstanding KPIs which were found in the inventory situation over the past 54 weeks. Then it was tried to find deviant parameters and corrections for parameters were done. Certain recommendations were done on changing parameters in the model.

## 7.5 Further Research

During this research certain subjects which could be interesting for further research were found. In this chapter, these subjects are mentioned.

### 7.5.1 Implementing seasonality and trend in past real demand

The real demand must be known in order to determine the achieved fill rate. In this research, the real demand is determined by adding the average demand on the days that there was stock for the days that there was zero stock with taking backorders into account. This way of determining the real demand does not take seasonality and trend into account. Further research can be done into implementing seasonality and trend into the past real demand.

### 7.5.2 Implementing a target fill rate that takes backorders into account

Further research could be done to look if it is possible to implement a target fill rate that considers backorders. The target fill rate is currently the percentage of demand that is filled directly out of inventory on time however when it is measured in the amount of demand that is missed the target fill rate can be made quantifiable. Another benefit of this is that the target fill rate can be better compared with the actual performance of inventory.

### 7.5.3 Saving lead times and implementing lead time variability and forecasting

When the achieved lead times are saved, further research can be done into implementing lead time variability and lead time forecasting. Adding lead time variability is a module in Slim4 that can be chosen. The result of implementing this lead time variability module on the service performance can be elaborated on in further research for the DIY company. When lead times, in reality, seems to be really unpredictable there could be even looked into lead time forecasting. This will enable the company to be able to make better estimations of the real lead time.

### 7.5.4 Looking at the impact of over-ordering due to filling of containers

Another subject for further research is looking at the impact of over-ordering due to filling of containers. The current order policy is based on the target fill rate which takes the quantity that is expected to be ordered into account. However, when due to filling of a container another amount is ordered, this has impact on the MOQ, With larger orders there will be more time between orders fixed review times throughtout products of the same supplier could be beneficial to easier combine orders. The effects of filling of containers could be evaluated more thoroughly.

### 7.5.5 Precise analysis of ordering and holding cost

The second last subject that could be interesting for further research is a precise analysis of ordering and holding costs. Holding and ordering costs are important inputs to determine the economic order quantity. In this research, assumptions were taken out of Slim4. With the help of further research, the ordering and holding cost could be determined more precisely such that the EOQ better corresponds with reality.

### 7.5.6 Implementing dynamic smoothing factor

When Slimstock starts saving the past forecasts there can be looked into implementing a dynamic smoothing factor. When using simple exponential smoothing to forecast demand (Section 2.10.1), a smoothing factor is used. This smoothing factor is currently set at a standard factor of 0,3. This means that the relative weight of the last month demand is 0,3 and that the old forecasted demand has a weight of 0,7 (Equation 2.6). When the past forecasts are saved the forecast error can be determined, this means that the past forecasts should be compared with the realised demand. For example when the forecast error is high maybe the last demand should weigh higher than previous months thus the smoothing factor should be higher. When the forecast error is low the last demand should maybe have a lower impact on the forecast thus the smoothing factor should be lower. Further research could be done on implementing a dynamic smoothing factor that changes with the forecast error. It should be evaluated if this increases the forecast accuracy.

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# Appendix.

## A. Standard normal loss function table.

**Standard Normal Loss Function Table, $L(z)$ (Concluded)**

| $z$ | 0.00 | 0.01 | 0.02 | 0.03 | 0.04 | 0.05 | 0.06 | 0.07 | 0.08 | 0.09 |
|---|---|---|---|---|---|---|---|---|---|---|
| **0.0** | 0.3989 | 0.3940 | 0.3890 | 0.3841 | 0.3793 | 0.3744 | 0.3697 | 0.3649 | 0.3602 | 0.3556 |
| **0.1** | 0.3509 | 0.3464 | 0.3418 | 0.3373 | 0.3328 | 0.3284 | 0.3240 | 0.3197 | 0.3154 | 0.3111 |
| **0.2** | 0.3069 | 0.3027 | 0.2986 | 0.2944 | 0.2904 | 0.2863 | 0.2824 | 0.2784 | 0.2745 | 0.2706 |
| **0.3** | 0.2668 | 0.2630 | 0.2592 | 0.2555 | 0.2518 | 0.2481 | 0.2445 | 0.2409 | 0.2374 | 0.2339 |
| **0.4** | 0.2304 | 0.2270 | 0.2236 | 0.2203 | 0.2169 | 0.2137 | 0.2104 | 0.2072 | 0.2040 | 0.2009 |
| **0.5** | 0.1978 | 0.1947 | 0.1917 | 0.1887 | 0.1857 | 0.1828 | 0.1799 | 0.1771 | 0.1742 | 0.1714 |
| **0.6** | 0.1687 | 0.1659 | 0.1633 | 0.1606 | 0.1580 | 0.1554 | 0.1528 | 0.1503 | 0.1478 | 0.1453 |
| **0.7** | 0.1429 | 0.1405 | 0.1381 | 0.1358 | 0.1334 | 0.1312 | 0.1289 | 0.1267 | 0.1245 | 0.1223 |
| **0.8** | 0.1202 | 0.1181 | 0.1160 | 0.1140 | 0.1120 | 0.1100 | 0.1080 | 0.1061 | 0.1042 | 0.1023 |
| **0.9** | 0.1004 | 0.0986 | 0.0968 | 0.0950 | 0.0933 | 0.0916 | 0.0899 | 0.0882 | 0.0865 | 0.0849 |
| **1.0** | 0.0833 | 0.0817 | 0.0802 | 0.0787 | 0.0772 | 0.0757 | 0.0742 | 0.0728 | 0.0714 | 0.0700 |
| **1.1** | 0.0686 | 0.0673 | 0.0659 | 0.0646 | 0.0634 | 0.0621 | 0.0609 | 0.0596 | 0.0584 | 0.0573 |
| **1.2** | 0.0561 | 0.0550 | 0.0538 | 0.0527 | 0.0517 | 0.0506 | 0.0495 | 0.0485 | 0.0475 | 0.0465 |
| **1.3** | 0.0455 | 0.0446 | 0.0436 | 0.0427 | 0.0418 | 0.0409 | 0.0400 | 0.0392 | 0.0383 | 0.0375 |
| **1.4** | 0.0367 | 0.0359 | 0.0351 | 0.0343 | 0.0336 | 0.0328 | 0.0321 | 0.0314 | 0.0307 | 0.0300 |
| **1.5** | 0.0293 | 0.0286 | 0.0280 | 0.0274 | 0.0267 | 0.0261 | 0.0255 | 0.0249 | 0.0244 | 0.0238 |
| **1.6** | 0.0232 | 0.0227 | 0.0222 | 0.0216 | 0.0211 | 0.0206 | 0.0201 | 0.0197 | 0.0192 | 0.0187 |
| **1.7** | 0.0183 | 0.0178 | 0.0174 | 0.0170 | 0.0166 | 0.0162 | 0.0158 | 0.0154 | 0.0150 | 0.0146 |
| **1.8** | 0.0143 | 0.0139 | 0.0136 | 0.0132 | 0.0129 | 0.0126 | 0.0123 | 0.0119 | 0.0116 | 0.0113 |
| **1.9** | 0.0111 | 0.0108 | 0.0105 | 0.0102 | 0.0100 | 0.0097 | 0.0094 | 0.0092 | 0.0090 | 0.0087 |
| **2.0** | 0.0085 | 0.0083 | 0.0080 | 0.0078 | 0.0076 | 0.0074 | 0.0072 | 0.0070 | 0.0068 | 0.0066 |
| **2.1** | 0.0065 | 0.0063 | 0.0061 | 0.0060 | 0.0058 | 0.0056 | 0.0055 | 0.0053 | 0.0052 | 0.0050 |
| **2.2** | 0.0049 | 0.0047 | 0.0046 | 0.0045 | 0.0044 | 0.0042 | 0.0041 | 0.0040 | 0.0039 | 0.0038 |
| **2.3** | 0.0037 | 0.0036 | 0.0035 | 0.0034 | 0.0033 | 0.0032 | 0.0031 | 0.0030 | 0.0029 | 0.0028 |
| **2.4** | 0.0027 | 0.0026 | 0.0026 | 0.0025 | 0.0024 | 0.0023 | 0.0023 | 0.0022 | 0.0021 | 0.0021 |
| **2.5** | 0.0020 | 0.0019 | 0.0019 | 0.0018 | 0.0018 | 0.0017 | 0.0017 | 0.0016 | 0.0016 | 0.0015 |
| **2.6** | 0.0015 | 0.0014 | 0.0014 | 0.0013 | 0.0013 | 0.0012 | 0.0012 | 0.0012 | 0.0011 | 0.0011 |
| **2.7** | 0.0011 | 0.0010 | 0.0010 | 0.0010 | 0.0009 | 0.0009 | 0.0009 | 0.0008 | 0.0008 | 0.0008 |
| **2.8** | 0.0008 | 0.0007 | 0.0007 | 0.0007 | 0.0007 | 0.0006 | 0.0006 | 0.0006 | 0.0006 | 0.0006 |
| **2.9** | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0004 | 0.0004 | 0.0004 | 0.0004 |
| **3.0** | 0.0004 | 0.0004 | 0.0004 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 |
| **3.1** | 0.0003 | 0.0003 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 |
| **3.2** | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| **3.3** | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| **3.4** | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| **3.5** | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| **3.6** | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| **3.7** | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| **3.8** | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| **3.9** | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| **4.0** | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |

## B. Calculations mutation stock cost April 2021

The calcultations of the mutation of stock cost for the month of April 2021 make use of the following two assumptions:

1. The buffer stock is on stock for the whole month of April.
2. On average half of the baseforcast is on stock during the month of April.

These assumptions lead to the following formula for the calculation of the mutation of the stock cost in April 2021:

$$Mutation\ stock\ cost\ = 0{,}25 * UP * \frac{1}{12} * CSS + \frac{CBF}{2} * 0{,}25 * UP * \frac{1}{12} \qquad \text{(Equation B.1)}$$

Where:

$UP\ = unit\ price$

$CSS\ = Change\ bufferstock$

$CBF\ = Change\ base\ forecast$

In Tables B.1 and B.2 the result of filling in Equation B.1 can be found for the different products for the new review/lead time ratio out of section 6.4.

| Product | CBF | CSS | Unit price | Mutation stock cost April 2021 |
|---|---|---|---|---|
| **1** | 1790 | 37 | €8,93 | +€173,20 |
| **2** | -1846 | -166 | €0,38 | -€8,62 |
| **3** | -529 | 0 | €0,2 | -€1,10 |

*Table B.1: Calculation mutation stock cost April 2021.*

| Product | CBF | CSS | Unit price | Mutation stock cost April 2021 |
|---|---|---|---|---|
| **4** | -71622 | -1713 | €1,89 | -€1477,51 |
| **5** | -220 | -116 | €0,83 | -€3,91 |
| **6** | -412 | -8 | €0,80 | -€3,57 |

*Table B.2: Calculation mutation stock cost April 2021.*

# C. Analyses of Selected products

### *Product 2*

Figure 5.3 shows the demand per week for this product, and Figure 5.4 shows the stock development of the average stock per week for this product. When looking at the stock levels of this product in Figure 5.4 and orders in Table 5.5, the orders did come in, but that the stock levels really quickly went to zero again. Figure 5.3 shows that when there was stock there are real high spikes in demand, this indicates a higher demand than anticipated, which was also confirmed by the DIY company. This means that the forecasted demand probably did not correspond with reality. However, the past forecasts are not saved so this cannot be checked.


*Figure C.1: Demand per week for product 2 extracted out of Slim4.*


*Figure C.2: Stock evelopment per week for product 2 extracted out of Slim4.*

| Delivery date | Amount ordered | Amount delivered | Days between order delivery | Months between order delivery |
|---|---|---|---|---|
| **16/04/2020** | 9600 | 9600 | 51 | 1,87 |
| **04/05/2020** | 6400 | 6400 | 43 | 1,58 |
| **03/06/2020** | 14400 | 14400 | 18 | 0,66 |
| **22/07/2020** | 8000 | 8000 | 30 | 1,10 |
| **22/07/2020** | 1600 | 1600 | 49 | 1,79 |
| **27/08/2020** | 4800 | 4800 | 36 | 1,32 |
| **03/11/2020** | 19200 | 19200 | 68 | 2,49 |
| **13/11/2020** | 8000 | 8000 | 10 | 0,37 |
| **18/12/2020** | 3200 | 6400 | 35 | 1,28 |
| **03/02/2021** | 4800 | 4800 | 47 | 1,72 |
| **25/02/2021** | 8000 | 8000 | 22 | 0,81 |

*Table C.1: Procurement orderliness for product 2.*

When looking at the MOQ of this product and when comparing it with the procurement orderliness in Table 5.6 we can see that the MOQ is the minimum amount that is ordered and that the ordered amount is always in multiples of the IOQ therefore there are no indications that these parameters are put wrongly in the model.

| Parameters | Value parameter according to Slim4 |
|---|---|
| **MOQ** | 1600 |
| **IOQ** | 1600 |

*Table C.2: Parameters as they are currently filled in in Slim4 for product 2.*

### *Product 3*

Figure 5.5 shows the demand per week for this product. Figure 5.6 shows the stock development of the average stock per week for this product. Figure 5.5 and Figure 5.6 show that every time stock came in after a period of stock-outs there was a peak in demand. This indicates higher demand than anticipated which was also confirmed by the DIY company. When looking at the procurement orderliness in Table 5.7, it is noticeable that the DIY company went out of stock on 4/8/2020 and a new order was not delivered until 2/12/2020. This means that there were 4 months between the company went out of stock and until a new amount came in. Which is the lead time and review time combined. This is noticeable because you would assume that inventory would be below the order level in an earlier review period.

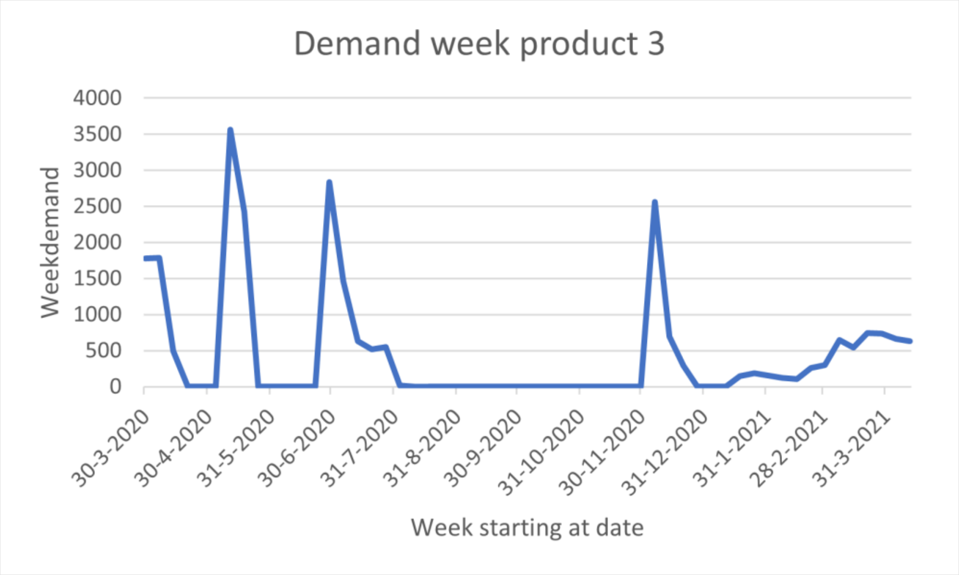


*Figure C.3: Demand per week for product 3  extracted out of Slim4.*

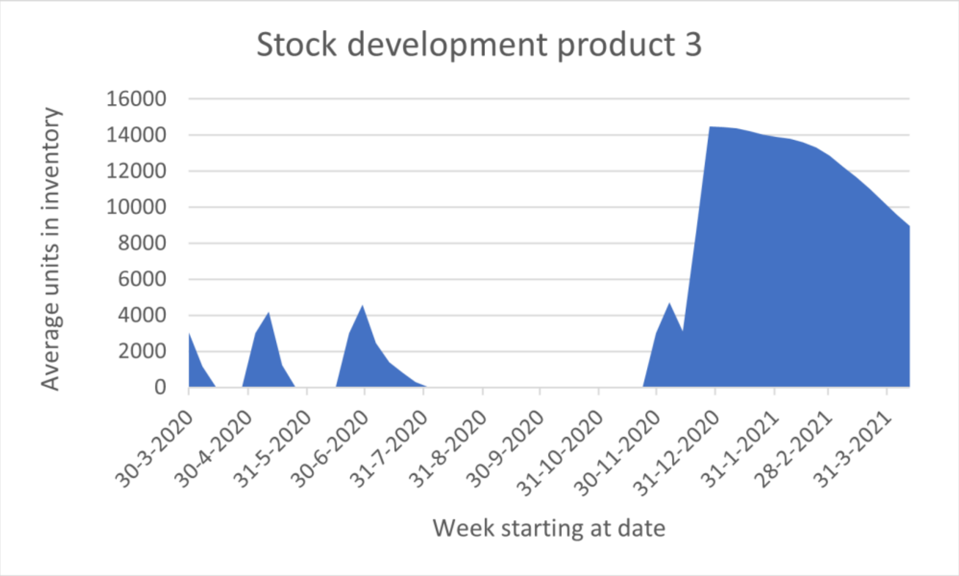


*Figure C.4: Stock development per week for product 3 extracted out of Slim4*

When looking at the MOQ of this product and compare it with the procurement order lines in Table 5.7 we can see that the MOQ is the minimum amount that is ordered and that the ordered amount is always in multiples of the IOQ therefore there are no indications that these parameters are put wrongly in the model.

| Delivery date | Amount ordered | Amount delivered | Days between order delivery | Months between delivery |
|---|---|---|---|---|
| **04/05/2020** | 6000 | 6000 | | |
| **22/06/2020** | 6000 | 6000 | 49 | 1,79 |
| **02/12/2020** | 6000 | 6000 | 163 | 5,97 |
| **18/12/2020** | 12000 | 12000 | 16 | 0,59 |

*Table C.3: Procurement orderliness for product 3.*

| Parameters | Value parameter according to Slim4 |
|---|---|
| **MOQ** | 6000 |
| **IOQ** | 6000 |

*Table C.4: Parameters as they are currently filled in in Slim4 for product 3.*

### *Product 4*

Figure 5.7 shows the demand per week for this product. Figure 5.8 shows the stock development of the average stock per week for this product. We can see in Figure 5.7 that demand for this product peaked in the spring. And in Figure 5.8 we can see that the inventory slightly declined after which it is quickly build up again. When looking at Table 5.9 we can see that there are a lot of orders which arrive within one day. It should be noted that this does not correspond with the review time. When checking this with the DIY company it was found out that this is due to the fact that orders are delivered in different parts and are therefore saved in the data as independent orders.


*Figure C.5: Demand per week for product 4  extracted out of Slim4.*


*Figure C.6: Stock development per week for product 4 extracted out of Slim4*

When comparing the MOQ and IOQ of this product with the procurement orderliness in Table 5.7 we observe multiple discrepancies. However, it is noticeable that between some orders there was only one day between delivery. When checking this with the DIY company they stated that this is due to the fact that orders are delivered in parts. The data lines are made per delivery of an order therefore the amount ordered is in parts as well. This leads to not knowing the actual amount ordered and this can therefore not be compared with the MOQ and IOQ.

| Delivery date | Amount ordered | Amount delivered | Days between order delivery | Months between delivery |
|---|---|---|---|---|
| **16/04/2020** | 15552 | 15552 | 1 | 0,03663 |
| **16/04/2020** | 15552 | 15552 | 0 | 0 |
| **12/05/2020** | 6264 | 6264 | 26 | 0,952381 |
| **13/05/2020** | 11664 | 11664 | 1 | 0,03663 |
| **20/05/2020** | 11232 | 11232 | 7 | 0,25641 |
| **27/05/2020** | 11664 | 11664 | 7 | 0,25641 |
| **28/05/2020** | 11664 | 11664 | 1 | 0,03663 |
| **14/09/2020** | 11664 | 11664 | 109 | 3,992674 |
| **14/09/2020** | 11664 | 11664 | 0 | 0 |
| **07/12/2020** | 8640 | 8640 | 84 | 3,076923 |
| **08/12/2020** | 10368 | 10368 | 1 | 0,03663 |
| **09/12/2020** | 10368 | 10368 | 1 | 0,03663 |
| **10/12/2020** | 11232 | 11232 | 1 | 0,03663 |
| **11/12/2020** | 13824 | 13824 | 1 | 0,03663 |
| **25/01/2021** | 4320 | 4320 | 45 | 1,648352 |
| **26/01/2021** | 10368 | 10368 | 1 | 0,03663 |
| **27/01/2021** | 10800 | 10800 | 1 | 0,03663 |
| **28/01/2021** | 13392 | 13392 | 1 | 0,03663 |
| **29/01/2021** | 15552 | 15552 | 1 | 0,03663 |
| **25/02/2021** | 7776 | 7776 | 27 | 0,989011 |

*Table C.5: Procurement orderliness for product 4.*

| Parameters | Value parameter according to Slim4 |
|---|---|
| **MOQ** | 7776 |
| **IOQ** | 7776 |

*Table C.6: Parameters as they are currently filled in in Slim4 for product 4.*

### *Product 5*

Figure 5.9 shows the demand per week for this product. Figure 5.10 shows the stock development of the average stock per week for this product. This product seems to have been out of stock when looking at Figures 5.9 and 5.10. However, this was not the case the stock levels were at a really low level for a certain amount of time and there was no demand during this time. This is probably due to the fact that the shops were closed during that period due to COVID-19


*Figure C.7: Demand per week for product 5 extracted out of Slim4.*

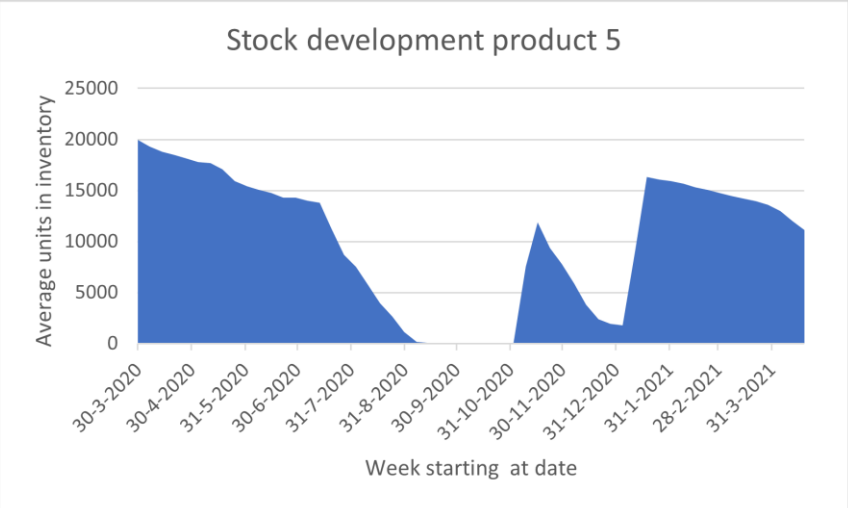


*Figure C.8: Stock development per week for product 4 extracted out of Slim4*

Only three orders can be found in Table 5.11. When comparing the MOQ with the IOQ we can see that a lot more is ordered than the MOQ, this can be due to the high peaks in demand as can also be seen in Figure 5.9. Therefore there is no indication that these parameters are put wrongly in the model.

| Delivery date | Amount ordered | Amount delivered | Days between order delivery | Months between delivery |
|---|---|---|---|---|
| **10/11/2020** | 15000 | 15000 | | |
| **15/01/2021** | 15000 | 15000 | 66 | 2,42 |
| **27/04/2021** | 30000 | 30000 | 102 | 3,74 |

*Table C.7: Procurement orderliness for product  5.*

| Parameters | Value parameter according to Slim4 |
|---|---|
| **MOQ** | 3000 |
| **IOQ** | 12 |

*Table C.8: Parameters as they are currently filled in in Slim4 for product  5.*

### *Product 6*

Figure 5.11 shows the demand per week for this product.  Figure 5.12 shows the stock development of the average stock per week for this product. We can see that there was really high peak demand in the spring for this product. The stock levels were really high when the data starts as can be seen in Figure 5.12. During the year demand really slows down.

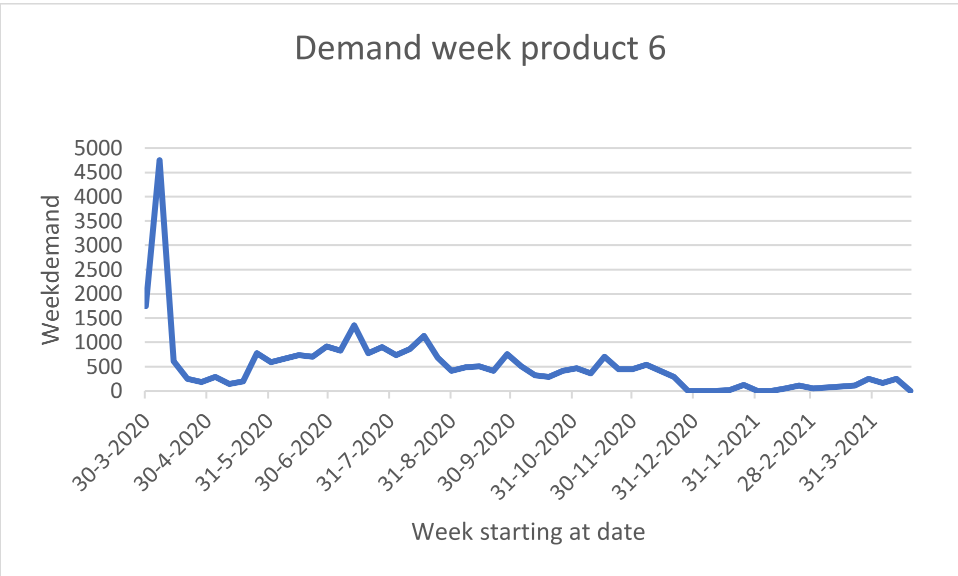


*Figure C.9: Demand per week for product 6  extracted out of Slim4.*

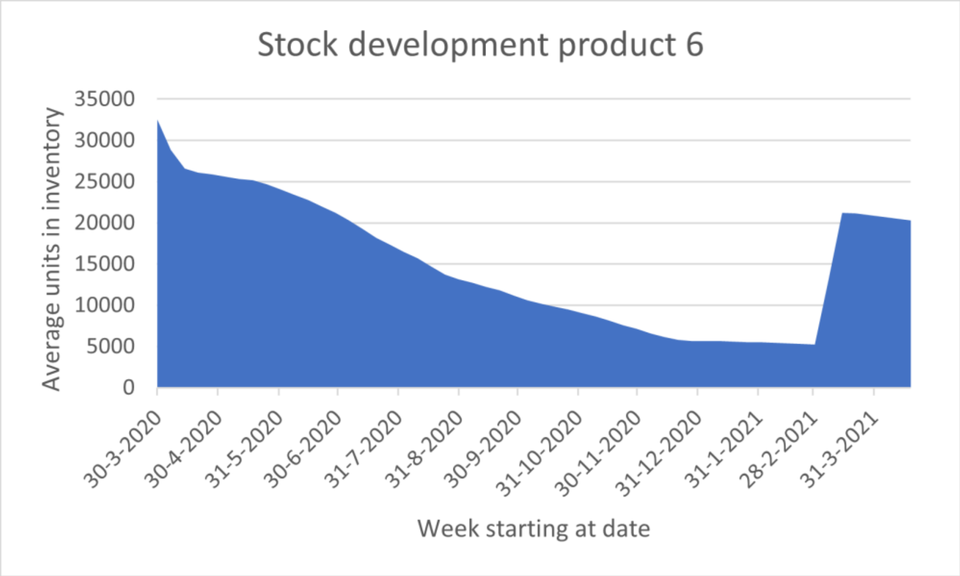


*Figure C.10: Demand per week for product 6 extracted out of Slim4.*

As can be seen in Table 5.13 only one order comes in during the whole year. When we compare the orderliness with the MOQ and the IOQ we can see that only one order is placed. This can be due to the fact there is only one high peak demand in the spring for this product. The amount ordered is more than the MOQ and is a multiple of the IOQ.

| Delivery date | Amount ordered | Amount delivered | Days between order delivery | Months between delivery |
|---|---|---|---|---|
| **05/03/2021** | 16092 | 16092 | - | - |

*Table C.9: Procurement orderliness for product 6.*

| Parameters | Value parameter according to Slim4 |
|---|---|
| **MOQ** | 5400 |
| **IOQ** | 108 |

*Table C.10: Parameters as they are currently filled in in Slim4 for product REG_630647.*