Reaching optimal levels of inventory by using the ABC inventory classification method and setting service levels

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Abstract
Lienesch, a company that sells window decoration fabrics to other businesses, sees demand growing faster than their inventory capacity can manage. Due to that, the allocation of warehouse space for their various products is something that needs reconsideration. In this study, an ABC-XYZ classification is applied to determine optimal service levels per SKU. Subsequently, corresponding target inventory levels will be found, which we then tune according to the given space in the warehouse. The joint application of inventory classification, inventory level setting and capacity considerations is what makes this approach a novel one. Key findings are that the R should be higher than it currently is, though current inventory levels should be reduced. This new method leads to a space/cost reduction, because it provides Lienesch with a clear path as to how to manage their inventory. A way of dealing with overcapacity is introduced, giving Lienesch and possibly other organisations the possibility to determine which products' inventory levels should be brought down first.

Keywords: optimizing inventory levels, ABC-XYZ classification, service levels, (R,Q) model, warehouse capacity

1 Introduction

Inventory management, and more specifically optimizing levels of inventory, is a complex process due to the many factors that influence it on a real-time basis. Inventory is a major investment for most companies, as it strongly influences the internal flexibility of a company by allowing production levels to change easily and by providing good delivery performance to customers (Bonney, 1994). The typical trade-off is between high holding and obsolescence costs of excessive stock on the one hand and poor service and high shortage costs resulting from low inventory levels on the other. Inventory management also concerns fine lines between, among others, replenishment lead time, carrying costs, inventory forecasting, valuation of inventory, future inventory price forecasting, physical inventory and available space for inventory (Shafi, 2014). The ideal scenario would be to have a suitable inventory control policy that will guarantee a satisfactory service level without keeping unnecessarily large amounts of inventory that are costly to handle (Nenes et al., 2010).

In recent years, more and more attention has been paid to optimizing levels of inventory. All of that is done to balance the mentioned trade-off as well as possible. There are various ways and methods that can help companies in optimizing their inventory levels. A good starting point could be using the ABC method of classification. With this method, products are separated and put in different groups, for example based on their revenue or their margins, and depending on their classification, they get more or less attention when it comes to monitoring and (re)ordering these products. By categorizing products and attaching a service level to each category, it becomes easier for firms to manage very large amounts of stock keeping units (SKUs) (Millstein et al. 2014). In this paper, the Cycle Service Level

(CSL) will be used, which is the probability that there will not be a stock-out in a certain order cycle. An order cycle is the time it takes from ordering the product to actually receiving it. This metric is used to determine the order up to level, which shows how much of a product should be ordered to achieve the set CSL in a given period (Silver et al, 1998). Attaching a service level to products can help companies determine how much inventory they should have on hand for their products. Ideally, firms would strive to have a 100% service level. Though, because demand is uncertain and very hard to predict, this would mean that companies would need to have very high amounts of inventory on hand. Thus, it is always a trade-off between the cost of inventory and the cost of stock-out. The biggest challenge is to achieve a balance between various costs: have enough inventory to sell, but not so much that inventory costs do not outweigh the benefit of extra sales.

This thesis will be written from the perspective of Lienesch, a company that specializes in the production and supply of window decoration fabrics. Because a part of their core business is processing the materials, they are part of the textile industry. The company, that has been around since 2001, is located in Haaksbergen, the Netherlands, and has around 85 employees right now. In 2021, their total revenue was €28.8 million. There are two core components to their business. On the one hand, they produce a part of their products themselves, in their own production facility. Attached to that production facility is a warehouse in which these products are stored. On the other hand, Lienesch purchases these products from Asia, ships them from there, and sells them to their customers. These products are ready to be sold as soon as they are received in their warehouse. Lienesch' customers are all other businesses that process these products further (B2B). There are three broad categories which Lienesch focuses on. The first one is the 'home' market, where products are destined to be used in houses. Then, there is the 'form' market, which entails products that help architects focus on the form and function of the building, and can be adjusted accordingly. Lastly, there is the 'move' market, in which products are made that are used in planes, cars, trains, caravans and other moving objects. Last year, the firm grew incredibly fast, much faster than all predictions. The main reason for this was the coronavirus and the lockdowns that it brought along. Because people were not allowed to travel and had to stay home, a lot of people started (re)decorating their homes. That led to a 21% rise in their revenue, which was way higher than the forecasted 5%. Though, when comparing revenue levels between 2021 and 2022, up until week 33, an 7.5% decline can be seen. The main argument for this is that last year was an extremely good year (COVID-19), and this year, things are back to 'normal' growth levels, especially when looking at long-term growth trajectories within the firm.

Right now, Lienesch is struggling with finding optimal levels of their inventory. Up until about two years ago, the company would order products and keep inventory based on their gut feeling and with a minimal use of data, and therefore have levels of inventory that would be inaccurate for a lot of products. For a large amount of products, there is a lot of inventory that has been on the shelves for years and will probably never get sold. Another group of products are out of stock on a regular basis, which is obviously an issue. Combined with long lead times on most of those products, problems arise. Before, when the company was still fairly small, they would get away with doing this. Now, because of their tremendous growth, especially in the last couple of years, it has basically become impossible for Lienesch to order products and manage levels of inventory without using numbers to back their decisions up. Since then, they have started to collect, analyse and implement data in their decision-making process regarding their ordering behaviour, and thus in working towards optimal levels of inventory. Lienesch works with software from Slimstock, Slim4, that helps them in ordering and forecasting as accurately as possible. The system provides advice as to what should be ordered and in what quantities, and the people in the purchasing department check this and order accordingly. On top of that, Slim4 has set service levels for all products, which vary between 50 and 97 percent, and has classified products according to the ABC-method. These two things influence the ordering policy. However, these classifications are still very much standardized per category. The ABC categories are subdivided as follows: A products are the top 70% of revenue, the next 20% are B products, and the remaining 10% are C products. The same is done for the order quantity. The top 70% of products that are ordered the most are A products, the next 20% are B products, and the 10% of least ordered products are classified as C products. Slim4 combines both of these aspects to get a combined product classification. There is still a long way to go in this process before it is both (almost) self-sufficient and accurate. Too little is known about what amounts of inventory is good and what amounts are too low/high compared to what Lienesch expects to sell.

Something that could help Lienesch determine what their optimal levels of inventory for each product (group) might be, is determining a service level for their products. Currently, they are using a standardized set of service levels as provided by Slim4. Right now, the ABC-method of product classification seems the most suitable option. This would require Lienesch to categorize their products in A/B/C products, each with their own service level.

Tying into this, because of their excessive growth recently, their warehouse is almost full. The company has planned an expansion of their warehouse, but this will probably not be finished until early 2024. In the meantime they are expected to keep growing, so space for their products will become an even bigger issue than it already is. They have already rented additional warehouse space to store most of their slow-mover products. Though, this brings about complications, especially in efficiency, too. Lienesch is also considering other warehouse expansion opportunities that have recently come to the table.

1.1 Research set-up

With this research, the ideal scenario is to combine the following pieces described above: product classification, using the ABC-method to determine service levels for each product, , and warehouse capacity. The following central research question has been phrased for that: *How can Lienesch's inventory levels be optimized, using the ABC-XYZ method of classification, setting service levels, and taking into account a limited warehouse capacity?* Here, Lienesch will be used as an example of an SME that is active in the textile industry.

The first step would be to classify all the products in either the A, B or C category, and determine a service level for each category. Then, the forecasts come in. If it is known what the service level is for each product, and the forecasts show the predicted demand for the next time period, Lienesch should be able to come closer to maintaining optimal levels of inventory. In the end, the inventory levels will be determined by the demand forecast and a level of safety stock. This level is dependent on the variance of the forecast error.

An additional area of investigation to this could be to determine what the maximum warehouse capacity is. With this information, decisions could be made in choosing what percentage of products should be classified as A/B/C category products. There are obviously differences in terms of service level and levels of inventory that should be kept between the different categories of the ABC method. If it is known how much space there is (left) in the warehouse, that could have an impact on the division of the amount of A/B/C products.

This paper contributes to theory and practice in two ways. First and foremost, this study aims to combine various elements that have, to the best of our knowledge, not been combined before. Using the ABC method of classification, setting inventory levels, and taking into account a limited warehouse capacity has not been done before. To be more precise, the goal is to reclassify the A/B/C categories in such a manner that the warehouse capacity is used as optimally as possible. Earlier studies have just focused on using ABC classifications and optimizing levels of inventory, but they have not looked at how warehouse space and capacity could play a role in this.

Secondly, there is no significant research about inventory optimization in the textile industry, which is the industry Lienesch operates in. All research is related to the production piece of the textile industry, which is all located in Asia and Africa, and is outdated (Shafi, 2014). With the contributions this paper hopes to make, other companies than Lienesch that operate in similar industries can possibly benefit from the outcomes of this study, especially when these firms are dealing with a lack of warehouse capacity. To recap, the relevant theoretical components that will be used in this study are the ABC-XYZ method, service levels, the (R,Q) model and warehouse capacity. These aspects will be explored in section 2.

The remainder of this thesis paper is organized as follows. In section 2, a literature review about the various subjects of this study will be conducted. Section 3 will give an insight into the current situation at Lienesch with regards to the topics that are relevant aspects for this thesis. The methodology of this study will be described in section 4, and the findings will be presented in section 5. Lastly, recommendations, limitations and other concluding thoughts will be shared in section 6.

2. Literature Review

In this section of the paper, the various relevant components and theories will be discussed. The four aspects that will be covered are the ABC-XYZ method, service levels, the (R,Q) model and warehouse capacity.

2.1 ABC method

In this part of the literature review a closer look will be taken at both single- and multi-criteria classifications, and at possible extensions/elaborations of the ABC-method.

The ABC-method is a way of classifying items in inventory. The method is used because most companies deal with a number of SKUs that runs in the thousands (Buxey, 2006), and this number is too high to implement individual measures for each SKU (Ernst and Cohen, 1990). Inventory items are classified according to their transaction volume or value (Millstein, Yang, & Li, 2014). Products are often ordered in descending order of their annual dollar usage values, which includes the quantities and average unit prices of these products (Guvenir & Erel, 1998). The relatively small number of items at the top of the list, which take up the majority of the annual dollar usage of total inventory, are classified as ‘A’ products. Group ‘C’ consists of most of the products, that make up only a small part of the total dollar usage on a yearly basis (Guvenir & Erel, 1998). Lastly, there is group ‘B’, that is the remainder of the products with an average dollar value usage.

Often times, a small percentage of the inventory items contributes to the majority of a company’s sales and revenue. As a rule of thumb, the *80-20 rule* (Pareto, 2014) is applied, which assumes that approximately 20% of sold articles contribute to 80% of total sales. When combining the Pareto rule with an ABC classification, you get a division as depicted in Figure 1. The 20% as just described is usually classified as A products. Products in group B make up about 15% of the total sales, and the remaining part is classified as C products. It is important to note that this division of products is arbitrary and that it might differ per company.

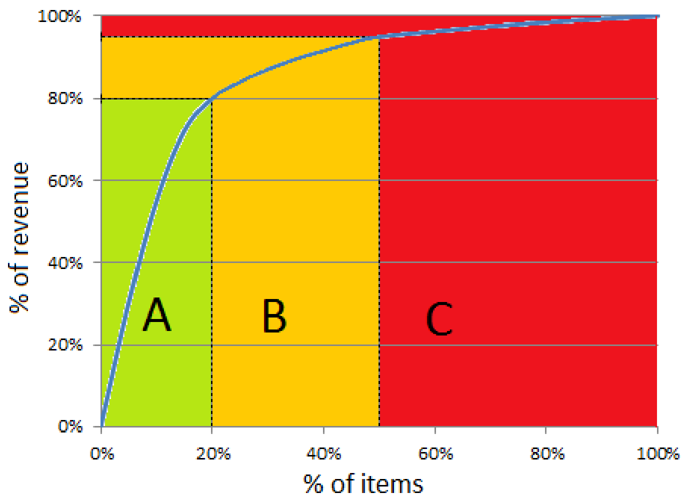

Figure 1: ABC curve according to 80-20 rule

Some typical characteristics of A products are a large capital occupation, high unit price of goods and a high turnover rate. When looking at B products, the following characteristics jump out: large capital occupation, high unit price of goods and low turnover rate. Lastly, these are the most common characteristics from C products: small capital occupation, low unit price of goods and a low turnover rate (Li, Huang, Zhang, & Gao, 2019).

These classifications help management decide how their time and resources should be spent. Generally speaking, most time and effort should be spent on managing the A category items, because this relatively small amount of products bring in the most revenue (Ravinder & Misra, 2014). Tight management control of ordering procedures and individual demand forecasts should be made for class A items. Class C items should receive a loose and not very intensive control, and class B items should have a control effort somewhere in between the methods used for class A and C products (Guvenir & Erel, 1998).

However, in recent years, more and more attention has been paid to more extensive ABC classifications, using multiple performance criteria to classify products. Flores and Whybark (1986) argued that considering multiple criteria in an ABC classification can provide a more comprehensive managerial control. These two categories will be expanded upon in the following subsections.

2.1.1 Single-criteria classifications

In this section, ABC-methods in which a single performance criteria was used will be highlighted. Before, ABC classifications were created using only a single performance criteria, most of the time being sales volume and/or value. Its popularity was based on the simplicity, applicability and empirically observed benefits of the ABC-method for inventory management. (Guvenir & Erel, 1998).

Teunter et al. (2010), as one of very few, propose a criterion that includes criticality. Their criterion ranks stock keeping units (SKUs) based on the value of (b*D)/(h*Q), where b is the criticality measured by calculating shortage cost, D is demand volume, h is holding cost per unit, and Q represents the order size. Their single criterion does take four parameters into account, being the demand volume, holding cost (purchase price), average order quantity, and shortage cost (criticality), as can be found in the formula (Teunter et al, 2010). This ABC classification has been developed from an inventory cost perspective, which means that the aim is to minimize total inventory cost whilst reaching a required average fill rate. Most of the ABC classifications are developed from an inventory value perspective, which aims at maximizing performance scores (Millstein et al., 2014).

2.1.2 Multiple-criteria classifications

Here, ABC-methods in which multiple performance criteria were used will be discussed. When the initial ABC classifications were made, the only thing that was looked at was the dollar-usage of the item. However, this single-criteria procedure has a serious drawback that may decrease the effectiveness of the method in some cases. Because only one criterion is used, most of the time the annual dollar usage, problems of significant financial loss might arise (Guvenir & Erel, 1998). Only using annual dollar usage may over-emphasize the importance of items that have high annual cost, but are not seen as critical to the operation of the firm. On the other hand, important products or services that are of critical importance to the firm, but that have low annual cost, may be overlooked (Flores et al, 1992). Thus, the classification that is obtained from the ABC method is sometimes subject to further adjustments. Example: the dollar usage of certain stock keeping units may not be significant, but the stock-out cost might be very high. In cases like that, it is appropriate to switch products to a different group. What is important here is that in these re-classification situations, relevant criteria other than dollar usage may start playing a role in determining how much attention should be paid to specific stock keeping units (Chen et al., 2008).

Flores and Whybark (1986) suggested that using multiple criteria in an ABC classification would provide a more comprehensive managerial control. Lead time, criticality, commonality, obsolescence, certainty of supply and substitutability are examples of this. All of these criteria are noncost criteria. Criticality seemed to be the most important and comprehensive aspect for managers, as it would take into account factors such as the severity of the impact of running out, how quickly the item could be purchased, if there were political consequences of having no products left, and if there were any substitutes readily available. Though, if multiple criteria are marked as important, they should somehow be incorporated together, or companies would end up with a massive number of possible combinations, which is not workable.

Flores and Whybark (1986) used dollar-usage and criticality as their categories. Participants of the experiment in the study were able to classify items based on their criticality (A,B or C), and were after that capable of combining this with the more standard dollar-usage classifications (A,B or C), which would lead to three initial classifications (AA, BB, CC) (Flores and Whybark, 1986). They created a joint criteria matrix for two criteria, which required the development of nine different policies for management as to how to interact and take care of the various products in the newly created classifications. A big limitation of this study is that it only takes into account two criteria. Once more than three criteria are seen as relevant, this matrix becomes impractical (Guvenir & Erel, 1998).

The Analytic Hierarchy Process (AHP), developed by Saaty (1988), has been applied successfully to multicriteria inventory classification by Flores et al. (1992). The AHP is a multicriteria decision-making approach in which various factors are organized in a hierarchic structure. The AHP is used to reduce the multiple criteria that are identified as important to a univariate and consistent measure to consider multiple inventory management objectives (Flores et al, 1992). A big advantage of the AHP method is that it is able to incorporate a lot of relevant qualitative and quantitative criteria when classifying inventory. On top of that, its ease of use and a minimal reliance on big measurements and accounting systems are seen as benefits of AHP (Partovi & Anandarajan, 2002).

Ideally, the AHP can benefit managers or other people in charge by channelling various criteria into making sure there is an accurate ranking of SKUs, which will help companies make good decisions. Some shortcomings of the AHP method were identified by Partovi and Anandarajan (2002). First and foremost, a significant amount of subjectivity is involved in pair wise comparisons of criteria, rating levels and assigning a rating levels and weights to SKUs. With an increased amount of data available, the amount of human involvement in the produced could be reduced. This would increase accuracy and consistency in the decision-making process, while at the same time reducing processing time. As of right now, the AHP method is not something that would suit Lienesch very well. Though, in the future, when the company has better insights into both qualitative and quantitative data, and has identified what is important for them, it might be a method that could be applied to further help the cause of optimizing inventory management.

2.1.3 ABC-XYZ: combining value with forecastability

In this section, a possible extension and/or elaboration on the ABC-method will be discussed, being the ABC-XYZ method. Here, the ABC method as has just been described is combined with the XYZ method. The ABC analysis facilitates the arrangement of materials or products into sets in consideration of given criteria. The benefit of this is that it enables managing the assortment groups rather than having to worry about single elements, which can be complicated in large quantities.

The XYZ classification method is a modification of the ABC analysis and consists of classifying products based on the structure (rate) of their selling, whether there are lots of fluctuations, or if the product is more of a constant seller (Bulinski, Waszkiewicz & Buraczewski, 2013). X products are products that are fairly constant in their selling. Fluctuations are rare. Y products have fluctuations in consumption, usually related to trends or seasonal reasons. Z products are known for their completely irregular consumption. Generally speaking, when calculating values, products with a coefficient of variation below 0.5 are classified as X products, products with a variation between 0.5 and 1 are classified as Y products, and products with a coefficient of variation above 1 are labelled as Z items (Scholz-Reiter, Heger, Meinecke, & Bergmann, 2012).

Stojanovic and Regodic (2017) add to this by stating that group X consists of products for which there is continuous demand, characterized by very minimal variations, which makes it a product group that can be forecasted with great accuracy. Group Y products are products that are sold discontinuously, with regular fluctuations in demand, with forecasts that are of middle-degree accuracy. Group Z products entails products encompasses products that are sold on occasions, with big differences in volume of demand, which makes it a very hard group of products to forecast. The division of products into the various categories is done as follows: Group X consists of the top 10% of products which can be most accurately estimated, group Y consists of products in the 10-25% range of products that can be most accurately estimated, and group Z consists of the remaining 65-80% of products that are harder to estimate demand for. For each of the nine categories, Stojanovic and Regodic (2017) give a brief description:

- AY: products with big share in total value, but consumption is discontinuous, which leads to a lower forecasting precision. Adequate attention should be dedicated when planning for this category.
- AZ: products with high share in total value. This group’s products are sold with a high variance, which makes forecasting complicated. Managing inventories is the hardest with this group.
- BX: products with middle share in total value, continuous consumption, which makes it possible to forecast with great accuracy.
- BY: products with middle share in total value, discontinuous consumption and a middle-degree of accuracy for its forecasting demand.
- CX: products with a small share in the total value, continuous consumption and great accuracy of forecasting needs. This type of product should be purchased in accordance with the needs.

The product groups BZ, CY and CZ have negligible impacts on an enterprise's business operations. They are purchased rarely and their planning is frequently neglected or left to suppliers in combination with other products. To generalize, the categories AX, BX and AY can be said to qualify for just-in-time approaches, where efforts must be minimized for items of low value with bad predictability of demand, which can be found in the CZ category (Stojanovic & Regodic, 2017). The limitations to the ABC analysis that have been discussed before can be overcome by using the XYZ as an additional tool. It can be used as a secondary tool of inventory analysis, because it compares the demand variability (XYZ) with the average level of demand (ABC) (Stojanovic & Regodic, 2017).

Combining it with the mentioned XYZ classification, nine separate groups are formed (AX,AY,AZ,BX,BY,BZ,CX,XY,CZ). Bulinski et al. (2013) made the assumption that AX, AY,AZ, BZ and CZ products should be ordered according to a company's internal system, and BX,BY,CX,CY products should be ordered according to periodic inspection. This is because of their fairly high demand and their relatively small value.

2.2 Service levels

In this part of the paper, a closer look will be taken at service levels and their impact on inventory classifications, more specifically the ABC method. A service level measures the performance of a system. Service levels are used to determine a proper reorder point or level of safety stock (Axsäter, 2015). There are different types of definitions within the literature. One of the most well-known definitions is the fill rate (volume fill rate), which determines the percentage of demand that is satisfied directly from stock-on-hand. The main advantage of using the fill rate as a service level is that it reflects the service as experienced by the customers (Teunter, Syntetos, & Babai, 2017).

A second definition is the ready rate, which is defined as the fraction of time when the net inventory is positive (Larsen & Thorstenson, 2008), and as the percentage of periods in which demands are completely fulfilled within a pre-specified time window (Wang, Chen, & Feng, 2005). Thirdly, there is the cycle service level (CSL), which is defined as the probability that there is no stockout in a certain order cycle, also described as the probability that an order arrives on time (Teunter et al. 2010).

Within the ABC-method, the service levels are one of the most important performance measures. They have a direct impact on the net profit and revenue of a company (Millstein et al., 2014). Most of the time, these service levels are fixed per category (Teunter, Babai, & Syntetos, 2010). Normally, the A category is seen as the most important category. This category should be used to enhance managerial effectiveness. The A-class items get the highest service levels, and the C-class the lowest (Millstein et al., 2014).

Teunter et al. (2010) cite experts from Slimstock and NONSTOP, both companies with a lot of expertise in the inventory classification field, that the standard approach is to fix service levels per class. Though, determining what those service levels for every class should be is unclear. There is even discussion about which category (A or C) should get the highest service level. On the one hand, there are experts that claim that A products should receive the highest service level, as these products have the biggest impact on firm profit (Stock & Lambert, 2001). On the other hand, it has been argued that C level products should receive the highest service level, because dealing with stockouts for these products is not worth the effort in the first place (Knod and Schonberger, 2001). These differences can be attributed to the fact that Teunter et al. (2010) have taken a look at classification from an inventory cost perspective, whereas previously the main perspective was the demand value perspective, as touched on above. In the case of Lienesch, because the ABC and XYZ methods will be combined, a total of nine different categories will be created. Each category will receive its own service level, meaning that there will be a maximum of nine service levels. It might not necessarily be the case that the classification made in this study will have nine different service levels, because there might be certain service levels that apply to multiple categories. Later on, in section 4, the service levels per category will be discussed.

2.3 (R,Q) model

There are various ordering policies that can be used. The two most common policies will be highlighted briefly. First, there is the (R,Q) policy. To state in very simple terms, when the inventory position declines to or below the reorder point R, a batch quantity of size Q is ordered. If demand is continuous and the continuous review method is used, the reorder point will always be hit exactly. When applying the periodic review method, it will often happen that the inventory position is below R when ordering. In this case, the optimal position, R+Q, will not be reached after ordering (Axsäter, 2015). This can be seen in Figure 1.

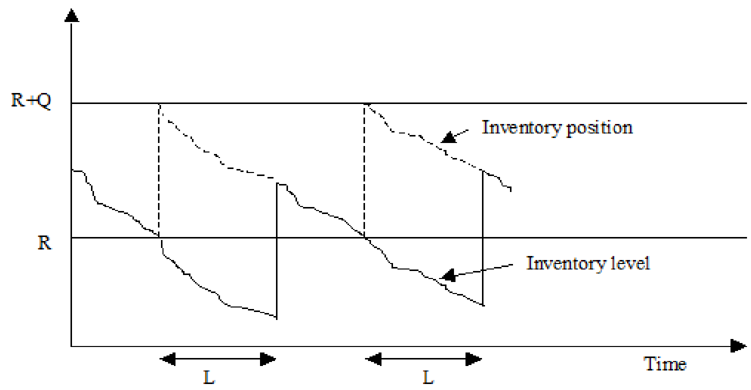

Figure 1: (R,Q) policy with periodic review (Axsäter, 2015)

The second policy that is well-known is the (s,S) policy. It is similar to the (R,Q) method. The reorder point is denoted by s, and orders are made up to the maximum S. If the reorder point is always hit under the continuous review method, both methods are identical (Axsäter, 2015). With the periodic review method, there might be moments at which no order is triggered, because the s/R is not hit. A variation on the (s,S) method, called S /order-up-to-S/base stock policy, will always order back up to the level S, unless the demand in a period is zero.

The difference between the two policies can be found in that the (R,Q) policy always orders amount Q, and that with the (s,S) policy, everything is being ordered up to the maximum level S. This means that with the (s,S) policy, there will not be multiple orders of a given batch quantity. If the reorder point is always hit exactly, there is no difference between the two methods. But if the reorder point is not always hit exactly, there are variations that will occur, as just described (Axsäter, 2015).

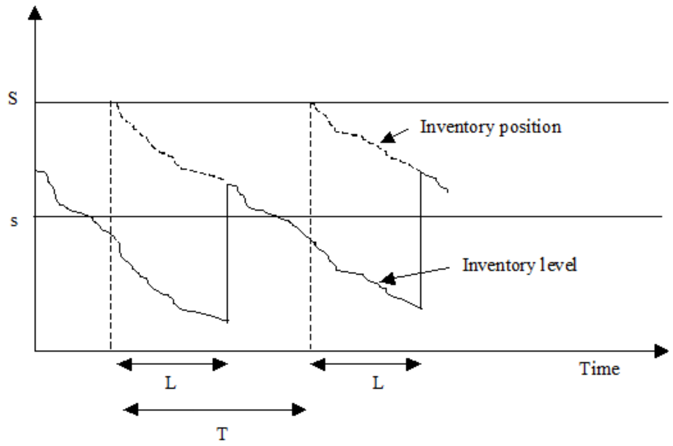

Figure 2: (s,S) policy with periodic review (Axsäter, 2015)

There are also various ordering policies that can be used. One of the most common policies that is being used is the (R,Q) policy. To state in very simple terms, when the inventory position declines to or below the reorder point R, a batch quantity of size Q is ordered. If demand is continuous and the continuous review method is used, the reorder point will always be hit exactly. When applying the periodic review method, it will often happen that the inventory position is below R when ordering. In this case, the maximum position, R+Q, will not be reached after ordering (Axsäter, 2015).

When looking at ways of monitoring the inventory position, the continuous review method, in which inventory is monitored continuously, stands out as one of the most significant methods. As soon as the inventory position is sufficiently low, a purchase order is triggered (Axsäter, 2015). To be more specific, when the reorder point is reached, a specific amount is ordered to bring inventory levels back up to a specified level (Hung, 2016). An advantage of this is that it can handle variations in demand, because it can vary in order quantity (Rizkya et al., 2018). Another advantage is that the continuous review will reduce the needed safety stock, because the inventory position is constantly checked and there will therefore be fewer surprises that make high levels of safety stock necessary. Lienesch currently employs a method that is very similar to the (R,Q) method, as they work with minimum and maximum levels of inventory. In section 4, further details about what this entails will be shared.

To figure out what the level of inventory is that belongs to a certain SKU with a certain service level, the following formula can be used:

$$R *= (\mu \times L) + (k \times \sigma \times \sqrt{L})$$

Formula 1: R* formula

R* = level of inventory that matches with certain service level
μ = average demand over the last specified time period
σ = standard deviation of μ
L = lead time, measured in the same time period
k = safety factor

The μ is calculated based on the demand of the last twelve months. The mean of those twelve months is the number that will be implemented in the formula. The σ is the standard deviation of that same set of numbers, namely the demand of the last twelve months. Important to remember is that the μ and σ are approximations. The lead time is calculated in months, this data can be found in Slim4. Lastly, k is the safety factor. This number is dependent on the service level that is being attached to an SKU. R* is the level of inventory per product that would be seen as (very close to) optimal given the formula above.

2.4 Warehouse capacity

This part of the literature review discusses (limited) warehouse capacity, and how it may impact decisions about classifying inventory (using the ABC-method) and attaching service levels to these various classes. Effectively managing the inventory of multiple items under limited warehouse storage capacity is critical to ensure good customer service without incurring very high inventory holding costs (Choi et al., 2005). Hariga (2011) describes how companies can no longer afford warehouses with large storage capacities due to the increased cost of acquiring land. Hariga identifies managers having to turn down supplier discounts because of that as a big disadvantage. A solution to this could be to store excess inventory in rented warehouses.

Capacity and inventory decisions can be tied into (differentiated) service levels. Nowadays, more choice and faster response times are expected by customers. Normally, these do not come for free. Service level (and price) differentiation has gathered more attention, as customers do not need, nor want to pay, for the increased choice and faster response times all the time (Song et al, 2020). Therefore, mechanisms are created and used, such as service levels, that help prioritize companies in which products are of high importance and should always be present, and which products are less important.

Warehouse capacity problems can be classified into three major categories: throughput capacity models, storage capacity models, and warehouse design models. Throughput capacity models are comprised of picking policies, batching policies, storage assignment policies and dynamic control models. Storage capacity models are used to either find the optimal warehouse size or else maximize space utilization. The focus of warehouse design models are things like rack orientation, space allocation and external building configuration (Cormier & Gunn, 1992).

A big aspect of utilizing the capacity of a warehouse in the most efficient manner is the design of the warehouse. According to Gu et al. (2010), designing a warehouse involves five major decisions. The first one is determining the overall warehouse structure. The overall structure determines material flow patterns within the warehouse, the specification of functional departments, and the flow relationships between departments. Secondly, sizing and dimensioning the warehouse and its departments is important. This determines the size and dimension of the warehouse, as well as the space allocation among various warehouse departments. The third decision is about determining the detailed layout within each department. The department layout is the detailed configuration within a warehouse department, for example, aisle configuration in the retrieval area. Then, warehouse equipment has to be selected. With this decision, things like an appropriate automation level for the warehouse, and identifying equipment types for storage, transportation, order picking and sorting, are significant. Lastly, selecting operational strategies is an important decision. This determines how the warehouse will be operated, for example, with regards to storage and order picking. Operational strategies refer to decisions about operations that have global effects on other design decisions (Gu et al, 2010).

3. Current Situation

In this section of the paper, a closer look will be taken at the current situation of Lienesch, more specifically at aspects relevant for this study.

Lienesch has four main product categories: pleated, vertical, roller and honeycell. These four categories make up the entire inventory that could possibly be sold. The company has implemented the ABC method of classification, although they do not really act on these classifications yet. For each separate product category, an ABC classification is made based on the Pareto rule. Two separate classifications are made for each of the four categories. One of the classifications is based on revenue in the last 12 months. The top cumulative 80% of revenue is classified as A products, the cumulative revenue between 80-95% is classified as B products, and the remaining 5% is classified as C products. The same is done for margin in the last 12 months. The top cumulative 80% of the total margin is categorised as A products, the cumulative margin between 80-95% is classified as B products, and the remaining 5% is classified as C products. Then, these two classifications are put together, as is depicted in the table below.

		Revenue		
		A	**B**	**C**
Margin	**A**	A	A	B
	B	A	B	C
	C	B	C	C

Table 1: Way of classifying products, according to the ABC method, as done by Lienesch

This is the way in which Lienesch classifies its products. In total, the organisation has 3,202 active SKUs. 493 of those products are categorised as A products, 447 as B products, and the remaining 2,262 products are classified as C products. In the table below, the four categories are depicted, showing how many products each category contains, how many are A/B/C products, and what percentage of products are A/B/C products. Right now, these classifications are not acted upon consistently. The supply & demand planner utilises these categorisations to make forecasts and to install a minimum and maximum level of inventory for each product. Besides that, not much is done with this classification. Especially in combination with the service levels, which will be discussed later in this section, a lot of unexplored terrain is present.

	Pleated		**Vertical**		**Roller**		**Honeycell**		**Total**	
A	191	14.9%	60	12.8%	114	20.2%	128	14.4%	493	15.4%
B	193	15.1%	44	9.5%	76	13.4%	134	15.1%	447	14.0%
C	896	70.0%	363	77.7%	376	66.4%	627	70.5%	2262	70.6%
Total	1280	100%	467	100%	566	100%	889	100%	3202	100%

Table 2: Overview of product categories and classification according to ABC method

Table 2 above shows how many A, B and C products there currently are in each category at Lienesch. This might be confusing. It is important to note that the four respective product categories (pleated, vertical, roller, honeycell) all have their own ABC classification. This might need some additional explaining. It might seem more logical to make one big classification of all the 3202 SKUs Lienesch possesses. In the past, Lienesch made the deliberate decision to not do this. Two of the four categories (pleated and honeycell) make up more than 90% of annual revenue. Especially the vertical category barely contributes to the overall revenue of Lienesch. A result of this given would be that in a general ABC classification, where all SKUs would be combined, (almost) all vertical products would be classified as C products. The same would go for the majority of the roller category. In terms of margins and revenue this might make sense, but the complexity of it is that a lot of the products in the vertical and roller category have very long lead times, which are not always met. Due to that, Lienesch decided to classify each category separately, leaving them with four smaller classifications. In this set-up, it becomes easier for Lienesch to manage the few products in the vertical and roller category that bring in almost all the money in that category. Therefore, the same will be done in this study.

Besides the ABC classification that Lienesch has made themselves, the company also works with software from Slimstock, called Slim4. Slim4 is an integral solution for forecasting, demand planning and inventory control. It works on the basis of Management by Exception, which is backed up by reliable and clear analysis.[1] For this study, Slim4 is relevant in that it produces both an ABC classification and service levels for Lienesch's products. Though, Lienesch only makes use of the service levels, which will be discussed later. The ABC classification that Slim4 produces has a major limitation for this study, as it only incorporates 1873 products out of the total of 3202 SKUs. There are various reasons for Slim4 to exclude products in their classifications. First, products that have not been sold in the past 12 months are excluded in the Slim4 classification. Second, there are products that receive certain labels (by Lienesch), such as 'while stock lasts', that do not receive a classification. These products do not receive a forecast due to their label, and if a product has no forecast, Slim4 does not attach a category to that product. Due to these reasons, only 1873 products receive an ABC classification.

On top of that, Slim4 also uses other parameters for their classification. Whereas Lienesch uses revenue and margins, Slim4 uses sales and order lines as parameters to divide SKUs. This makes comparing them and using them next to one another complicated. Out of the 1873 products that are part of both ABC classifications, only 73.4% (1375 SKUs) have the same classification in both the Lienesch and Slim4 classification. This means that 26.6% (498) of products have a different classification. That is a big difference which makes it hard to use both. Lastly, it is important to note that Slim4 only makes one 'big' classification compared to the four smaller ones Lienesch works with. This leads to major discrepancies in classifications too, as explained at two paragraphs above.

Next, the service levels come into play. Right now, the only service levels that are available are the ones produced by Slim4. Lienesch does not have their own service levels, they solely use the ones produced by Slim4. The Slimstock software produces a total of 7 different service levels. The parameters that Slim4 uses in classifying products are sales and order lines. With sales, the amount of revenue a product has brought in in the last 12 months is the basis on which products are classified as either A, B or C products. With order lines, the amount of times a certain SKU has been ordered in the last 12 months is what is being looked at. A products are products that are ordered on a more regular basis than C products. In the table below, the current situation with regards to the service levels can be found.

Table 3 depicts the service levels Slim4 has set right now for final products at Lienesch. What stands out here, is that the service levels from products in the A category for sales increase as they move from A to C products.

	Order lines			
Sales		**A**	**B**	**C**
	A	95%	96%	97%
	B	96%	95%	90%
	C	97%	90%	80%

Table 3: Current service levels for end products at Lienesch as done by Slim4

According to Steven Koenders (2022), consultant at Slimstock, this is not logical and should be adjusted. This is something that will get extra attention in this study. Koenders said that it should be the case that service levels decrease as they move from the A to the C

[1] https://www.qbsgroup.com/solutions/slim4-supply-chain-management/

category, the opposite of what is happening here. Another, smaller, discrepancy can be identified in the BA and CA categories. Where the BA category has a service level of 96%, the CA category has a 97% service level. According to various articles about ABC classifications, it would make more sense for the BA category to have a higher service level than the CA category, as the former products tend to be of higher importance to organizations. Normally, they bring in more revenue and are sold on a more regular basis.

	Order lines			
Sales		**A**	**B**	**C**
	A	80%	70%	70%
	B	80%	70%	65%
	C	80%	70%	50%

Table 4: Current service levels for components at Lienesch

Table 4 shows the service levels that Slim4 has set right now for components at Lienesch. Components are products that Lienesch purchases or produces, but that are not sold as end products to customers. For the sake of this study, the assumption will be made that all components are always present to be used for the production of an end product. Questions could be asked about the service levels that these products receive. Because they are vital for the production of other products too, it might make sense to attach significantly higher service levels to this category in general. There are a couple of exceptions within this category that do receive high service levels (96% and 97%), but Slimstock was not able to explain why certain products do receive high service levels and others don't.

In Table 5 below, an overview of the current division of service levels by Slim4 is given. For each category of the ABC classification, it is shown how many products have what service level.

	ABC classification				
Service level		**A**	**B**	**C**	**Total**
	50			4	4
	70	7			7
	80	139	201	1266	1606
	90	39	157	107	303
	95	114	35	964	1113
	96	158	25	2	185
	97	31	29	4	64
	Total	488	447	2347	3282

Table 5: Overview of the various service levels and their respective classifications

Table 5 is, in terms of the various service levels, a combination of Tables 3 and 4. All the service levels that Slim4 produces are displayed in this Table, showing what category (A/B/C) has what service levels right now. There are a couple of things that stand out and should be noted. First, in Table 2, a total of 3202 SKUs is mentioned, whereas Table 5 contains 3282 SKUs. This difference can be attributed to the fact that 80 SKUs have been filtered out because of their lack of relevance for this study. These products lack relevance because the historical data of these products is incomplete or not available. Therefore, the decision was made to bring the original number of 3282 down to 3202 SKUs.

Secondly, it is important to notice that the four respective product categories (pleated, vertical, roller, honeycell) all have their own ABC classification, which means that calculations and proportions might vary for the different categories. This has been touched on earlier in this section.

Thirdly, very significantly, some of the outliers and discrepancies when comparing the classifications to the service levels can be attributed to the fact that Lienesch has created the ABC classification, and that Slimstock has created the service levels for the products. Due to Lienesch using revenue and margins as the basis of their ABC classification, and Slimstock using sales and the amount of order lines as the basis of creating the service levels, variations that might seem illogical can be contributed to that given. Fourthly, when looking at Table 5, there are a few things that might seem weird and stand out.

- There are 4 products in the C category that have a service level of 50%. The reason for this is that these four products are components, which means that these products are used in the production of other products that Lienesch creates. Therefore, the service level attached to these exceptions is very low. This is something that might be questioned, as one could argue that components are vital for the production of end products. If components are not present, end products cannot be completed. Because of that, it would seem logical to attach a higher service level to these type of products, as the absence of these products might have large consequences.
- 139 SKUs that are categorized as A products have a service level of 80%. All these products fall in the vertical and roller categories, which are product categories that do not experience as much activity and do not bring in nearly as much money as the other two categories. Therefore, even A products might have a lower service level than expected. This will be taken into account in this study too.
- 201 B products that have received an 80% service level. The majority of these products are categorized as B products in the vertical and roller sections, but their activity might be comparable to the just described A products in those categories. Because Lienesch uses revenue and margins as indicators, and Slim4 uses order lines and demand as indicators, products that show similarities in order lines and demand get the same service level, but because revenue and margins on these products might be higher/lower for some, they vary in classification (A or B). Initially, in this study, the decision was made to attach one service level to a certain category. From there on, possible finetuning of categories might occur.
- 964 C products have gotten a 95% service level. Most of these products are new products that have not experienced any demand and/or sales yet. The system automatically attaches this service level to new products. This gives a troubled image of the current situation, and the majority of these products will be reclassified accordingly in this study.
- There are a couple of products within the C category that have a very high service level. 2 products have a 96% service level, and 4 products have a 97% service level**.** These SKUs can be seen as exceptions, because it concerns components. Such products are used in the production of a variety of other products within Lienesch. The discrepancy between a C category product and a service level of 96/97% can be contributed to the fact that Lienesch and Slim4 use different indicators to come to the respective ABC categories and service levels. These products are C products because the margins are very low, and they have a very high service levels because the demand is very high.

. It might come across as confusing and illogical that there are different parameters involved in determining the ABC classification by Lienesch on the one hand (revenue, margins), and the ABC classification (done by Slim4) used to separate service levels on the other hand (sales and order lines). In an ideal scenario, the two would align. On top of that, the classifications of Lienesch and Slim4 differ in another, significant way. As elaborated upon, Lienesch has made the decision to make four separate classifications, a more extensive explanation can be found at the beginning of this section. The ABC classification that is available in Slim4 is made in the more common way, as only one classification is made in which all SKUs are combined. This leads to discrepancies between those two classifications, because out of the 1873 products that appear in both classifications, 26.6% (498 products) of the SKUs does not fall in the same ABC category in both classifications. This has the consequence that 1054 SKUs, out of the total of 3202 SKUs, have a service level that does not match with the prescribed service levels (Tables 3 and 4) for that category. Overall, this major discrepancy can be attributed to the fact that the service levels Slim4 produces are compared to the ABC classification of Lienesch. In this study, there will be unity in that sense. The parameters that will be used for both the ABC classification and the service levels will be the same.

Lastly, the capacity problem comes into play. In an ideal world, Lienesch would like to find out how much of their warehouse would be occupied with the outcomes of the R* formula, of which the outcomes will be presented in section 5. Tying into that, based on the strategic growth numbers Lienesch's board has produced, it would help Lienesch a lot of it could be determined when the warehouse would be full. Right now, Lienesch has total inventory of 1,028,979 meter. An elaboration to this will be given later on in this paper. Approximately 90% of the maximum warehouse capacity is currently in use. With this knowledge, calculations and estimations will be made to find out when the warehouse would be completely full. These will be presented in section 5.

4. Research Methodology

The methodology section will elaborate on the research design. The way in which the various significant aspects discussed in sections 2 and 3 will be implemented and used will be described.

4.1 Research design

In this study, the aim is to find out whether or not the ABC-method of inventory classification can be combined with the service levels and the forecast of Lienesch, while also taking into account a limited warehouse capacity, to optimize inventory management. The research question that was phrased to get to that objective is as follows: *How can Lienesch's inventory levels be optimized, using the ABC-XYZ method of classification, setting service levels, and taking into account a limited warehouse capacity?*

4.1.1 ABC classification

The first step in this process was to create an elaborate dataset of all the active and relevant SKUs Lienesch possesses. This resulted in, as explained before, a total of 3202 SKUs. Per SKU, relevant data from the last 12 months, such as revenue, margins, and demand, was identified and put together.

Categorizations into the various classes was done based on the revenue, margin and demand of SKUs. Broadly speaking, the aim was to classify 80% of the revenue, margins and demand as A products, the products in the 80-95% as B products, and the remaining 5% as C products. As mentioned in the 'current situation' section, Lienesch has four distinct product categories with their own ABC classification. This format will be kept intact for this study, which means that four different ABC classifications will be made for the four different product categories pleated, vertical, roller and honeycell. The main reason for Lienesch to

decide upon four different ABC classifications for their respective product categories is because the company wants to keep control of the top sellers in each category, but in this case especially the vertical and roller categories. If one big ABC classification would be made, almost all the vertical and roller products would be classified as C products, meaning they would receive less attention and a lower service level. It would make sense in terms of revenue and margins when looking at these products, but because a lot of these products have very long lead times, it seemed more convenient for Lienesch to make four separate classifications. With that set-up, the few products in the vertical and roller categories that are responsible for the majority of revenue are classified as A products. This makes it easier for Lienesch to manage their important products in each category. Therefore, the decision was made to separate them when it comes to the ABC classification.
Three separate classifications will be made, and they will afterwards be put together into one combined ABC classification. As an example: If the result is that a product has multiple outcomes (A/B/C), the outcomes that comes up most often will be used as the result for the combined outcome. So say that the three separate classifications give A/A/B as an outcome, then the product will be classified as an A product. If the outcome of the three classifications is B/C/B, then B will be the way in which that product will be classified. In the case that a product has three different outcomes, so A, B and C, then a closer look will be taken at the product to see what classification would suit best.

4.1.2 XYZ

After the ABC classification is done, an additional step into separating products as best and accurately as possible is the use of the XYZ method. The choice was made to combine the ABC and XYZ analyses, which will then lead to 9 different classes that the products can be categorized under. Where with the ABC classes a distinction between the volume of sales/revenue/demand is made, the XYZ method separates products based on their fluctuations in demand, on how easy it is to predict these products. The coefficient of variation of the monthly demand of the last twelve months is the parameter that is used to separate and classify products as either X, Y or Z. This parameter measures the variability of a series of numbers, independently of the unit of measurement for these numbers. In essence, the standard deviation of these numbers is divided by the mean of the same set of numbers (Abdi, 2010). Products with a coefficient of variation below 0.5 will be classified as X products, meaning that their demand is relatively stable and easier to predict. Y products are products with a coefficient of variation between 0.5 and 1. These products have some fluctuations in their demand and are therefore harder to forecast. Lastly, the Z products are those products that have a coefficient of variation above 1. These products follow an irregular demand pattern and are very hard to forecast.

4.1.3 Service levels

Then, the service levels come into play. Because there are four different product categories, and there are significant differences between them, as elaborated upon in the previous paragraph, a distinction will also be made between service levels for the various categories. The pleated and honeycell categories are the two categories responsible for the majority of total revenue, approximately 90%, which makes those two categories the most important ones for the company. Therefore, these two categories, together with the roller category, will receive initial service levels that are higher than the levels of the vertical category. The roller category is included with the pleated and honeycell categories, because lead times are significantly longer than for any of the other categories, involving regular shipping from Asia. The various categories and their respective service levels can be seen in Tables 6 and 7 below. With that, the majority of products in the vertical category are produced in-house. Because of that, adjustments can be made quickly, and, if necessary, scaling-up can be done without creating a long lead time. Due to that given, the service levels are lower for this category. Important to note is that there are exceptions in each product category where some products might receive an alternative service level that does not match with the general service level assigned to that class. These products are filtered and manually receive an adjusted service level that does fall within the service level range of that product category.

Service levels	X	Y	Z
A	97%	96%	93%
B	95%	92%	90%
C	92%	85%	80%

Table 6: Overview of service levels per category for pleated, honeycell and roller

Service levels	X	Y	Z
A	95%	93%	90%
B	92%	85%	80%
C	85%	80%	75%

Table 7: Overview of service levels per category for vertical

*4.1.4 R**

When all of this is done, Formula 1 will be used to determine the target inventory level each SKU.

In this study, an addition to the formula will be made, based on the current way of doing things at Lienesch. Throughout the years, Lienesch has learned that some suppliers struggle with meeting the agreed upon lead times. To illustrate, for one of Lienesch's biggest suppliers, their delivery reliability over the past twelve months was 42.3%. This means that of the total amount of products that Lienesch ordered from that supplier in the last year, the agreed upon lead time was met in only 42.3% of the cases. Therefore, Lienesch adds an additional security into the lead times. For products with demand under 150 meters a year, an additional 15 weeks of inventory will be used as the minimum reorder point. This minimum inventory level is the trigger to reorder or reproduce a certain product. These products often have a very inconsistent demand pattern, and Lienesch does not want to risk stockouts. The 15 week buffer should help overcome that. For products with demand over 150 meters a year the same principle applies, the only difference being that the timeframe is 5 weeks instead of 15 weeks. Often times, these products have a more stable demand pattern, which makes it easier to forecast them and creates less need for additional weeks (above the 5) of safety stock. For Lienesch, it is very important that they meet the demands their customers have, their service is critical to them. That is why they have made the deliberate choice to up their R and thus have additional safety stock on hand. They know that it brings about more costs, but they rather spend a little more money on inventory than ending up in the situation where they have to sell the customer 'no' on a regular basis.

For extra context, Lienesch works with a minimum and maximum level of inventory for each product. This helps them streamline their ordering and inventory management process. Whenever the inventory of a product falls below the set minimum, the system is triggered to order or produce again. The aim is to get the inventory levels up to somewhere between the minimum and maximum level of inventory. In some cases, because of the Minimum Order Quantity (MOQ) of the product, the replenishment leads to a level that is above the maximum. As this method is very similar to the already mentioned (R,Q) method, going forward, the minimum and maximum level of inventory will be renamed as R and R+Q respectively.

In this study, the 5 and 15 weeks will be taken into account in the R* calculation, they will be incorporated in the lead time (L) to be precise. The initial lead times, that are available in Slim4, will be adjusted upwards to include these additional weeks. This will lead to higher inventory levels, that reflect the increased safety that Lienesch wishes to have. These numbers might not be the optimal amount of weeks that Lienesch should take into account. Various numbers will be tried and combined to see what happens with inventory levels and possible stockouts.

Lastly, Lienesch also makes a differentiation between products by classifying them as either stock controlled or non-stock controlled. Stock controlled items are regular items that are produced or ordered based on forecasts. Normally these products get sold on a more regular basis and have a higher demand than non-stock controlled items. Non-stock controlled items are items that are only produced or purchased when a customer orders the product. This means that, in theory, the inventory levels for these products would always be 0. Because these items are non-stock controlled, there should be no inventory except for when there is a customer that wants the product. Tying into that, for these items, the earlier mentioned minimum and maximum levels of inventory that Lienesch uses are also 0. Out of the total of 3202 SKUs, 2001 SKUs are stock-controlled, which leaves 1201 SKUs to be non-stock controlled. The focus in this study will be on the first 2001 SKUs.

The aim of this study is to find out what, based on the predetermined optimal service levels, a good target level of inventory per product is. Because of that, the decision was made to set the R* for these non-stock controlled items to 0. Due to the fact that in the current situation a lot of these products do have inventory, these products will be excluded in the comparison between the current situation and the outcome of R*. In a separate way, some attention will be paid to this group of products. As these products are meant to be zero, the R* for these products will manually be set to 0 in the calculation that will be done in the next section.

Next to the first R* outcome, two alternative scenarios will be worked out. In both scenarios, service levels and the amount of weeks of (additional) safety stock will be adjusted, so that this study can present three different scenarios to Lienesch. This might help Lienesch make thoughtful decisions about the future, and what decisions they wish to make with regards to the service levels and the desired height of safety stock.

4.1.5 Warehouse capacity

After this, the warehouse capacity will become relevant. As described, Lienesch is dealing with a limited warehouse capacity, which means that choices with regards to either the service levels or the amount of products per A/B/C category have to be made. Here, the initial amount of inventory, that is reached with using the service levels in Tables 6 and 7, will be compared against the amount of available space in the warehouse.

As briefly touched on in Section 3, Lienesch is currently occupying approximately 90% of their total warehouse capacity, with a total inventory level of 1,028,979 meters. For each scenario that is worked out, calculations will be made as to when, based on the outcome of the R* formula combined with the projected strategic growth per product category, the maximum warehouse capacity of Lienesch will be reached. The board of Lienesch has projected the growth for each of the four product categories up until 2030. Important is that for this year, only the honeycell category is expected to grow with 5%. Starting in 2023, the honeycell, vertical and roller categories are projected to grow 5% each year. The pleated category differs a little from this. In 2023, 2024 and 2025, this category is projected to grow 7.5% per year. Starting 2026, the growth is projected to be 5% per year.

The calculation will be done as follows. It is known what the current level of inventory is (1,028,979 meter), and how much of the total warehouse space is occupied by that amount

(90%). We can then calculate what the maximum amount of inventory is that would still fit in the warehouse. Making that calculation gives a maximum level of inventory of 1,143,310 meters. It is important to remember that this is not an exact calculation, but rather an estimate based on the current circumstances.

Then, the outcome per category will be multiplied with the strategic growth percentage that exists for each category, as elaborated on earlier in this subsection. This will be done for each category, and for each year it will become clear whether or not the projected growth and the levels of inventory that come with that will still fit in the warehouse. With this information, an estimate can be made about approximately when the maximum warehouse capacity would be reached. This information can help Lienesch make strategic long-term decisions with regards to, among other things, possible expansions.

4.2 Data collection

A big aspect of this study is to properly classify, according to the ABC-method, all products Lienesch possesses. Because of that, the main unit(s) of observation will be the data from the operational systems the company uses. This means that quantitative data will be the main source of data used in this paper. All the necessary information will be filtered from these systems and put into a comprehensive Excel sheet, in which the needed calculations will be made.

In the initial data collection, information about all 3282 SKUs was collected. This initial data collection included finding lead times, margins, revenue and demand per SKU over the last twelve months. This information was needed to be able to classify the SKUs according to the ABC-method. For the R* formula, the two most important aspects are the lead times and the average demand of the last twelve months. The latter was needed for some further calculations, as the mean and standard deviation of the average demand were used in the R* formula.

5. Results

The first aspect that will be described in this section is the division of classification of products, based on the combination of ABC and XYZ methods. The outcome that is presented in section 5.1 is the outcome based on the service levels shown in section 4, combined with the division of products according to the ABC-XYZ method, that can be found in Tables 8 through 11 below. As of right now, this is the scenario that seems most suitable for Lienesch. Going forward, this outcome will be named R*. Afterwards, two different scenarios will be presented. One in which service levels have been increased over the whole spectrum, and one scenario in which lower service levels are used. This has been done after consultation with Lienesch, as they perceive receiving multiple scenarios as valuable.

Pleated								
	X		**Y**		**Z**		**Total**	
A	51	4.0%	70	5.5%	32	2.5%	153	12.0%
B	17	1.3%	109	8.5%	124	9.7%	250	19.5%
C	0	0.0%	30	2.3%	847	66.2%	877	68.5%
Total	68	5.3%	209	16.3%	1003	78.4%	1280	100%

Table 8: Division of products in the Pleated category

Vertical								
	X		Y		Z		Total	
A	0	0.0%	5	1.1%	50	10.7%	55	11.8%
B	0	0.0%	0	0.0%	59	12.6%	59	12.6%
C	0	0.0%	0	0.0%	353	75.6%	353	75.6%
Total	0	0.0%	5	1.1%	462	98.9%	467	100%

Table 9: Division of products in the Vertical category

Roller								
	X		Y		Z		Total	
A	5	0.9%	34	6.0%	61	10.8%	100	17.7%
B	0	0.0%	12	2.1%	78	13.8%	90	15.9%
C	0	0.0%	2	0.4%	374	66.1%	376	66.4%
Total	5	0.9%	209	8.5%	513	90.6%	566	100%

Table 10: Division of products in the Roller category

Honeycell								
	X		Y		Z		Total	
A	43	4.8%	66	7.4%	8	0.9%	117	13.2%
B	4	0.5%	91	10.2%	56	6.3%	151	17.0%
C	0	0.0%	21	2.4%	600	67.5%	621	69.9%
Total	47	5.3%	178	20.0%	664	74.7%	889	100%

Table 11: Division of products in the Honeycell category

The way in which this division came to be has been described more extensively in section 4. Three separate ABC classifications, based on revenue, margins and demand, were made and combined into one. The outcome of this way of classifying will be explained briefly per category.

- In the pleated category, 79.8% (1022 products) of the SKUs had the same letter for each of the three categories. 20% (256 products) of the SKUs matched on two out of the three categories, and only 0.2% (2 products) of the SKUs in the pleated category had a different outcome for each of the three individual classifications.
- In the vertical category, 84.6% (395 products) of the SKUs had the same letter for each of the three individual classifications. The remaining 15.4% (74 products) of SKUs had the same outcome for two out of the three classifications. There were no products that had three different outcomes.
- In the roller category, the division was as follows: 74.7% (423 products) of the SKUs matched across all three classifications, 24.9% (141 products) had the same letter in two out of the three sections, and only 0.4% (2 products) of the SKUs had different outcomes in all three classifications.
- In the honeycell category, 92% (818 products) of the SKUs had the same outcome for all three classifications, and 8% (71 products) matched on two out of the three classifications. No products had three different outcomes.

When combining the four individual categories, 83% of the SKUs matched in all three different classifications. 16.9% had the same outcome for two out of the three classifications, and only 0.1% had different outcomes in the three classifications. Then, the XYZ method, based on the coefficient of variation of the demand in the last twelve months, was combined with the ABC method, leading to the division of the nine different categories, as can be seen in the four tables above.

In the next step, the respective service levels, that can be found in Tables 6 and 7, were attached to their assigned categories. Important to note here is that, with regards to the extended lead times, some changes have been made to the 15 and 5 weeks that Lienesch works with right now. In this initial classification, 10 and 4 weeks are used as extended lead times, to create higher safety stocks to deal with uncertainty around suppliers. An exception has been made for the vertical category. This category makes up a very minimal part of total revenue, and the category does not receive as much attention as the other three categories in day-to-day tasks. With that, a part of this category is purchased from suppliers, with very long lead times already installed. The remainder of the products is produced inhouse, with very low and fluctuating demand. Therefore, the decision was made that products in the vertical category would not receive an extended lead time. If needed, Lienesch can adjust very quickly to deal with unexpected demand.

5.1 Outcome R*

In Tables 12 and 13, the outcome of the application of the R* formula is shown. The numbers in the R* columns represent the outcome per category that, in this scenario, can be seen as (near) optimal, based on the use of the said service levels, in both meters and €. For each individual SKU Lienesch possesses, the R* calculation was made. When adding up all the individual outcomes of these SKUs, the totals as presented in Tables 12 and 13 are the result.

	R*	R*+Q	Current inventory	R	R+Q
Pleated	395,993	566,756	534,474	298,075	468,838
Honeycell	64,137	75,655	52,263	53,520	65,038
Vertical	76,023	152,523	196,383	54,197	130,697
Roller	95,875	161,600	103,987	75,153	140,878
Total	**632,028**	**956,534**	**887,107**	**480,945**	**805,451**

Table 12: Comparison of the R* outcome vs the current, minimum and maximum levels of (desired) inventory in m

	R*	R*+Q	Current inventory	R	R+Q
Pleated	€2,243,775	€3,739,178	€3,513,077	€1,885,003	€3,380,406
Honeycell	€1,042,855	€1,261,575	€884,653	€904,226	€1,122,946
Vertical	€32,667	€64,084	€87,970	€23,530	€54,947
Roller	€725,174	€1,356,056	€922,074	€609,891	€1,240,773
Total	**€4,044,471**	**€6,420,893**	**€5,407,774**	**€3,422,650**	**€5,799,072**

Table 13: Comparison of the R* outcome vs the current, minimum and maximum levels of (desired) inventory in €

As has been mentioned in section 4.1.4, non-stock controlled products are excluded in the two tables above. The reason for this is that in an ideal scenario, the inventory levels for these products would be 0. Though, for context, it is valuable to identify how much redundant inventory Lienesch has on hand. The 1201 non-stock controlled SKUs make up a total of 141.872 m of inventory, with a value of €1,468,585. This piece of inventory is something that Lienesch should take a very critical look at, because it is inventory that takes up space and money that could be put to better use. This means that total current inventory is 1,028,979 m, with a total value of €6,876,359.

Later, various scenarios will be worked out in which different service levels will be used, leading to different R* outcomes for the various categories. When comparing the current R Lienesch applies with the R* outcome, a difference of about 150,000 meters and €600,000 can be noted. When adding all the individual SKUs together, Lienesch currently (re)orders or (re)produces at the 480,945 level, whereas this amount lies around 632,028 with the R*. When looking at the monetary aspect, the reordering and/or reproducing happens at the €3,422,650 level for R. With the outcome of the R*, this amount will be around the

€4,044,471 mark. The reason for the R* amount being higher than the current R is in the fact that higher service levels are enforced, leading to higher levels of (safety) stock for products. Both of these amounts are significantly lower than the current level of inventory Lienesch possesses, indicating that Lienesch might want to lower its inventory levels to, among other things, make better use of their limited warehouse capacity and their financial resources.

What stands out is the comparison between the current levels of inventory Lienesch possesses and the outcome of the R* formula. Especially in the pleated and vertical categories very big differences (35% and 158% higher respectively) can be noted. The best explanation for this is that last couple of years, due to the pandemic, sales skyrocketed. The 5% strategic annual growth was exceeded by a lot and adjustments in forecasts were made, leading to high production and purchase amounts. Though, as this year started, sales went down a lot compared to 2020 and 2021. Because of that, there was a lot of stock on hand, and not a lot of demand to meet such inventory levels. Right now, Lienesch is adjusting their production and purchasing behaviour and their forecasts, but these huge amounts of inventory are still present. Most important is that the company is aware of it and is actively working towards solving it. The reason that only the pleated and vertical categories show such big differences, is because the majority of these categories are produced in house at Lienesch, whereas the honeycell and (the majority of the) roller categories are purchased from suppliers. Because the machines that Lienesch operates are very expensive to run, very high MOQs are set for most of the products that are produced in house. This results in high levels of inventory compared to products that are purchased from suppliers, and have way lower MOQs.

5.1.1 Capacity

With the outcomes of the R* formula given in Table 12 something can be said about the current use of capacity. Again, it is important to remember that there is still 141,972 meter of non-controlled stock, that Lienesch still possesses and that should be taken into account here. This will be added up to the outcome of the R* formula to get a reliable picture. For the sake of this projection, the amount of non-controlled stock will be kept constant. As shown in section 4.1.5, the maximum capacity is 1,143,310 meters. Right now, in the 'optimal' scenario as presented in Table 12, (632,028+141,972)/1,143,310, which is 67.7%, of the total capacity would be in use.

Now, the strategic growth percentages are known for each category. They can be found in section 4.1.5. Table 14 below depicts the projected growth per product category for the years until 2026. It is important to note that the numbers that have been used in the projections are averages between the R* and the R*+Q. This has been done because the R* is the minimum level at which reordering or reproducing starts, and the average inventory levels normally fall somewhere between the R* and the R*+Q. Therefore, the R* might not be a realistic number to use in certain projections. This has the consequence that the estimated inventory levels might be higher than expected, but that is not necessarily a bad thing, because it might help Lienesch stay ahead of possible situations of overcapacity.

	2022	2023	2024	2025	2026
Pleated	481,375	517,478	556,289	598,011	627,911
Honeycell	73,391	77,060	80,913	84,959	89,207
Vertical	114,273	119,987	125,986	132,285	138,900
Roller	128,738	135,175	141,934	149,030	156,482
NS inv	141,972	141,972	141,972	141,972	141,972
Total	**939,749**	**991,672**	**1,047,094**	**1,106,257**	**1,154,472**

Table 14: Projection of amount of inventory (in m) per category based on the R* formula

The amount of the honeycell category in 2022 has already been adjusted towards the growth percentage of 5% for that calendar year.. What becomes clear from this table, is that with the outcome of the R* formula as shown above, the warehouse would be full in 2026. As said, several assumptions about, among other things, the warehouse capacity and future strategic growth rates have been made, making this projection not completely airtight. Nevertheless, with the given information, given is that in 2026 the total inventory rises above the mentioned 1,143,310 meters for the first time. With this scenario and the current (maximum) capacity available, Lienesch's warehouse would be too small in 2026. This does not mean that Lienesch should wait until 2026 to act on this. On the contrary, it would be a smart thing for the company to act proactively and see if there are ways in which more room for inventory could be created.

For context and because it is good comparison material, if Lienesch would keep going with their current levels of inventory, the maximum warehouse capacity would be reached in 2024 already, as can be seen below in Table 15.

	2022	**2023**	**2024**
Pleated	534,474	574,560	617,652
Honeycell	54,876	57,620	60,501
Vertical	196,383	206,202	216,512
Roller	103,987	109,186	114,646
NS inv	141,972	141,972	141,972
Total	**1,031,692**	**1,089,540**	**1,151,282**

Table 15: Projection of amount of inventory (in m) per category based on current inventory levels

This given and outcome was one of the reasons for doing this study, and the concern Lienesch had was a fair concern. Optimizing their inventory levels will be a great way of making sure that there will be plenty of capacity the coming years, given the growth trajectories that are available now.

5.2 Scenario with higher service levels

As mentioned, additional scenarios would be presented, besides the outcome that has just been described earlier in this section. The first scenario is a scenario in which the service levels have been put higher for all categories. The significance of this scenario is that it would present Lienesch with numbers that could be seen as optimal in case they want to build in additional security into their inventory levels. In Table 16 below, the service levels that have been used can be found.

Service levels	**X**	**Y**	**Z**
A	99%	97%	95%
B	97%	95%	93%
C	95%	90%	80%

Table 16: Overview of the service levels for the various categories

Another thing that has been added in these calculations, is the change of the lead times. Where in the start scenario 10 and 4 weeks were used as additional safety stock, here 11 and 5 weeks were used for the pleated, honeycell and roller categories. Because of the fact that this scenario is to decrease the risk of potential stockouts, the weeks of safety stock that Lienesch works with has been raised. For the vertical category, an additional 3 weeks were added for all SKUs. Here only 3 weeks were used because this category is an exception compared to the other three categories, and the lead times are already very high compared to the other categories. Afterwards, new calculations were made based on these service levels and weeks of safety. The logical consequence of this adjustment is that the R* outcomes would go up. In Table 17 below, the results of this new calculation are shown. Important to note is that the vertical category has not been changed, as has been explained before in this paper.

	R*	R*+Q	Current inventory	R	R+Q
Pleated	459,395	630,158	534,474	298,075	468,838
Honeycell	79,149	90,667	52,263	53,520	65,038
Vertical	104,942	181,442	196,383	54,197	130,697
Roller	111,144	176,869	103,987	75,153	140,878
Total	**754,630**	**1,079,130**	**887,107**	**480,945**	**805,451**

Table 17: Outcome R* in m

	R*	R*+Q	Current inventory	R	R+Q
Pleated	€2,569,735	€4,065,138	€3,513,077	€1,885,003	€3,380,406
Honeycell	€1,274,561	€1,491,281	€884,653	€904,226	€1,122,946
Vertical	€44,297	€75,714	€87,970	€23,530	€54,947
Roller	€813,275	€1,444,157	€922,074	€609,891	€1,240,773
Total	**€4,701,958**	**€7,078,380**	**€5,407,774**	**€3,422,650**	**€5,799,072**

Table 18: Outcome R* in €

As was expected in this scenario, because the service levels were increased compared to the numbers in Section 5.1, the outcomes of the R* and R*+Q are higher than in the initial calculation that was made in Section 5.1. This also means that the differences between the current R and R+Q and the outcomes in Tables 17 and 18 are more significant. This would mean that for most products, (safety) stock levels would increase even more than in the previously discussed scenario. Again, this makes sense, because the higher service levels would give extra security for Lienesch in terms of delivery reliability.

5.2.1 Capacity

Just as has been done in section 5.1, for this scenario, too, a projection about the future capacity will be made. The only difference with section 5.1 are the beginning numbers in the R* category. Important to remember is that again the average of R* and R*+Q was used as starting numbers for the projections. Except for that, all the underlying assumptions and used growth percentages are identical. This again means that the amount of honeycell in 2022 has already been calculated based on the growth percentage of 5%

	2022	2023	2024	2025
Pleated	544,777	585,635	629,558	676,775
Honeycell	89,153	93,611	98,292	103,206
Vertical	143,192	150,352	157,869	165,763
Roller	144,007	151,207	158,768	166,706
NS inv	141,972	141,972	141,972	141,972
Total	**1,063,101**	**1,122,777**	**1,186,458**	**1,254,422**

Table 19: Projection of amount of inventory (in m) per category based on the R* formula used in scenario 1

In this scenario, where service levels where higher than in the initial classification, just as the amount of (additional) weeks of safety stock, the maximum capacity of the warehouse would be reached in 2024, as projected inventory levels reach above the level of 1,143,310. This is still a few years away, but especially in this scenario, it would be wise for Lienesch to start making concrete plans about what steps could be taken to make sure inventory will still fit in the coming years. Because as said, these numbers are rough estimates, and there might be a scenario in which the maximum warehouse capacity will be reached even sooner than 2024.

5.3 Scenario with lower service levels

In this second alternative scenario, the service levels in all categories have been lowered, as can be seen in Table 20. Though, in this scenario, the amount of weeks of safety stock has not been adjusted from the initial scenario, which means that 10 and 4 weeks are used as weeks of (additional) safety stock. This was done after consultation with Lienesch, as they see the mentioned 10 and 4 weeks as the absolute minimum amount of weeks that they need.

Service levels	X	Y	Z
A	95%	93%	90%
B	93%	90%	85%
C	90%	85%	75%

Table 20: Overview of the service levels for the various categories

As said, the service levels in this category are lower than what they were in the initial scenario. The reason for this is to give Lienesch an idea of what would happen to (optimal) inventory levels when lower service levels were used. In Table 21, the outcomes of the calculations according to the R* can be found.

	R*	R*+Q	Current inventory	R	R+Q
Pleated	371,204	541,967	534,474	298,075	468,838
Honeycell	59,813	71,331	52,263	53,520	65,038
Vertical	76,023	152,523	196,383	54,197	130,697
Roller	89,125	154,850	103,987	75,153	140,878
Total	**596,165**	**920,671**	**887,107**	**480,945**	**805,451**

Table 21: Outcome R* in m

	R*	R*+Q	Current inventory	R	R+Q
Pleated	€2,084,666	€3,580,069	€3,513,077	€1,885,003	€3,380,406
Honeycell	€973,010	€1,491,281	€884,653	€904,226	€1,122,946
Vertical	€32,667	€64,084	€87,970	€23,530	€54,947
Roller	€670,115	€1,300,997	€922,074	€609,891	€1,240,773
Total	**€3,760,458**	**€6,436,431**	**€5,407,774**	**€3,422,650**	**€5,799,072**

Table 22: Outcome R* in €

Here, the R* and R*+Q are way closer to the current R and R+Q levels Lienesch operates. This is a logical consequence of the fact that service levels have been adjusted downwards, leading to lower (safety) stock levels for most products. Nevertheless, the R* is still higher than the current R, meaning that Lienesch should probably adjust their R upwards. This scenario might not be the most realistic and workable for the company, as they are very big on being able to always provide customers the products they want. With lower service levels, chances for stock-outs increases, a risk that Lienesch might not be willing to take.

5.3.1 Capacity

For this second alternative scenario, a projection about the future levels of inventory was made. Here, just as in the other two projections, the honeycell amount in 2022 has already been adjusted to the 5% growth that was projected for that year. For visibility purposes, the years 2025 to 2029 have been left out.

	2022	2023	2024	2025	2026	2027
Pleated	456,586	490,830	527,642	567,215	595,576	625,355
Honeycell	68,851	72,293	75,908	79,703	83,688	87,873
Vertical	114,273	119,987	125,986	132,285	138,900	145,845
Roller	121,988	128,087	134,492	141,216	148,277	155,691
NS inv	141,972	141,972	141,972	141,972	141,972	141,972
Total	**903,670**	**953,169**	**1,006,000**	**1,062,392**	**1,108,413**	**1,156,735**

Table 23: Projection of amount of inventory (in m) per category based on the R* formula used in scenario 2

The outcome of this projection is that the maximum warehouse capacity at Lienesch would be reached in 2027, as this is the year in which the projected total inventory level goes above the 1,143,310 limit for the first time. This scenario might become relevant in case Lienesch might experience unexpected (financial or logistical) difficulties, and downward adjustments are needed.

5.4 Integration of aspects

In this subsection, the ABC-XYZ analysis with its corresponding service levels, the inventory levels that are a result of those service levels, and the (limited) warehouse capacity will be integrated together. A brief example to show proof of concept will be given here. In case the warehouse overflows, meaning there is too little capacity to store all products that are present, decisions will have to be made about inventory. The two important pieces in this are the loss of service and the available capacity. The trade-off here is gaining as much available warehouse capacity, while losing as little service as possible. Which service levels could be adjusted downwards to create enough available space again, without having to compromise towards customers too much?

In this example, there are three products. See Table 24 below.

	Average demand	Inventory	Service level
Product A	120	114	95%
Product B	110	99	90%
Product C	100	85	85%

Table 24: Overview of products

Currently, total inventory is 298 (114+99+85). Though, because the maximum warehouse capacity is 297, decisions have to be made with regards to the inventory levels of products A, B and C. Now, the impact for each product about decreasing inventory with 1 unit will be calculated. For product A, service is currently at 95% (114/120). When decreasing inventory to 113, service will decrease to 94.2% (113/120). For product B, service would drop from 90% (99/110) to 89.1% (98/110). For product C, service would drop from 80% (85/100) to 84% (84/100). Because capacity decreases by 1 unit for each product, the loss of service for product A is 0.8%, for product B 0.9% and for product C 1%.

Then, to find out how big the impact is, the loss of service will be multiplied by the average demand for each product. This gives us the following ‘impact’ numbers. For product A the impact is 0.96 (120*0.8%), for product B the impact is 0.99 (110*0.9%), and for product C the impact is 1 (100*1%). This calculation shows that the impact is the smallest for product A, meaning that it might be smartest to decrease inventory for that product by 1 unit. This will lead to the smallest loss of service, and inventory would fit in the warehouse again.

As said, this is a simplified calculation, but it could possibly help Lienesch determine which products should be considered first when in need of extra warehouse space. The best way for Lienesch to go about this is to identify products per product category (pleated, honeycell, vertical, roller) that might be suited to have lower inventory levels.

6. Conclusion

The aim of this study was to find out whether or not there was a certain level of inventory for Lienesch that could be identified as (near) optimal. The following research question was phrased for that purpose: "*How can Lienesch's inventory levels be optimized, using the ABC-XYZ method of classification, setting service levels, and taking into account a limited warehouse capacity?"* A couple of elements, namely the ABC-XYZ analysis, service levels and a limited warehouse capacity, were important factors in getting to a certain level that might be (near) optimal. But, maybe even more important than the actual outcome of the used formula, is the thought process behind getting there, using the mentioned elements to create a process that can systematically help Lienesch keep their inventory at a certain level that is seen as optimal, even when quantities increase or decrease.

In Tables 25 and 26, a complete overview of the current situation and the various scenarios is given. One of the most important findings is that Lienesch should probably take a critical look at their R and R+Q levels. The R* outcomes in both Tables are a good indication of what these new levels might be. The 632,028 can be identified as the ideal (cumulative) point where Lienesch should reorder and/or reproduce. With each SKU having a certain MOQ, the result is that total inventory will be between the R and R+Q parameters. This is significantly higher than the current R and R+Q levels Lienesch operates. The main reason for this is the new ABC-XYZ classification and the corresponding service levels, that are higher than they were in the past.

	R	**R+Q**	**R in €**	**R+Q in €**
Current situation	480,945	805,451	€3,422,650	€5,799,072
R*	632,028	956,534	€4,044,471	€6,420,893
Scenario 1	754,630	1.079,130	€4,701,958	€7,078,380
Scenario 2	596,165	920,671	€3,760,458	€6,436,431

Table 25: Overview of the outcomes of the various scenarios presented in section 5

In Table 26, the current/projected meters column shows the current amount of meters for the 'current situation' header. For the R* and scenarios 1 and 2, the average of the R and R+Q is projected. As expanded upon in Section 5 before, this number is used because it might give a more reliable picture for making projections about future capacity in the warehouse. The non-stock controlled inventory is included in the projections, because it is still there and takes up space.

	Current/projected meters	NS inventory	Total inventory	Warehouse full
Current Situation	887,107	141,972	1,029,079	2024
R*	797,777	141,972	939,749	2026
Scenario 1	921,129	141,972	1,063,101	2024
Scenario 2	761,698	141,972	903,670	2027

Table 26: Overview of the amount of meters and the projections for the future

These results might be a good spot on the horizon for Lienesch to works towards. Obviously, it is not possible for the company to just lower their inventory overnight. This will be a gradual process that takes time to become successful. Especially when the company keeps growing, it will stay a challenge to keep inventory levels at (near) optimal heights. Three different scenarios have been presented, and dependent on what direction the company wishes to go, choices can be made about classifying products and attaching service levels.

6.1 Recommendations

After conducting this study and comparing current practices at Lienesch to existing literature that is out there, some important recommendations can be made about relevant topics in this thesis.

The first two recommendations are related to each other. Firstly, Lienesch should seriously consider adding the XYZ analysis to their already existing ABC analysis. Using both of these methods will give a more comprehensive image about how an SKU performs, which is critical. In this study, three separate ABC classifications, based on margins, revenue and demand, were conducted and combined into one comprehensive classification. This is a good starting point for dividing your products and deciding how to treat each category in terms of service levels and ordering policies, but it might not be detailed enough. That is where the XYZ method comes in. Here, products are separated based on the structure of their selling rate, on how much fluctuation there is in demand. When combining the said ABC classifications with an XYZ classification, a more complete picture about a product. Lienesch would end up with 9 different categories, which is still manageable, for which they can create different rules when it comes to (re)ordering or producing. Classifying like this makes it also easier to filter out products that are critical for the company and products that probably will not need as much attention.

The second recommendation ties into this. Right now, Lienesch uses service levels that, according to literature, might not necessarily be logical and correct. Therefore, careful attention should be paid to (re)setting these percentages for the various categories. Especially when the company decides to implement the ABC-XYZ classification for its products, it is crucial that these various categories receive service levels that reflect their significance. In section 4, Tables 6 and 7 to be precise, a first shot was given at determining service levels per category. Obviously, these percentages are not set in stone, but something in this direction might be what Lienesch would be looking at when they decide to use the ABC-XYZ method.

The third recommendation has to do with the recommendations above. Right now, the ABC classification Lienesch has created is based on different parameters from the ones that Slim4 uses. This might not be a problem in itself, but it becomes problematic when the service levels produced by Slim4, related to their ABC classification, is used for the ABC classification from Lienesch. On the one hand, there is Lienesch using margins and revenue as parameters, and on the other hand there is Slim4 using sales and order lines as parameters. Combining and comparing is what Lienesch is doing right now, and this might give a troubled image for a lot of SKUs. Therefore, the recommendation would be to align parameters for both in the future.

Fourthly, Lienesch might want to take a good look at their minimum (R) level of inventory. As described, Lienesch currently tweaks these levels by adding additional weeks of safety stock. This results in R's that might be (unnecessarily) high, bringing about higher levels of inventory and extra costs for the company. Right now, Lienesch adds an extra 15 weeks of inventory, based on the current forecasts, to the R of products with an annual demand that is lower than 150 meters. For products with demand higher than 150 meters a year, 5 weeks of additional safety stock is held on hand. One might argue that products with lower demand should have more additional weeks of safety stock and vice versa. Though, for Lienesch, the complexity is in the fact that most products with demand below 150 meters are products with a very irregular demand pattern, which makes it very hard to predict when they will be needed. Though, given the current circumstances, in which Lienesch's production capacity is not running at full speed, it could be a good idea to bring down the amount of weeks of additional safety stock. In case there is unexpected demand, scaling up could be done in a matter of days.

Then, the capacity problem Lienesch is facing. This is currently a very hot topic at the company. As mentioned earlier, if the company would keep going with current inventory levels, the warehouse would be completely full in 2024. Because that point might not be too far away, the company is already taking clear steps towards deciding what to do next. Expand the current warehouse? Purchase additional warehouses? If the company will adopt aspects of the already made recommendations, it will probably lead to their inventory levels decreasing significantly to what the current levels are. A logical consequence would be that there would be more for additional products in the warehouse. This might mean that expansions in terms of warehouse capacity can be delayed or even be thrown overboard all together.

The next recommendation is related to this capacity problem. Lienesch differentiates products as stock controlled and non-stock controlled items. In the perfect scenario, Lienesch would have no inventory at all for non-stock controlled items, because these items would only be ordered or produced when there is an order for that item. In the current situation, Lienesch possesses 141.972 meter of non-stock controlled inventory, with a total worth of €1.468.585. Lienesch should make great efforts to get rid of these products. Getting rid of (a big part of) 141.972 meter of inventory would make a very big difference in the available space in the warehouse. 13.8% (!) of the total warehouse inventory is inventory that should, in an ideal scenario, not even be present. Action plans should be made, all the way from the top of the organization, to really push for these items to get sold. Reducing prices, organizing auctions or simply throwing away old products are just some examples of what could and should be done with these products.

These last two recommendations are very significant for Lienesch, because implementing them could alter the strategic course of the company. As said, the company is currently in the middle of making decisions with regards to expanding or purchasing warehouse space. This would bring about major financial investments that will have an impact for years. Though, if the ABC-XYZ classification with their respective service levels would be implemented, and real efforts would be made to get rid of the non-stock controlled inventory, a lot of warehouse space would become free again. As a consequence, Lienesch might be able to delay the decision to invest in additional warehouse space.

6.2 Limitations

During the course of writing this thesis, a few limitations were encountered. First of all, to be able to work with the standard deviation and the mean of the demand in the past twelve months, the assumption that the demand was normally distributed had to be made. This is a limitation, because it does not precisely represent reality and might therefore give a little bit of a troubled image. But for the sake of this thesis, that assumption had to be made. Another limitation, specifically for Lienesch, is that only the end products that are located in their warehouses in Haaksbergen are taken into account in this thesis. In their warehouses in Haaksbergen, a section is also dedicated to storing materials that are used for the production of end products. This might put a limit on the applicability for Lienesch, because these products take up inventory, money and space as well. Beforehand, excluding these products was agreed upon, but it can nevertheless be seen as a limitation.

The fact that for the R* calculation the demand of the last twelve months was used, can be interpreted as a limitation. Due to constantly changing circumstances in basically any environment, it might not be accurate enough and outdated to use data that goes back as far as a year. Instead, measuring the forecast reliability, which means comparing forecasts to actual demand in that time period, could give a more complete picture. If you know how much your forecast is off on average, it can help you make better predictions about future forecasts.

For the products that Lienesch produces inhouse, the assumption was made that the components that are needed for the production of these SKUs are always present and never delayed. This is obviously not always the case, but having to take extended lead times of components into account for this thesis would make things very complicated.

Another limitation that might complicate things for Lienesch is that a lot of their production items have a very high MOQ. Because it is very costly to run their machines, Lienesch has installed MOQs that are high enough so they do not lose money when operating the machines. This might complicate reaching optimal levels of inventory. Say that for example product X needs an additional 100 meters to reach (near) optimal levels of inventory, but its MOQ is 1000 meters. This would make it very hard for products to reach optimal levels of inventory. Therefore, having to deal with very high MOQs can be seen as a limitation.

With regards to the warehouse capacity, there might be some limitations too. The projections carry some assumptions. The growth percentages are estimates (made by the board), and different outcomes might impact the consequences it has for the available warehouse capacity in the future, specifically when and if Lienesch would reach its maximum capacity. Also, the non-stock controlled inventory was kept constant in the calculations, which again is an estimate. The reason for this is that Lienesch would ideally see it go down. But, when the company is growing and there are more products, chances are that this level will go up. Therefore, the decision was made to keep it constant. Yet another piece tying into the warehouse capacity that might complicate things is the estimate about the total amount of meters (maximum capacity). There will probably be vast differences between the theoretical and the actual amount of meters available. Think of things like pallets that are not fully stocked and some shelves that might even be empty. The 90% assumption is a reasonable one, but it is not completely accurate and precise.

Another limitation of this study is that it was conducted at Lienesch, a SME active in the textile industry. The types of products that are prevalent in this industry do not share a lot of similarities with many other industries, and therefore it is a limitation that this study has been conducted from just the perspective of a company in the textile industry.

6.3 Future Research

For future research, it might be an option to improve the R* formula by using data that involves the forecast (reliability) rather than just demand in the past. Right now, this data was unavailable at Lienesch, but for future research it could be a good idea to use that data. This would give a more realistic image of the current situation the company is in, and therefore show levels of inventory that might match the present more.

Also, it would be a good idea to try out the used steps in a company that is not active in the textile industry. As said, the textile industry has some characteristics that are industry specific, and it would be interesting to see if the same process could be applied in other industries too.

Another aspect that would be interesting and relevant for future research is incorporating stochastic lead time. In this study, the assumption that lead time is fixed has been made, but that is obviously not always the case. It could be a very significant topic for future research if similar steps could be taken with stochastic lead times.

Next to that, another angle for future research would be to analyse the implementation of the steps that have been described in this research. What works well and where lies room for improvement? Possibly even making real-time adjustments could be a part of a study of that kind.

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