INCREASING THE AVAILABILITY OF PERSONAL PROTECTIVE EQUIPMENT

IN A BIG AD HOC SERVICE COMPANY

Public version

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MANAGEMENT SUMMARY

This research is written for Company X. Company X is a worldwide value-driven provider of fully integrated operations, maintenance, modification and asset integrity solutions. This research, however, only addresses the 13 locations of Company X in The Netherlands. Since Company X operates in a variety of industries where challenging and dangerous terrains are no exception, working safely is extremely important. To ensure the safety of its employees, Personal Protective Equipment (PPE) need to be available at all times. At this moment this is not always the case, which results in a business that cannot continue. To solve this issue, locations sometimes buy PPE from non-contracted suppliers nearby. This is called Maverick Buying (MB) and leads to using uncertified or unqualified supplies and higher uncontrollable costs. 14.5% of the total spend on PPE is made at non-contracted suppliers.

The availability of PPE at the Company X locations is sometimes low for two reasons. Firstly, the lack of a proper inventory management system. All locations manage their inventory in their own way and the way of working is not aligned. Their ERP systems are not fully utilized; therefore, demand data is unavailable to determine proper parameters.

The second reason is the performance of the contracted supplier, which is commonly lacking in terms of delivery times. When looking at the most bought items, shoes and gloves, they both are delivered with a fill rate of around 76%. Company X also uses items with a Company X logo attached to them. The logos are attached to the item after ordering, so there is no dedicated stock at the supplier with items where the logo is already attached. The contracted delivery time is five working days, but only 57% of the orders are delivered within these five days.

To improve the availability of PPE at the Company X locations the following research question is addressed within this thesis:

"How should Company X allocate their PPE stock in their supply chain to ensure the satisfaction and safety of its employees while reducing (extra and hidden) inventory costs?"

To be able to answer this question, the first step is improving the inventory management. With demand data from one location, a new way of working is established, focusing on the availability and inventory cost of the items. Target fill rates are based on criticality and not only on the costs, to ensure a fitting classification and policy. After deciding what the best policy is for each item, the total cost of inventory is improved by 43.3% when comparing it to the situation now. With this new policy all target fill rates are met and the ready rate improved from 0.9886 to 0.9920.

To get an idea of the impact of an unreliable supplier, some experiments were performed. These show that the impact is significant, costs can be almost 21% higher in comparison to a reliable supplier that can deliver within their contracted delivery window.

Company X suggested putting dedicated stock at the supplier to ensure faster delivery and increase the availability of the logo items. By comparing the costs of having items in stock at the Company X locations versus the costs of ordering every item separately from the dedicated stock at the supplier, the trade-off is made. It became clear that only for one certain type of item (the parkas) it is profitable to have stock at the supplier. For the other logo items, it is more profitable to have some stock at the locations to increase the availability. Since shoes are most bought at a non-contracted supplier, I also suggest

placing some shoe stock at all locations to decrease the change of maverick buying. This will cost roughly €6.550,- for one year.

The above-mentioned solutions will contribute to the decrease in Maverick Buying since the availability at the locations is higher when implementing a proper inventory management system. There are however more solutions to Maverick Buying regarding inventory management in which Company X should do further research in. One of the solutions is Vendor Managed Inventory (VMI), where the supplier is in charge of the stock at the locations. They obtain in this case more demand data and can respond fast to changes in this demand.

The above-mentioned solutions will however not improve the reliability of the supplier but are only a means to deal with it and ensure a higher availability at the locations. Solutions to improve the reliability of the supplier are also VMI since the supplier then has more insights into the demand on locations. Another possible and suited solution is Performance-Based contracting, where the supplier is motivated to reach the contracted delivery times, using bonuses when performing as contracted and penalties when performance is lacking.

PREFACE

In front of you lies my master thesis "Increasing the availability of Personal Protective Equipment in a big ad hoc service company", which marks the end of my study Industrial Engineering and Management. I conducted this thesis at Company X for their Procurement department at their headquarters in Utrecht.

It all started almost a year ago when John received my open application and immediately felt the need to contact me. They were having trouble with the availability of PPE and were looking for someone with more experience in the logistic field. I therefore would like to thank John for the opportunity to participate and be a part of such a big company.

I also want to thank my Company X supervisor Gudi for the weekly meetings filled with critical questions that encouraged me to get the most out of it and to fully satisfy Company X. I want to thank Fleur, for helping me understand the somewhat complex company and their different way of working.

I am also grateful for the support of my university supervisor Matthieu van der Heijden for the monthly meetings, the feedback and his knowledge and expertise on the subject. He guided me in the right direction and pointed me at details I would otherwise overlook.

Lastly I would like to thank my family and friends for being there when my stress levels were raising. They provided a space to talk and relax. In particular I want to thank Silke for being my layout expert, Laurens for reading trough the report and Irmak for fixing my Excel struggles.

I am looking forward to my coming time at Company X, where I will be implementing my thesis and guide Company X to a more quantifiable future to eventually get the most out of their supply chain management.

Femke Binnenpoorte,
November 2022

CONTENT

List of figures

List of Tables

CHAPTER 1 – INTRODUCTION AND APPROACH

1.1 Company

This thesis is written for Company X. Company X is a worldwide value-driven provider of fully integrated operations, maintenance, modification and asset integrity solutions.

The research will focus on the European part of the company, particularly the thirteen locations in the Netherlands. These different locations are discussed later.

Company X operates in a variety of industries where challenging and dangerous terrains are no exception, therefore working safely is extremely important and their core value. To ensure all employees work in a safe environment, clothing and other Personal Protective Equipment (PPE) are important. These need to be available at all times to ensure the continuity of the business.

1.2 Research Motivation

Unfortunately, PPE are currently not always available when they are needed, as Company X has problems with its inventory management. The entities sometimes solve this problem by buying from non-contracted suppliers, also known as Maverick Buying, which can lead to using uncertified or unqualified supplies and higher uncontrollable costs. The problem of uncontrollable costs arises because all locations use different systems and ways of working, leading to a loss of insight into the total costs. For example, when Maverick Buying occurs, many extra process costs need to be taken into account, because for example, extra checks that need to be done. The last issue is the dissatisfaction of some employees: they complain about the performance of the supplier of the PPE. Therefore, Company X wants to reconsider their inventory management to lower its costs and ensure the safety and satisfaction of its employees.

1.3 Problem description

Company X and its supplier for PPE agreed on a list of qualified PPE, the PPE catalogue. All PPE satisfy norms that are needed for specific working activities, for example, protection from extreme heat or chemicals. In this research, the division of PPE and clothing is used. All clothing is considered PPE, but not the other way around. Around 100 different items are on this list, which results in 600 Stock Keeping Units (SKUs). This amount is due to the fact that there are many size ranges of several products like shoes, jackets and overalls. Of those 600 SKUs, 70-80% are clothing, 40-50% have a logo (all clothing) and 15-20% are washed and repaired at an external company. Those numbers are visualized in Figure 1.

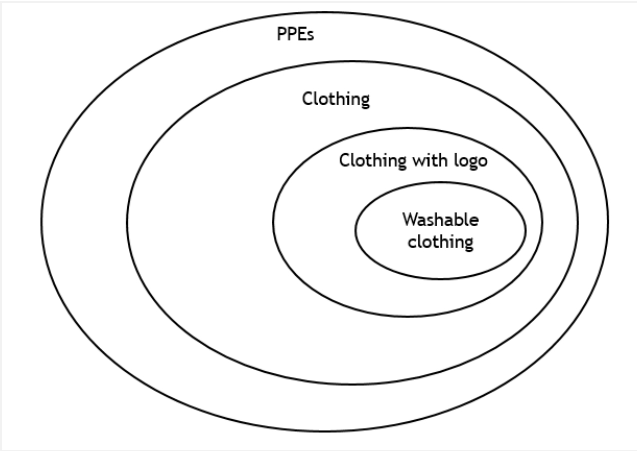

Figure 1: PPE catalogue division

One of the reasons that certain locations resort to Maverick Buying, is the low availability of the PPE. According to Company X, this is due to the lack of a uniform way of working. All locations manage their inventories in a different way; some locations have certain PPE in stock while others don't.

Another aspect of the cause of the lower availability of PPE is supplier issues. Firstly, lead times are long and unpredictable for some products, caused mostly by the pandemic resulting in scarcity. Company X's supplier guarantees delivery in 48 hours for regular PPE (without Company X logo) and 5 working days for PPE with a logo. In some extreme cases this can take up to several weeks due to the unavailability of clothing. Secondly, most of the clothing needs to be provided with a logo. So, the logo and the clothing need to be in stock at the supplier. This normally takes around 5 days. However even when the supplier delivers in 5 days, employees are not completely satisfied, since all other PPE can be delivered within the time window of 2 days. When ordering logo and non-logo items together, the order is shipped according to the longest lead time or split if preferred. This is the result of the fact that their supplier has no dedicated stock (with logo) for Company X.

Explanation of the process

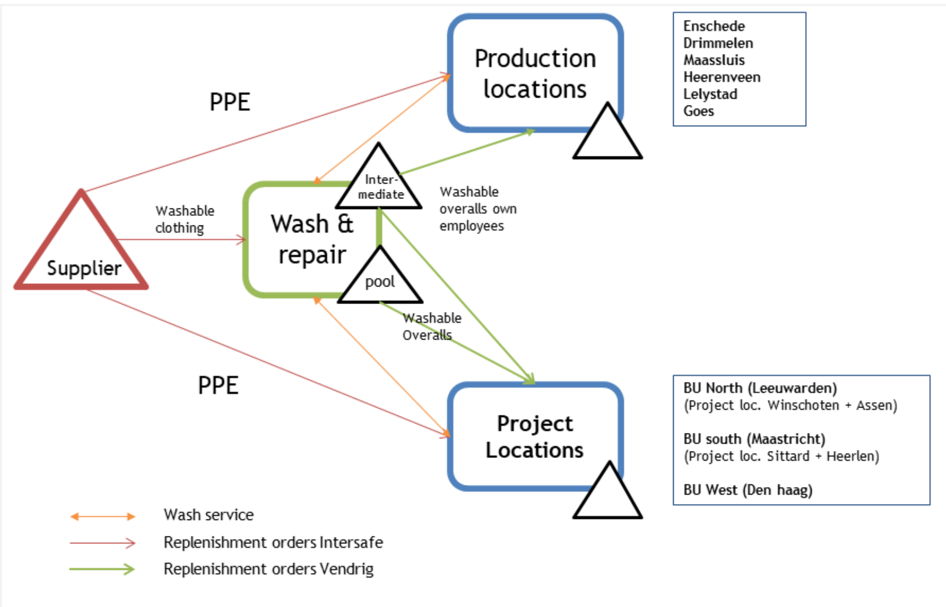

Figure 2: The supply chain

Considering the process of the work clothing and PPE, there are three stakeholders which are visible in supply chain in Figure 2. Company X itself, its supplier and the wash and repair service for the clothing. They all have a certain amount of stock on hand.

Supplier of PPE

They ensure that fast movers are in stock, so Company X can order and receive the items within their agreed time window. To make it clearer, the supplier serves all their customers from the same stock. There is no dedicated stock for Company X, but after a logo is attached to the clothing, it is owned by Company X.

Repair and Wash services

All overalls are washed and repaired here. Vendrig is responsible for the safety of the clothing, by providing special protection layers and ensuring that outgoing clothing satisfies certain standards. There are two different types of stock at Vendrig, pool stock and their intermediate stock.

Intermediate stock

When the overalls do not satisfy the technical standards, there are two options. They can be repaired or recycled. When recycled, the intermediate stock is used to provide the operator with a new one. The same holds for a new employee who needs his first overall.

Pool stock

When Company X uses temporary workers for projects, the pool stock is used. Project leaders will request the number of overalls they need in advance. The projects vary in duration and size. Therefore, the stock levels vary a lot.

Company X

There are several locations where Company X has some items in stock, the three Business Units and their other locations. All locations work with a floor stock, consisting of commonly used basic items like a helmet, gloves and protection glasses.

Project Locations

The projects are supported by the Business Units (BU), located in Den Haag, Leeuwarden and Maastricht. There all the workers get their equipment and PPE. The number of employees varies from 100 to 400 per center. The Business Units have a large assortment of PPE, around 30% of the PPE catalogue (basic items plus more clothing and shoes). The way of working regarding ordering and managing their stock is different per location. In BU South they, for example, use a Material Requirements Planning (MRP) to see which items need to be ordered. This MRP run is based on a fixed reorder point, which they evaluate every half a year.

Production Locations

It differs per location what they do and how they work. The items in stock at these locations differs, some only have their basic items in stock, whereas some have more items. Since these locations are smaller, varying between 15-100 workers, their inventory is managed in a different way and similar to the situation for the business Units, there is no fixed way of working. A more elaborate explanation about the way of working is discussed in the next chapter.

Problem cluster

In Figure 3, all the problems and their relations are visualized in a problem cluster. Some of the problems are clustered according to color. Below the problems are described per color cluster.

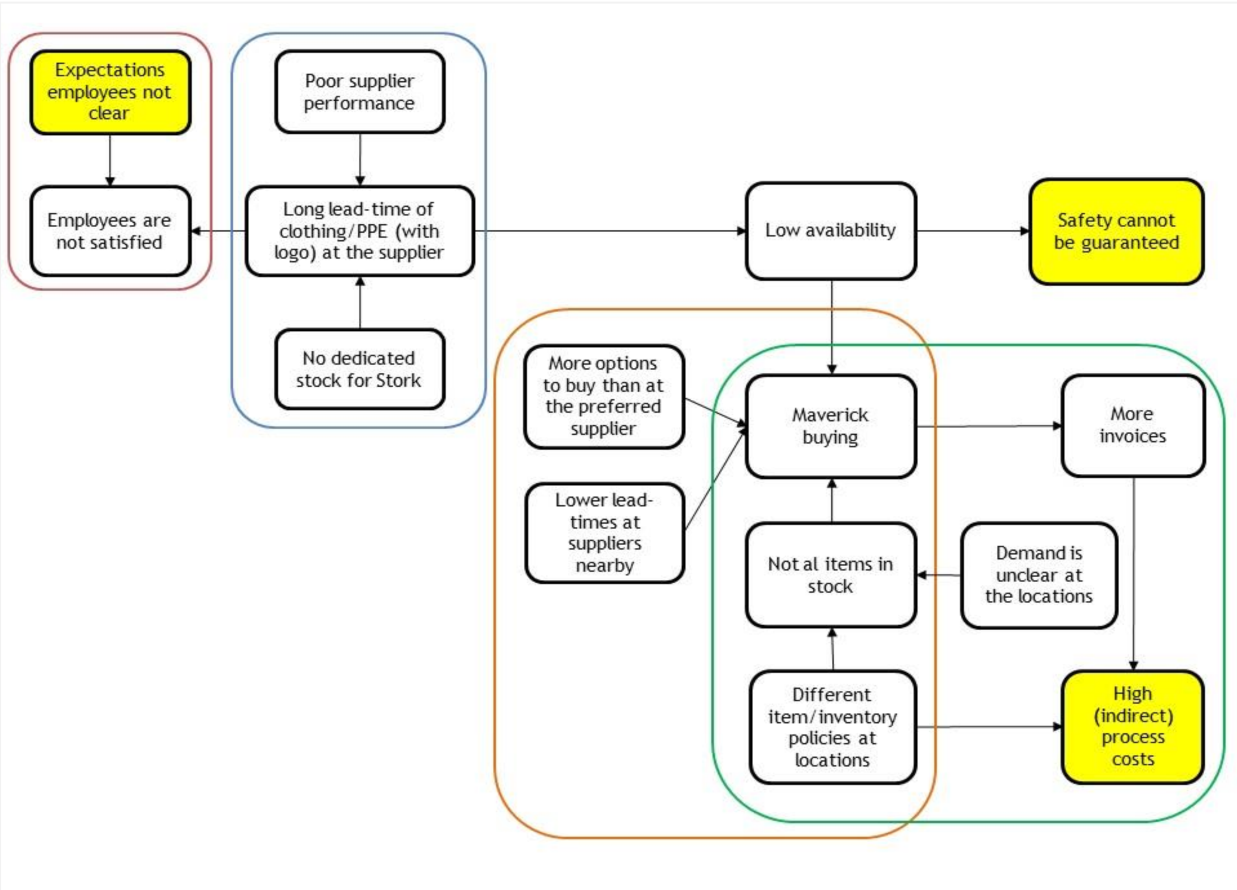

Figure 3: Problem cluster

Red problems

Employees, especially logistics employees, are not totally satisfied with the way of working. They, for example, cannot understand why clothing with a logo has a delivery time of 5 working days instead of the 2 days of regular items. Orders will be shipped according to the longest delivery time, and therefore other items will also be late. The supplier can deliver two separate orders, but this is not cost-efficient.

Blue problems

The longer lead times for clothing with logos are due to the fact that the supplier does not work with dedicated stock for Company X. Another aspect is the overall lower performance of the supplier.

Orange problems

Maverick Buying is the result of several factors. The first is the overall lower availability of clothing at the supplier and the fact that not all locations have all items from the PPE catalogue in stock. This is due to the lack of uniform items, the inventory policy at these locations and the demand at the locations is not known. The second aspect is a more isolated cause. There are more options to buy at suppliers other than Company X its contracted supplier and some employees have different wishes and logistics will listen to those. At suppliers nearby, the lead times are also lower most of the time since employees will drive to the nearest supplier and get shoes within less than an hour.

Green problems

The costs of inventory are high and hard to trace. There are hidden costs in the process, which are due to the fact that there are more invoices to deal with than normally, because of Maverick Buying. When all the PPE were bought at the contracted supplier, this would result in one overview and invoice. There will not be a need to check all those different invoices, which will increase the extra hidden labor costs.

Core problem

To solve the main issues, unsatisfied employees and the hard-to-trace inventory costs, the core problem must be identified. The problem cluster shows that the core problems are: different item and inventory policies at the different Company X locations, and the lack of dedicated stock at the supplier. Together with Company X, it has been decided to focus on the following problem:

There is no sufficient inventory management for all the stock locations in the supply chain, to ensure the satisfaction and safety of the employee while focusing on the costs.

Thus, the goal of this research is to design inventory policies for critical PPE for the whole supply chain. This consists of a plan to determine 1) which PPE are necessary to put in stock (at the Company X locations and their supplier and 2) to determine the amounts.

1.4 Research approach

The core problem descriptions as a question:

"How should Company X allocate their PPE stock in their supply chain to ensure the satisfaction and safety of its employees while reducing (extra and hidden) inventory costs?"

At the end of my research, Company X knows where in the supply chain which type of items need to be in stock and in which quantities. To come up with an appropriate plan, the following research questions need to be answered:

1 What is the actual situation at the Company X locations and how do they perform?

1.1 What are the characteristics of the different locations and their way of working?
1.2 How do the locations determine their inventory policies and how do they perform?
1.3 What are the important SKU characteristics and how are their delivery performances?
1.4 What is the level of Maverick Buying at the moment?
1.5 Which SKUs are poorly performing and need rearrangement?

Approach: I will conduct interviews with all the employees that are important regarding this subject. Employees that are working in the logistic centers, the end user and the procurement staff. These interviews will give a clear overview of the way of working and characteristics per location. I will ask Company X its contracted supplier, about their performance over the last year and will use their order history to see where the needs are for every location. For Maverick Buying, I will collect data within Company X its systems to see where, and for which amounts, are ordered outside the preferred supplier. In the end I will bundle all this information, to come up with a list of SKUs that I will take into consideration when executing a numerical example.

2 Which literature can support the research question?
2.1 Which demand determination methods are available in literature?
2.2 What is the relationship between availability and safety stock?
2.3 What is the relationship between availability and inventory costs?
2.4 What type of inventory policies are available for the characteristics of Company Xs PPE?
2.5 Which policy will fit the best?

Approach: I will conduct literature research for questions 2.1 – 2.5. I will focus on information that fits the situation best. I will combine the information from questions 1.1-1.5 and the found literature to determine which model will be used for which situation.

3 How should the model be formulated and validated?
3.1 How should the parameters be determined with the available data?
3.2 How sensitive are the parameters to the outcome?
3.3 Which validation and verification techniques need to be applied?

Approach: I will formulate the models for the specific Company X situation and evaluate how the parameters should be determined with the available data. I will check whether these parameters are sensitive enough to come up with a reasonable outcome. For validating the model, I will search for the best techniques that fit the chosen model and will perform experiments to check if the model will result in a reliable outcome.

4 How does the model perform compared to situation now (numerical example)?
4.1 How does the model perform compared to the old situation?
4.2 How does the model allocate the items in the supply chain?
4.3 What are the inventory costs?

Approach: for this section I will use the formulated model to come up with a detailed plan of where to allocate which PPE in the supply chain and in what quantities. I will compare the model with the old situation regarding inventory costs and other KPIs that first need to be determined after analyzing the situation more closely.

5 How should the model be implemented and evaluated over time?
5.1 Which steps need to be taken to implement the models per location?
5.2 How often should Company X evaluate the parameters over time to ensure the best results?
5.3 Which other steps should Company X take to minimize Maverick Buying?

Approach: For Company X this is an important aspect. I will focus on the use of the models and how they should implement them. I give guidelines at what time window the parameters should be evaluated, to ensure the consistency of the model. For the decrease of Maverick Buying, I will come up with clear steps Company X can take.

1.5 Scope

What is included?

I will take different PPE stock locations into consideration including: All the thirteen locations and the dedicated stock at the contracted supplier (clothing with a logo). I will focus on the use of appropriate models and will perform a numerical example to come up with the right quantities per location and SKU. The last aspect will be the implementation plan of the models and how to ensure Maverick Buying is not possible/needed anymore.

What is not included?
The overalls that are washed at Vendrig are not taken into account in this research. I will not determine the stock quantities at the German or Belgium locations since they work slightly different. I will not fully implement the inventory models into Company Xs ERP systems and will not make recommendations regarding with platform/ERP system to use when ordering the PPE.

Without focusing extensively on forecasting the demand for different locations. I will use historical data to come up with a demand distribution. Lastly, I will not look into bundling orders and the transportation aspects that comes along.

CHAPTER 2 - CURRENT SITUATION

In this chapter, the current situation is analyzed. First, the characteristics of the locations are explained along with their way of working, including the systems that they use, the number of employees and how they are performing. Second, the characteristics of the SKUs are described and divided into five categories. The performance of those characteristics is analyzed using supplier order data and interviews with staff. Third, Maverick Buying will be discussed, first an explanation and after that, the level of Maverick Buying per SKU characteristics with their reasoning is pointed out. In the last section, a conclusion will be made about which SKU characteristics, locations and ways of working need more attention. This information is the starting point for the next chapter, where literature is found to support those types of problems.

2.1 What are the characteristics of the different locations and their way of working?

As mentioned in the previous chapter, and visible in Figure 4 there are, when looking at the function, there are two divisions in type of location. Both with different needs and ways of working. The second division is made according to the maturity of the systems: there are different ERP systems used at the different locations which also result in a specific way of working.

Locations per function type

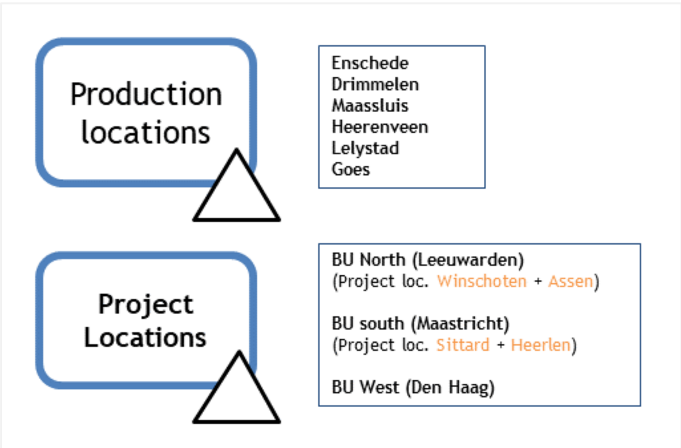

Figure 4: Function type (a part of figure 2)

Production locations

The business units that belong to this group are mostly working at the location where the stock is located. At some locations (Enschede & Drimmelen) actual products are manufactured and at other locations maintenance on specific parts is performed. For some locations, for example Maassluis, they also perform maintenance tasks at the customer site, which can be in or outside Europe. They work mainly with smaller groups (varies between 15-100 people) of permanent employees. At most locations the workload is known in advance and evenly spread. Since the groups are smaller and the workload is clearer and more plannable, the PPE demand is predictable in a way. However, there can always be an acute demand for items because of an accident with, for example, chemicals.

Project locations

This section of Company X is working on maintenance projects and other big construction projects. The projects are coordinated from a Business Unit nearby. The first major difference with the Production locations is therefore that the projects are executed somewhere else. However, there is a small workshop located at the Business Units where small maintenance tasks can take place. So, generally the demand for the projects is centralized at the Business Units. The second characteristic that is different is the use of temporary workers. Company X works with a group of permanent workers, but if more capacity or specialization is needed, temporary workers are useful. This reflects the third difference; the workload is not evenly spread. Company X can get a request to execute a project as fast as possible or already know months in advance where to carry out certain tasks. So, this part of Company X is an ad hoc organization where demand is sometimes not known.

When looking at Figure 4, the three Business Units are clear: BU North, BU South and BU West. The other locations that are pointed out are Winschoten, Assen, Sittard and Heerlen, those are long-term projects where Company X already operates several years. Company X created their own management within those projects, consisting of small groups of permanent Company X employees. Those locations match the description of the Production Locationsand therefore considered the same.

Matureness of the systems, information and way of working

In this section the way of working, the systems and the quality and use of information are discussed per location. This information is gathered with interviews and location visits.

There are two different ERP systems that are used within Company X. All Business Units and Lelystad are working with SAP and the E&ES locations use Infor as their ERP system. However, this does not influence the way of working regarding inventory management; since most of the locations do not use this as a tool to monitor their inventory. Stock levels are not visible since orders are not booked in their system, the same as the issuing of the items. Only one location does this. Business Unit South registered the issuing of items and therefore stock levels are visible in SAP. For most of the locations, the stock levels are visible for other types of inventory items such as spare parts. However, locations do not see the need to register the PPE the same way, since it is not their main business. A more detailed explanation is given below, where all locations are discussed.

Hengelo and Drimmelen
Number of employees: +-200
ERP system: Infor

For both locations, the same logistics worker is responsible for managing the PPE. There are a lot more employees working at this location than at other E&ES locations. Therefore, the variety of items that are in stock is higher, for example, there are also sweaters and T-shirts in stock. By the end of the week someone orders items that are almost out of stock via their Infor system. They do not use a calculated reorder point, based on experience they order what they think they will need. So, no reorder point or order-up-to level, only a fixed order moment.

In the interviews it became clear that Hengelo is looking for a more advanced system. They are looking into the use of a more automated way of working which helps them order on time.

Gears&Services – Maassluis
Number of employees: +- 80
ERP system: Infor

The way of working differs for different types of items. For the floor stock, a two-bin Kanban system is used, where an order unit is ordered when the first bin is empty. The empty bins are collected and scanned every week to combine into one order. The size of the bin is the order unit. Which results in an (R, s, Q) system with a review period of one week.

For shoes, they came up with an order-up to level themselves based on historical data. They have two different types of feet protectives, a shoe and a boot, each in the sizes that are often used (size 43, 44 and 45). For each SKU they decided that they always need three pairs in stock. Resulting in an (s, S) system for shoes. For the rest of the items, overalls, jackets etcetera, they order when they think they are running out soon.

The systems mentioned will be explained in more detail in the next section.

Location Lelystad – 20 employees –Infor
Location Assen – 25 employees – SAP

On both locations there is some floor stock for daily use. Since Lelystad and Assen are locations with a small number of employees, they just order items like clothing and shoes when they need them for a specific employee.

Location Winschoten
Number of employees: +- 75
ERP system: SAP

As for most locations, they have floor stock for daily use and some clothing. For some items, they came up with an order-up-level themselves, according to historical data or gut feeling. For example, with a jacket they order four new ones if there is one in stock, resulting in a (s, Q) system with s = 1 and Q = 4.

Locations Goes (company Y)
Number of employees: 130
ERP system: SAP

Goes has been part of Company X since 2007, however, they are still executing under their own name (company Y). Regarding PPE, they use different types of clothing and therefore do not buy most of them at the same supplier. But for the clothing that they do, they order when they are almost out of stock. Their order-up to level per SKU is based on the space they have left on their shelves and they only order a few times a year to fill up their shelves.

Business Unit North + Business Unit West
Number of employees: +- 150
ERP system: SAP

Both Business Units in BU North and BU West work the same way. Supplies for projects are ordered only when it is requested, they do not serve as a warehouse where items that are in stock can be taken at any moment. They both have a workshop on-site where the stock is located, for this matter floor stock is used.

For some items BU West uses a reorder point and order-up-to level, a (s, S) system. Furthermore, BU West is working on an expansion of another ERP program they use, to monitor the stock levels and in the end, be able to work with MRP runs. Those types of future plans are not in the ambition of BU North.

There is another big major difference in their way of working. As already described, one of the goals of the research is to reduce the amount of Maverick Buying. The amount of Maverick Buying is the highest in BU North. There is one supplier close by where 40% of their total spend on PPE is bought. A more detailed analysis is made further in this chapter.

Business Unit South
Number of employees: +- 350
ERP system: SAP

BU South is the biggest location with the most mature way of working. Their long-term project locations are closer than, for example, in BU North and BU West, therefore this Business Unit fulfils the function of a warehouse, since employees will stop by and pick up new items. Still, for bigger projects items are ordered per project. There is also no distinction made between floor stock and other items, they are all in the same place. All items are requested by workers via a small form at the desk of the warehouse, and each week the forms are put into SAP, so the system knows the actual stock levels.

BU South is the only location that works with an automated MRP run. At the end of the week the system sees which stock levels are at, or below, their reorder point and it will make an order. This order is checked manually to see if there are no mistakes or if adjustments need to be made. Resulting in a (R, s, S) or (R, s, Q) system with R = 7 days.

Performance of BU South

Since BU South is the only location that keeps track of its inventory level, an analysis can be made of their performance. It is somewhat hard to say when the stock levels were too low; since they only register what goes out when it is in stock. So, backorders are not tracked, and the fill rates therefore cannot be calculated. Instead the ready rate is used to measure the performance on the availability. The average ready rate over the past year is 0.9886. Which shows that the overall availability is good. A more detailed explanation about the ready rate is given in the following chapters.

When comparing the different stock levels, per item over time, it is visible that they are struggling with the right parameters. For some seasonal items there is too much stock. For example, see Figure 5 and Figure 6, around march (blue circle) it started to get warmer, and less rainy, and the stock stagnated. For shoes it is striking that there are different policies for a different type of shoe. Looking at Figure 7, it seems that the stock level of boot Merula never reaches zero and for the Billy shoe it does often. When asking the logistics employee, he stated that he did not know why he chooses to use different reorder points and was not aware of this difference in average stock levels. When looking at items in the same categories this is seen more often. The logistic employee explained that they do adjust the reorder points when stock levels specifically stand out. For example, he catches an eye on an t shirt that is ordered each week for a certain period, he will raise the reorder point to ensure a higher coverage period. So, BU South does not base their stock levels on quantitative measures, such as fill rate, but on gut feeling and adjusting it when striking things occur. Regarding availability, their way of working does perform well.

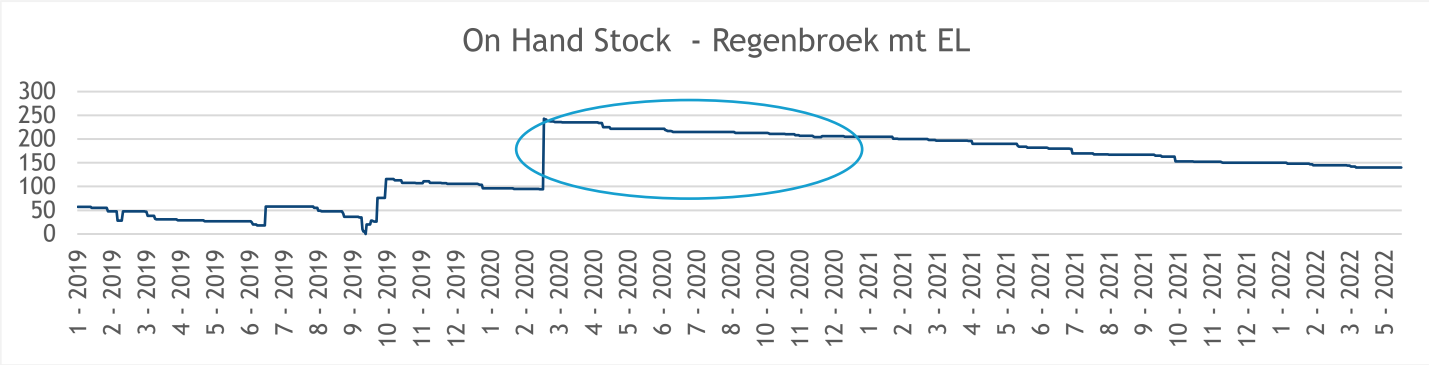

Figure 5: OHS Regenbroek (2019-2022)

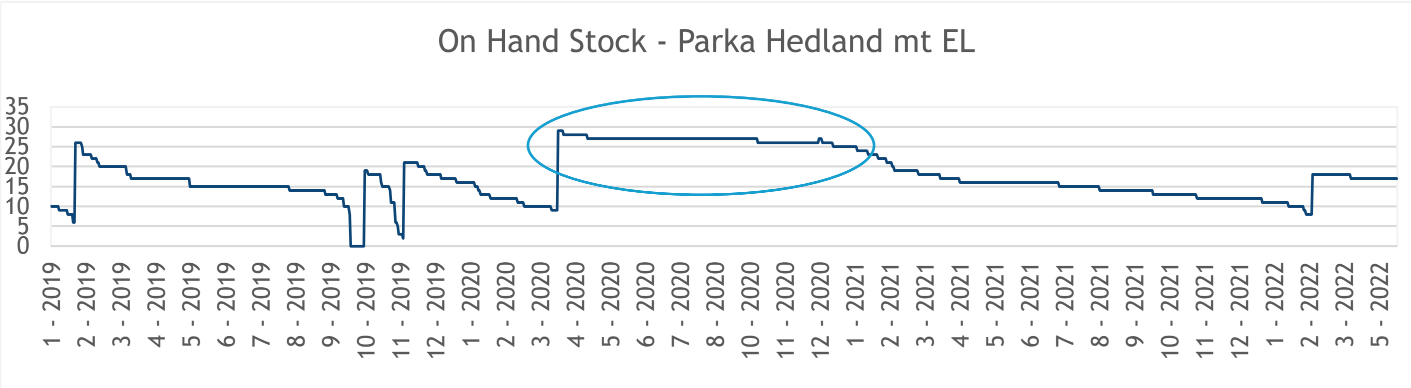

Figure 6: OHS Parka Hedland (2019-2022)

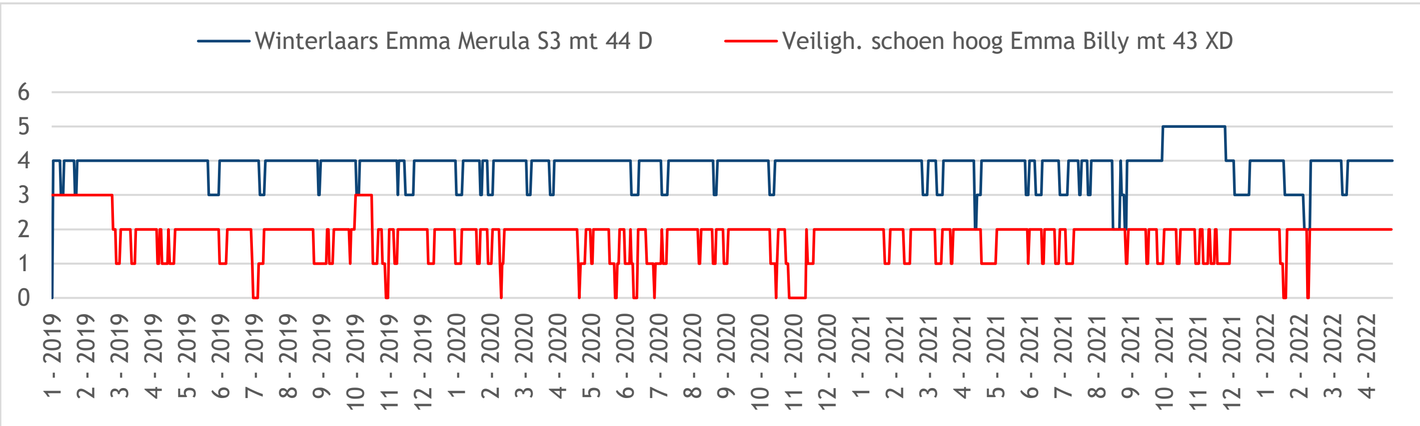

Figure 7: OHS boot Merula and Shoe Billy (2019-2022)

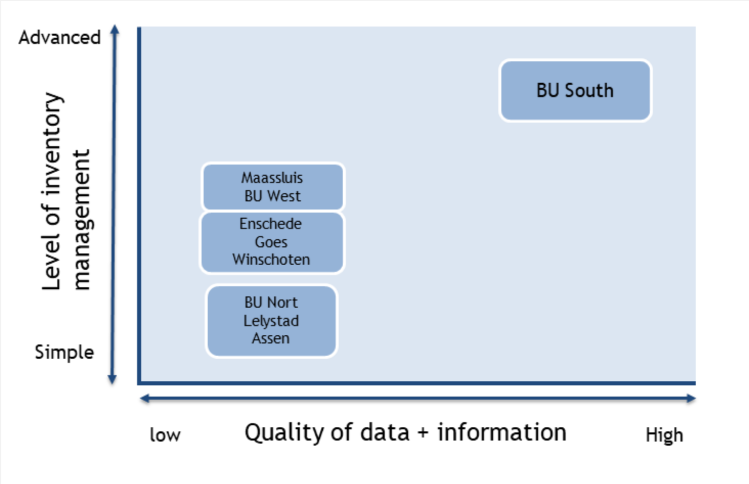

Figure 8: Summary way of working per location

In Figure 8 the previous section is visualized regarding the quality of the available information and the level of inventory management. It shows that with higher information quality, inventory management can be more advanced. Even literature shows that "Intrinsic information quality and contextual information quality are positively related to inventory decision quality" and "those are the underlying concerns in improving inventory decision quality" (Ge & Helfert, 2009).

Something that strikes, when comparing the Business Units, is the way of working of Business Unit North. They do not manage their inventory that well, and there is no thought-out process that they follow. The simple inventory management does not reflect the number of employees they need to serve. Also, when considering the Maverick Buying at the end of this chapter, it shows that they react slowly and do not consider ordering for the long term. For the rest of the locations their way of working or ambitions does reflect the number of employees they serve.

2.2 SKU characteristics and their performance

As mentioned in chapter 1, there are around 600 SKUs in the PPE catalogue, each with their own characteristics that influence their importance, demand and way of ordering. The following characteristics will be discussed: basic need, floor stock, placement of a Company X logo, washable and the items that are included in the new employee package. The availability and performance are discussed, those are based on the data from the supplier. So, the overall availability and performance of items at the supplier are combined with interviews and data from the locations.

Basic need – critical item

To ensure the safety of the employee, there are some items that are considered a basic need. If those basic needs are not available, the worker cannot continue his job, a so-called critical item. Those items are an overall, helmet, safety shoes, gloves and safety glasses. For some professions/specializations, other items can be considered critical as well, for example, welders need a face shield. There are two types of critical items, slow- and fast-moving items. Fast movers are considered floor stock, which is discussed in the next paragraph. Shoes, for example, are items that are slow moving and are highly critical, so they need to be available at all times. Looking at the slow-moving basic needs, shoes are performing low at the supplier. The target fill rate is 96% where some models have an item fill rate of 78%, see Table 1. In this table the performance is shown for the most bought items.

The average weighted fill rate of shoes is 76,4%. So, there are some problems with the supplier and therefore, it is hard to determine the right amount of stock at the locations.

Table 1: Item fill rate at supplier 2021 (most bought items)

Item Name	Characteristic	Item fill rate Supplier Target 96%
Ansell Hyflex 11-531	Basic item and floor stock	82,7%
Ansell Hyflex 11-537	Basic item and floor stock	78,8%
Ansell Hyflex 11-801	Basic item and floor stock	88,3%
Hs My-T-Gear Tropic	Basic item and floor stock	92,4%
Ansell Hyflex 11-518	Basic item and floor stock	60,0%
Schoen Billy S3	Basic item	77,6%
Boots Merulo	Basic item	84,8%
Schoe anatomic Bau	Basic item	77,8%
Glasses Pheos	Basic item and floor stock	84,9%
Glasses adaptec	Basic item and floor stock	76.2%
Helm HDPE	Basic item	87.9%

Floor stock

There are items that need to be close to the working area. Items that are used daily and wear down quickly, those are fast movers. Those items are specific gloves (mostly type Hyflex), safety glasses and earplugs (disposables). Looking at the performance, some of the gloves did perform horribly at the supplier, see Table 1. **The average weighted fill rate of gloves is 75,7%,** but since the locations do have enough stock, it is not a direct problem in many cases if items are delivered later. If they ran out and their order was not delivered soon, they could go to a non-contracted supplier for emergency replenishment. Conclusion, at the locations the availability was not an issue and did not get in the way of performing daily tasks.

Company X logo

There are lots of clothing with a printed logo. The logos are attached to the items by the supplier, after an order comes in. There are two different streams of logo orders known at the supplier. Their 015 stream, consisting of smaller batches (under 50 pieces of clothing), should take up to 5 working days to deliver. The 016 stream, which consists of orders with more than 50 items and their delivery time is in consultation, this can vary between 2 weeks and 2 months. For both streams the logos need to be in stock, for this research we consider the availability of logos no issue.

This characteristic influences the delivery performance of the orders. In 2021, 117 of the 205 logo orders were delivered on time, representing an order fill rate of 57%. In Figure 9, data is collected from 2020 and 2021, to visualize the lead time of the supplier. **57% of the logo orders are delivered on time and 90,5% of the orders are delivered within a month**. The whole order will be delivered regarding the items that can be delivered at the latest, so this influences the overall performance of the orders. Sometimes orders are split, but this is done manually.

According to the data, location visits and interviews it is clear that the level stagnated stock is high. Piles of clothing that is once bought but not used or even clothing with old logos. So, PPE with this characteristic is performing low on the supplier side and costs are high due to not used items.

Figure 9: Lead time Logo orders

Washable clothing

As earlier explained, clothing that meets certain safety standards is washed and repaired at an external party. At this location, there is an intermediate stock for new employees and to replace non-repairable clothing. This stock consists of only four types of items, the normal overall, the American overall, (overall) jackets and (overall) pants. To be clear, other clothing is washed here but is ordered from their preferred supplier and delivered directly to the new employee location. There are no outstanding problems regarding this stock.

New Employee Package

When a new employee is hired, they need new clothing. This package consists of a duffel bag with a helmet, a parka, safety glasses, a sweater, kneepads, safety shoes and some t-shirts. For some specializations or functions, it can differ a bit. The items are mostly the same as the list of critical items, except the duffel bag, sweater and t-shirts. The starter package is ordered at once and is needed most of the time in a few days, since Company X is a dynamic ad hoc company, where employees are sometimes hired on Friday and need to work on Monday.

The performance is somewhat harder to track since this package can be ordered in different ways and it is not clear whether, for example, a T-shirt is ordered as a single item or as the New Employee Package. However, the data shows that the availability of sweaters and T-shirts are not as high as preferred. For the Sweater, 75% were delivered on time and 82% of the T-shirts. When talking to the locations, in most situations this is doable but it is preferred to ensure delivery in 2 days for all orders.

Conclusion SKU characteristics and performance

From the supplier performance perspective, the clothing with a logo is performing badly. Only more than half of the orders are delivered on time and therefore making the supplier unreliable. This is all due to the fact that something goes wrong in their print process. The other characteristics are performing well enough for the business to continue.

2.3 Maverick Buying

Maverick Buying is defined as "the off-contract buying of goods and services for which an established procurement process is in place, based on pre-negotiated contracts with selected suppliers" (Karjalainen, Kemppainen, & Van Raaij, 2009). It can affect a company in several ways. The first and the most important way is **not reaching a certain expenditure each year**, which most of the time, will result in not receiving a certain amount of discount. For Company X the discounts are as follows; each quartile Company X will get a 3% bonus over their net spend and when reaching two million they will get an extra 0.5%. However, their spending is not reachable and they do not get the extra bonus at the end. Even if the level of Maverick Buying is lowered to zero this is not doable. The second aspect is the **extra handling costs that come along**, this can be transaction costs for ordering, invoicing and paying. It is hard to quantify these costs since those handling costs are hidden most of the time. The last way Maverick Buying can affect Company X is **the uncertainty of working with nonqualified normed items**. Especially for PPE, it is important to work with items that protect the employee. Company X came up with a list of preselected items (PPE catalogue) that are most of the time high quality and have high safety standards. When buying from other suppliers, products might physically look the same as in the catalogue but are in fact not.

But why does it happen anyway? For some of the locations, it is no exception to buy elsewhere than the contracted supplier. There are a few reasons why. The first reason is that the **products are in the first sense cheaper elsewhere**. The locations are comparing the actual purchase price between the suppliers, those can indeed be lower elsewhere. However, as explained, in the end, it might be the same or even a higher price when looking at the extra hidden costs and the discounts not attained. This follows by the second reason for Maverick Buying, **the discounts discussed are earned back at a corporate level and not directly at the actual locations**. Therefore, the locations do not care enough to help reach the total spend at the preferred supplier, since they feel more responsible for lowering and taking care of their own spending. The third reason is **the easy accessibility of items**. Many locations, especially the Business Units, are located in industrial areas where suppliers of PPE are located as well. This results in employees going for a small ride, to buy some new protection shoes after an accident happens. Easy accessibility prevents them from ensuring that their own on-site inventory can provide them with new items when needed. The fourth reason is related to the previous one. **Since the other suppliers are close by, they know the people there, which makes it more personal.** The last reason for Maverick Buying is also **the possibility of buying nice-to-haves**, where employees buy for example safety shoes from Puma or ear protectives with music in them, just because they can. These reasons can be summarized as **Casual Maverick Buying**, here the purchasing agent knows about the frame contract but chooses to buy from an outside source as they please. This behaviour is mostly driven by self-interest. "The employee may not feel a need to change old purchasing habits, because management is not guiding towards the preferred purchasing processes, the employee does not see the total cost of ownership effect of not complying with set procedures, or there are no organizational incentives to push towards using the preferred process and suppliers" (Karjalainen et al., 2009).

In 2021 a total of €632,669,- is spent by Company X on PPE at their preferred supplier, where €581,975,- euro is from the locations this research is about. As seen in Figure 10, Business Unit South and location Enschede are responsible for almost 54% of the total spend, together with BU North, 30% of the locations spend around 70% of the total amount.

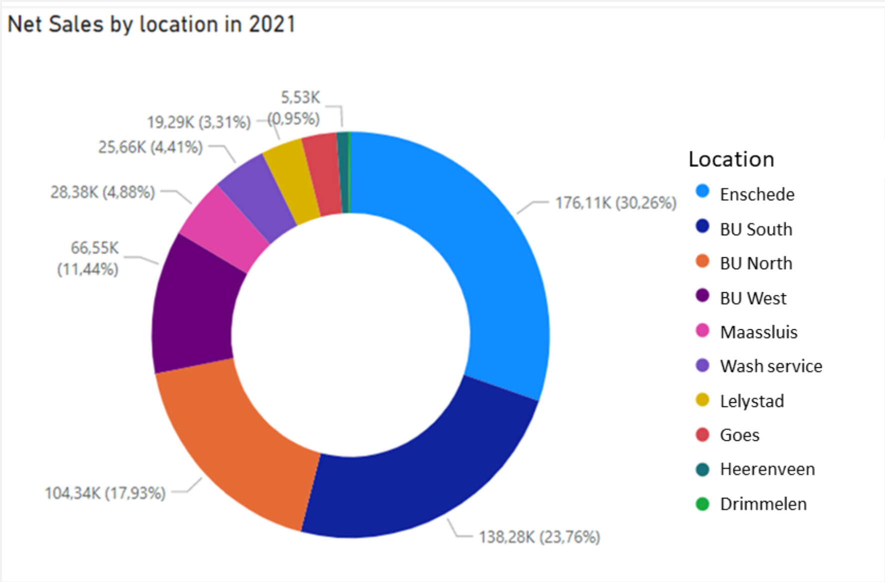

Figure 10: Total spend per location at preferred supplier

Level of Maverick Buying

When looking at the amount spent outside the preferred supplier, the total is €107,453,-. Which is 14,5 % of the total spend on PPE at both the preferred supplier and Maverick Buying. €91,317,- when only considering the locations this research is about. There are mainly five locations that are Maverick Buying, where Business Unit North is the most striking see Figure 11. It is visible that when combing the spend at the preferred supplier and Maverick Buying, BU North spends about the same as Hengelo on PPE.

When looking into the different suppliers, 70% is spent at one specific non-contracted supplier, Delftechniek (see Figure 12). They are located in the north of the Netherlands and matches the €61,400,- Business Unit North spent there. So, the biggest problem of Maverick Buying lies in BU North. In the next section is zoomed in on the spend per category and which specific products stand out.

Spend per category / characteristic

In this section, a more elaborate analysis is done on which items are bought somewhere else. Focused on the characteristics earlier explained; basic/critical item, floor stock, items with logo and the New Employee Package. The reasoning for Maverick Buying is also explained. In Appendix A a more detailed list is shown, with reasoning for each specific item.

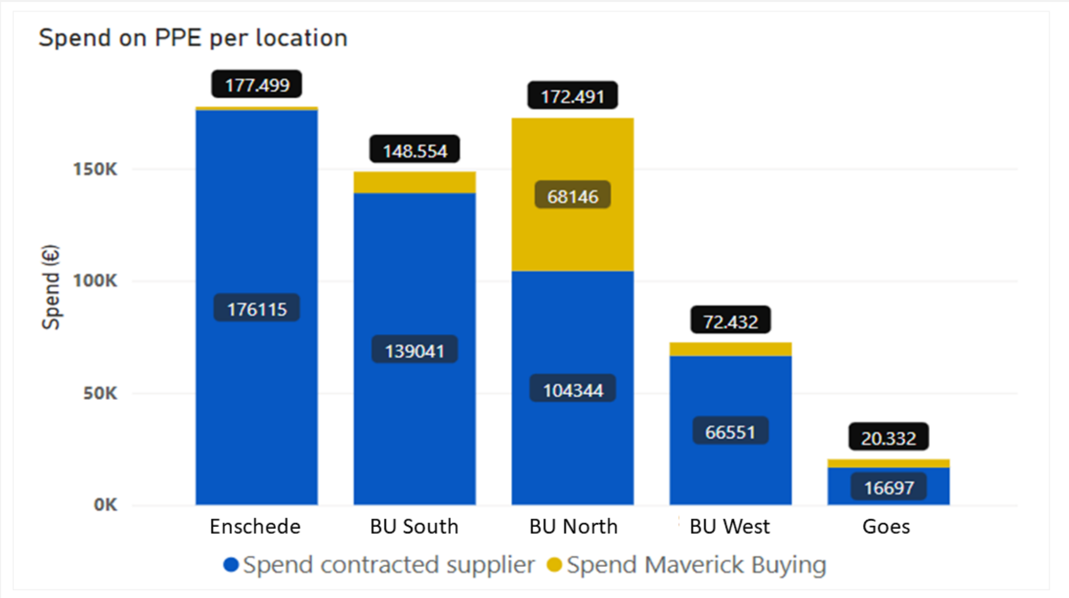

Figure 11: Spend contracted supplier and Maverick Buying

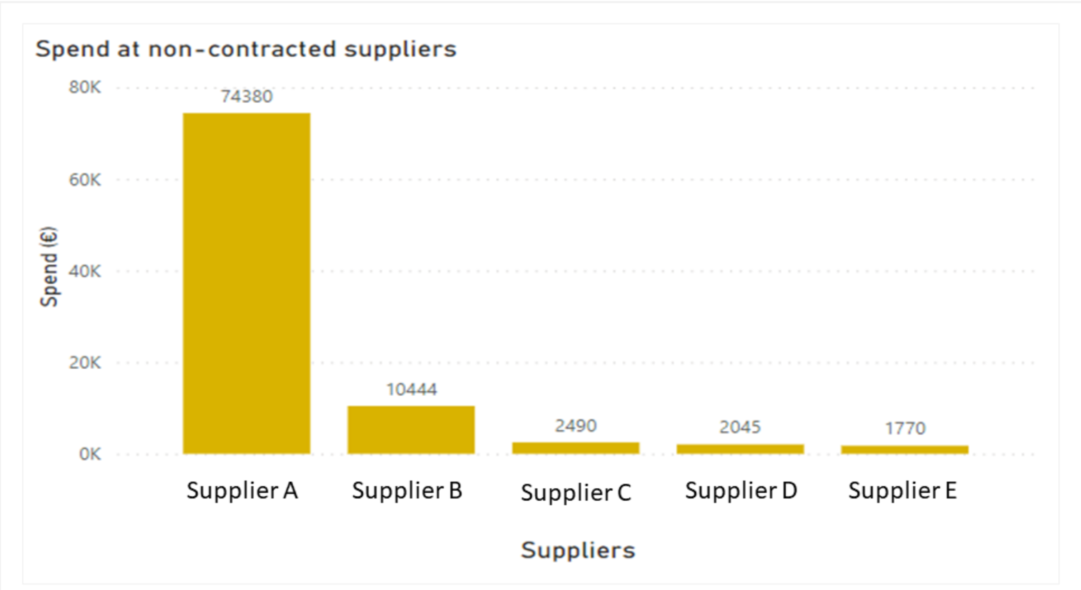

Figure 12: Spend at non contracted supplier

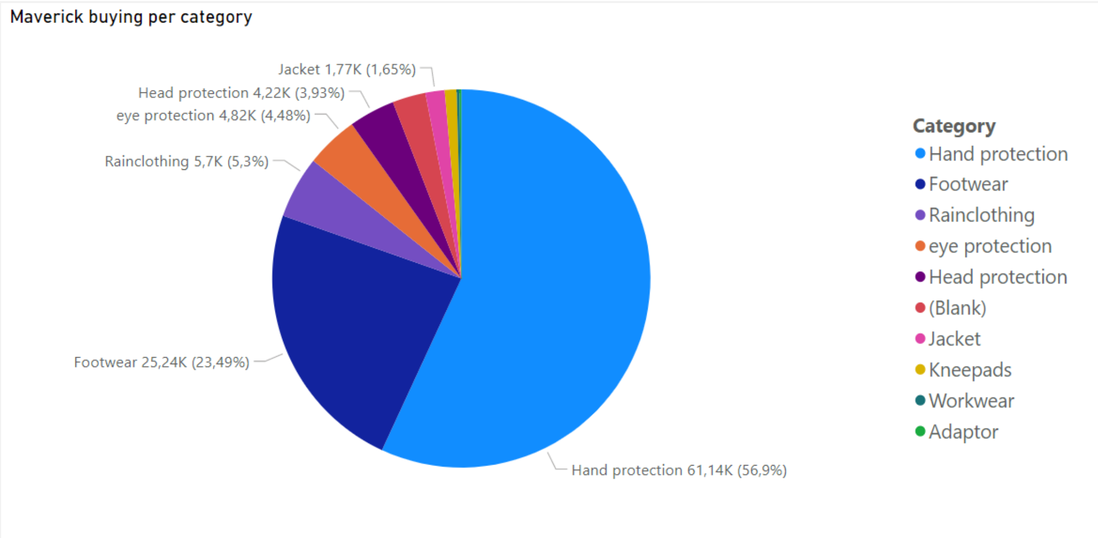

Figure 13: Spend per category

<u>Basic need – critical item + Floor stock</u>
In Figure 13 almost 80% is spent on hand protection and footwear. For both categories 30% of the total spend on those type of items is spent at a non-contracted supplier. Both shoes and hand protection are basic needs or critical items, where hand protection is most of the time a fast-moving floor stock and shoes are slow moving. For hand protection there is no clear reasoning, other than easier and faster accessibility. For only two types of gloves it is known that the performance where low at the preferred supplier, around 12% was delivered on time. Some locations explained that some gloves are cheaper elsewhere, this is in fact true. However, those are exceptions and for most of the gloves this is not true. BU North explained that some daily used gloves are not available at the contracted supplier, however this is also not true. So, there is some other reasoning behind it as earlier explained in the beginning of section 2.3.

For the category footwear, it is because it is easy to try on shoes at the nearby supplier before buying. There is also a big variation in feet sizes, and therefore a big variety of shoes are necessary. The locations also gave another reason; there are many employees that are working for years in the industry and always wearing the same type of shoes. Since shoes are an important part of the clothing and the work comfort of the employee, the locations are willing to buy those specific requested shoes.

<u>Logo items+ New Employee Package</u>
For both characteristics there is almost no Maverick Buying. This can easily be explained by the fact that all logo items can only be made at their preferred supplier and since almost all clothing from the New Employee Package is also with a logo, there is no Maverick Buying. Only shoes for new employees are sometimes bought elsewhere with the reasoning explained in the earlier paragraph.

Conclusion Maverick Buying

The only location that is striking, is Business Unit North. Where some locations might buy sporadic supplies elsewhere, they are buying consistently items at a non-contracted supplier with no valid reason. A lot of items can even be bought at the preferred supplier. This is called Causal Maverick Buying. Gloves and shoes are bought extensively somewhere else. For gloves the only reason is easy accessibility and for shoes there are other reasons besides that, for example, more choices.

2.4 Conclusion

After analyzing the actual situation, the following conclusions can be made (summarized in Table 2):

Performance of the supplier:

- Only 57% of the items with a logo are delivered within the agreed time of 5 working days.
- For gloves and shoes, the average weighted item fill rate is respectively 75,7% and 76,4% where 96% is the discussed SLA.

Performance of the locations:

- Since the quality of the data and information is lacking, it is hard to quantify the actual performance of the inventory policies at all locations.
- Only Business Unit South has more information, their availability is overall good but struggling with the right parameters for some items which sometimes results in overstocking.
- Insights from interviews: there is a lot of stagnated stock for logo items and not all locations do have shoes in stock.

Maverick Buying:

- In total €107,453,- is spent outside the preferred supplier on PPE. Where Business Unit North has the biggest spend, 40% of their total spend on PPE.
- Most items bought outside the preferred supplier are gloves and shoes. Where for gloves, it is mostly because of easily accessibility. For shoes the main reason is the lack of stock at some locations, the variety of models and the ease of fitting.

How to continue?

- The inventory management of only Business Unit South is improved (chapter 3, 4 and 5)
- For the other locations recommendations are made to improve their inventory management focussing on the implementation of the models (chapter 6).
- A solution needs to be found for the high level of Maverick Buying of Business Unit North (chapter 6).
- Other solutions need to be found for the unreliable supplier (chapter 6).

Table 2: Summary performance SKU characteristics and Maverick Buying

	MAVERICK BUYING	*SUPPLIER PERFORMANCE*	*AVAILABILITY LOCATIONS*	*EXPLANATION*
Basic need	√	√	√	Most of the basic needs are doing fine.
Shoes	X €25.240,- (23,5% of total Maverick Buying)	X / √ Item fill rates between 77% and 95% Weighted avg fill rate 76,4%	X	Shoes are hard to manage, and performance is low at the supplier for some items.
Floor stock	√	√	√	Most of the floor stock is doing fine.
Gloves	X €61.4100,- (59,9% of total Maverick Buying)	X / √ Item fill rates between 99% and 60% Weighted avg fill rate 75,7%	√	Gloves are bought elsewhere but therefore no big issues at the locations itself.
Logo items	√	X 57% delivered in 5 working days	X	Bad supplier performance and therefore stagnated stock at the locations.
New Employee Package	√	X	X	Long waiting times at the supplier and therefore bad availability at the locations and most complaints from workers.
Washable	√	√	√	No problems at all.

CHAPTER 3 – LITERATURE

3.1 Inventory classification

To decide the importance of an item and to fit the best inventory model, it is important to classify the SKUs. The most common way to achieve this is to use the ABC-classification. However, this method might say too little about an item. According to Flores and Olson (1992), this method can even be inappropriate under some circumstances. For example, if the annual dollar usage is high but for the production or service operation the item is not important. In such cases a multi-criteria model can be used. Flores and Whyback (1987) recommended using a two-dimensional classification where the ABC-method is used first, after which the criticality of an item is taken into account. This reflects the "impact of running out, whether there was an available substitute and the political consequences of being out of stock'' (Flores & Whybark , 1987). Each item is ranked from I to III, where I is clearly critical and III clearly noncritical. Those numbers are combined with the ABC classification into for example AII or CI. The last step is to convert those classification in three final ones where AI, AII and BI belongs to the AA classification, AIII, CI and BII to BB and BIII, CII and CIII to CC.

3.2 Forecasting

To ensure fulfilling future demand, it is important to know what the demand will be over time. There are several forecasting methods that are taking trends and seasonality into account. For this research, historical data will be used to fit a suitable distribution to forecast the demand in the future. Some guidelines were found to support the fitting of a distribution. Most of the inventory policies are based on the normal distribution. Silver et al. (2017) set as a rule of thumb; if the mean lead time demand is higher than 10 units, it is a regular fast-moving item. Is it lower than 10, it is a regular slow-moving item. When for a fast-moving item the covariance of the lead time demand is higher than 0,5 ($\frac{\sigma_L}{x_L} > 0{,}5$), the probability of negative lead time demand is too high to use the normal distribution. The gamma or log normal distribution is more suitable for those cases. For regular slow-moving items, Poisson and (negative) Binomial distributions are often used. All rules of thumb are summarized in Table 3.

Table 3: Rules of thumb demand distributions (Silver et al., 2017)

Regular, fast moving (x_L>10)
Normal $\frac{\sigma_L}{x_L} > 0{,}5$
Gamma / Lognormal $\frac{\sigma_L}{x_L} < 0{,}5$
Regular, slow moving (x_L<10)
Otherwise: Binomial ($\frac{Var}{mean} < 1$) or Negative binomial ($\frac{Var}{mean} > 1$)
Poisson (Variance-to-mean ratio ($\frac{Var}{mean} \approx 1$))

3.3 Inventory policies for single location items

In the earlier section it was mentioned that for different classes of items, different policies are suitable. In Table 4, five policies are shown that can be used for deterministic demand. The difference between these policies lies in how the stock levels are reviewed. Two types can be distinguished: a continuous review policy and a periodic review policy. When using a continuous review policy, an order is made when the stock level reaches a certain point. Instead, for a periodic review policy, the stock levels are reviewed only at a certain determined moment. Therefore, it is possible that the stock levels reach levels below the reorder point. For this type of reviewing, more safety stock is needed (see next section). Next, the terminology and the policies are explained (Tables 5 and 6) and later the safety stock levels and reorder points.

Table 4: Rules of thumb for inventory policy (Silver, et al. (2017))

CLASSIFICATION	CONTINUOUS REVIEW	PERIODIC REVIEW
A items	(s, S)	(R, s, S)
B items	(s, Q)	(R, S), (R, s, Q)

Table 5: Terminology

SYMBOL	MEANING	FURTHER EXPLANATION
s	Reorder point	If the on-hand stock is at or below this level, a new order will be placed
S	Order-up-to-level or base stock level	When ordering, the on-hand stock at the time of ordering will be raised to this level
Q	Fixed order amount	When ordering, Q items will be ordered
R	Review period	The on-hand stock will be reviewed with this interval. Can be daily, weekly etcetera.

Table 6: Explanations of the different policies

EXPLANATION OF THE POLICIES	
(s, S)	The on-hand stock is monitored **continuously** and when the stock level reaches **s**, an order is made to ensure the inventory level to be **S**.
(s, Q)	The on-hand stock is monitored **continuously** and when the stock level reaches **s**, an order is made with **quantity Q**.
(R, s, S)	The on-hand stock is **reviewed with frequency R** and when the stock level reaches **s**, an order is made to ensure inventory level to be **S**.
(R, S)	The on-hand stock is **reviewed with frequency R** and every time an order is made to reach level **S** (or no order if the level is unchanged).
(R, s, Q)	The on-hand stock is **reviewed with frequency R** and when the stock level reaches **s**, an order is made with **quantity Q.**

Order quantity

To calculate the order quantity, a well-known basic model is used (Silver, Pyke, & Thomas, 2017, p. 146). This formula (formula (1)) minimizes the total costs that are related to the ordering and holding costs of an item.

$$EOQ = \sqrt{\frac{2AD}{h}} \quad (1)$$

A = fixed costs component per order
D = Demand rate in items per unit time
h = annual holding costs per unit

Safety stock and reorder point (s)

Silver et al. (2017, p. 259) explain the general approach of determining **the reorder point** :

$$s = \textit{demand during the replenishement lead time} + \textit{safety stock} = \mu_l + SS \quad (2)$$

Where safety stock (SS) is the average level of net stock just before a replenishment order arrives. It provides a buffer to fill up higher-than-average demand during the lead time. The safety stock for continuous review policies can be calculated using:

$$SS = \textit{safety factor} * \textit{st.dev. of demand during lead time} = k * \sigma_{DL} \quad (3)$$

For a periodic review policy, the demand during the review period also needs to be considered. Therefore, the safety stock is then calculated using:

$$SS = \textit{safety factor} * \textit{st.dev of demand during lead time and review period} = k * \sigma_{DL+R} \quad (4)$$

A variable lead time due to a low reliability of the supplier leads to the demand during lead time to be variable as well. The following formula can then be used for the mean and standard deviation of lead time demand:

$$\mu_l = E(D_p) * E(L) \quad (5)$$

$$\sigma_L = \sqrt{E(L) * Var(D_p) + E(D_p)^2 * Var(L)} \quad (6)$$

This standard deviation is used to calculate the safety stock. In formula (6) the mean and variance are calculated for both the demand per period (D_p) and the lead time and then combined (Silver, Pyke, & Thomas, 2017, p. 284). The lead time and demand are considered independent in this situation. However, in general these are in fact not independent. Therefore, every reasonable effort should be made to reduce the variability in lead time.

Undershoot

Another factor that influences the reorder point is the undershoot. When using a periodic review policy, there is a chance that the inventory level is already below the reorder point days before the stock is reviewed (see Figure 14), resulting in a higher chance of stock out during the lead time. To calculate the level of stock that is already below the reorder point, the distribution of the undershoot should be determined, however this is a complicated procedure. To not neglect the undershoot, an estimate can be used. According to Chopra and Meindl (2019) **a rough estimate for the undershoot is half the demand during the review period.**

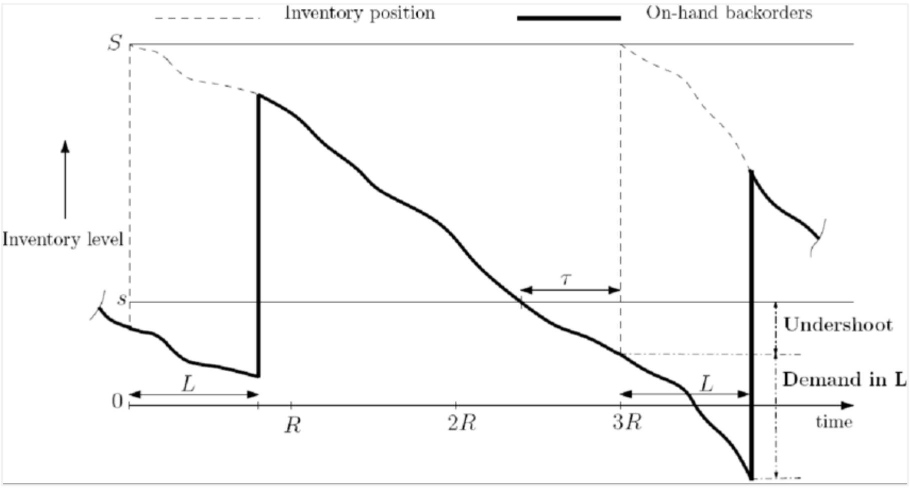

Figure 14: Periodic review with undershoot (Silver, Naseraldin, & Bischak, 2009)

Determination parameters (R, s, S) and (R, s, Q)

The safety factor is an important factor when calculating the safety stock. It can be done in several ways and depends on management decisions. The management can decide which measures they consider important. Different methods are based on for example costs per stock occasion, fractional charge per unit short or the fraction of demand satisfied directly from the shelf (the fill rate). When using the fill rate to determine the safety factor for a periodic (R, s, S) policy, formula (7) is used:

$$(1 - P_2) * Q \approx \frac{\sigma_{R+L}^2 J(k)}{2x_R} \tag{7}$$

Here the Q is the lot size and is calculated by the EOQ according to formula (1). For J(k) the table in Silver et al. (2017, pp. 726-739) is used where the values are displayed for several values of k. The reorder point is then calculated with: $\mu_{L+R} + k * \sigma_{DL+R}$. To calculate the order-up-to level use S = s + Q. Formula (7) can only be used when the demand is normally distributed.

Determination parameters (R, S) and (s, Q)

When determining the parameters for a periodic review policy (R, S) or the continuous review policy (s, Q), the parameters can be swapped according to Table 7. So, the swapped parameters are calculated in the same way.

Table 7: Transformations (s, Q) -> (R, S) (Silver et. al, 2017)

(s, Q)	(R, S)
s	S
Q	D*R
L	R + L

The reorder point for an (s, Q) system or the order-up-to level for the (R, S) system can be calculated using $\mu_{L+R} + k * \sigma_{DL+R}$. To calculate the safety factor, the expected shortage per replenishment cycle (ESPRC) is used. The ESPRC is $\sigma_{dL+R} * G(k)$ (8) and the relationship with the fill rate is as follows $P_2 = 1 - \frac{ESPRC}{D*R}$ (9), where the value of k can be found in the same table as described before. So, when using a higher target fill rate, the shortage per cycle is smaller and therefore the safety factor is higher. This ensures the least number of backorders and reaches the target fill rate.

Reorder point – non-normal lead time demand

In section Forecasting3.2, the use of different distributions for the lead time demand were discussed. All the methods above are based on the normal distribution. To determine the parameters using the other distributions, two ways are distinguished depending on the use of a continuous or a discrete distribution. The gamma distribution is continuous and the Poisson and (negative) binomial are discrete distributions. The basic idea for both distribution types is to calculate the expected shortage per cycle given a reorder point s with:

$$\text{ESPRC} = \int_{s}^{\infty}(x-s)f(x)dx \qquad (10)$$

where f(x) is the density function of the used distribution for the lead time demand.

For a given target fill rate (P_2) and order quantity (Q), the target ESPRC can be calculated using formula (9), the same formula that is used for (s, Q) and (R, S) policies with the normal distribution, To determine the reorder point (s) for the continuous gamma distribution, the inverse for a certain probability of no stock out (P_1) is used. For the discrete distributions, the smallest value of the reorder point that achieves at least the desired value of P_2 is used (Silver et al., 2019, p. 743). For the Order-up-to level for the (R, S) system, the same transformation can be made as described before in the earlier section.

3.4 Total (relevant) costs of inventory

In the previous sections, the reorder points were calculated using the availability (fill rate) as a goal. However, for most companies the total costs of inventory are also important. So, there is a trade-off between the two. There should be always enough stock to reach the target fill rates, but at the lowest costs possible. Teunter, Babai and Syntetos (2010) derived the following expression of the total relevant inventory costs over a period:

$$TRC = \sum_{i=1}^{N}\left(\frac{A_i D_i}{Q_i} + h_i SS_i + h_i\frac{Q_i}{2} + B_i D_i(1-FR_i)\right) \qquad (11)$$

With:
N = Number of SKUs
A_i = fix cost component per order
h_i = Inventory holding costs per item per unit time
SS_i = Safety stock for SKU i
Q_i = Average order quantity of SKU i
B_i = cost of backordering of SKU i
D_i = Demand SKU I per unit time
FR_i = Fill rate of SKU

The first term is the cost of ordering, the second term the cost of holding the safety stock, the third term expresses the cycle stock costs and the last term the costs of shortage. Teunter et al. (2010) stated that this function can be used for all demand distributions and policies.

3.5 Conclusion

The findings of this chapter can be summarized as follows:

- Taking criticality into account is important if the annual dollar usages are, for some reason, not a reflection of the importance of the item.
- For slow moving items, the negative binomial, binomial, and Poisson distributions are the best to use.
- Based on the distributions and classifications there are policies that fit the best. Most literature is however focussed on a normally distributed lead time demand.
- If the lead time is (also) variable, there are models to take this into account. However, reducing lead time variability is a must.
- For slow moving items, continuous review policies are often used. Therefore, almost no literature is found on calculating reorder points in a periodic review system without using the normal loss function. Therefore, it is harder to find the right reorder point for discrete demand.
- The total relevant costs of inventory have the following cost components: Ordering costs, holding costs, cycle costs and the costs of shortage.

CHAPTER 4 - MODEL FORMULATION AND APPROACH

In this chapter, the models will be formulated and an approach to solve the problems will be explained based on the information of the location BU South, and the found literature in the previous section. **The first step is the demand determination of the SKUs at the BU South**, where the rules of thumb of section 3.2 are used. The demand will be forecasted using the demand data from 2019, 2020 and 2021 and validated using the latest data from this year (2022). **The second step is the SKU classification,** using the proposed method of section 3.1, where the criticality of the items is the most important aspect. When all SKUs are classified, **the appropriate policy is selected** using the rules of thumb from section 0. **In step 4, the reorder points, order quantities, total costs and availability of the items are discussed**. In the next step, **the model will be validated** by comparing the total costs and availability with the policy BU South uses now. The contracted lead times are used in the first place, but i**n step 6, experiments will be performed with the variable lead time**. To see the impact of an unreliable supplier.

Literature shows that when the lead time is shorter and more reliable, less safety stock is needed at the location. So, the **last step is to come up with the levels of dedicated stock for the logo items**. So, for some logo items, it will be determined what the best safety stock will be at the supplier to serve the business within 2 days, the same as for the other non-logo items.

The first 4 steps will be discussed in this chapter, the same for the determination of the total cost formula. The validation of the policies and numerical experiments are discussed in chapter 5. The safety stock calculations for the dedicated logo items will be discussed in chapter 6. See Figure 15 for the visualization of the approach.

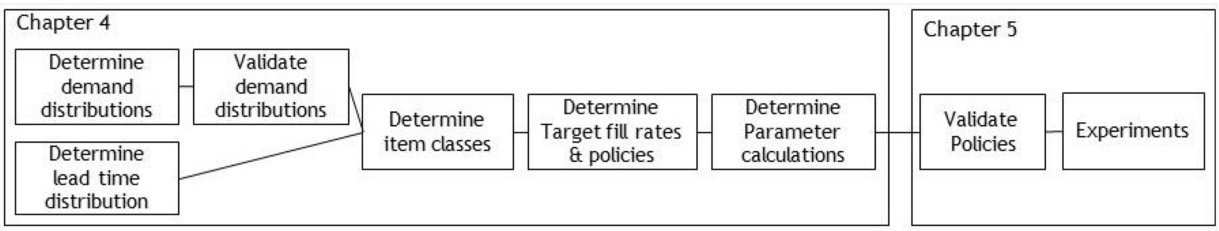

Figure 15: Approach

4.1 Demand patterns

In Table 8, the division of the distributions is shown, which were determined using the rules of thumb discussed before in section 3.2. None of the items is normally distributed, which makes it harder to calculate the parameters for the policies. Because, as discussed before, a lot of parameters are determined by using the normal loss function to determine the safety factors. A second observation is that there are only 9 items that are fast-moving, which are mostly gloves, face masks and two types of safety glasses. Consequently, almost all items have a discrete distribution.

Table 8: Demand distributions

DISTRIBUTION	NUMBER OF ITEMS
Gamma	9
Negative Binomial	86
Poisson	12

Validation of the distributions

When plotting the demand distributions (suggested distribution versus empirical), it seems to not fit properly for some items. This is especially the case for items with peak demand, resulting from package sizes and projects. For example, for a type of gloves the demand patterns looks like the graph in Figure 16, with demand peaks at 12, 24, 36 etcetera. This is the result of giving rather one package than 11 pieces to the employee. The gamma distribution is suggested according to the literature.

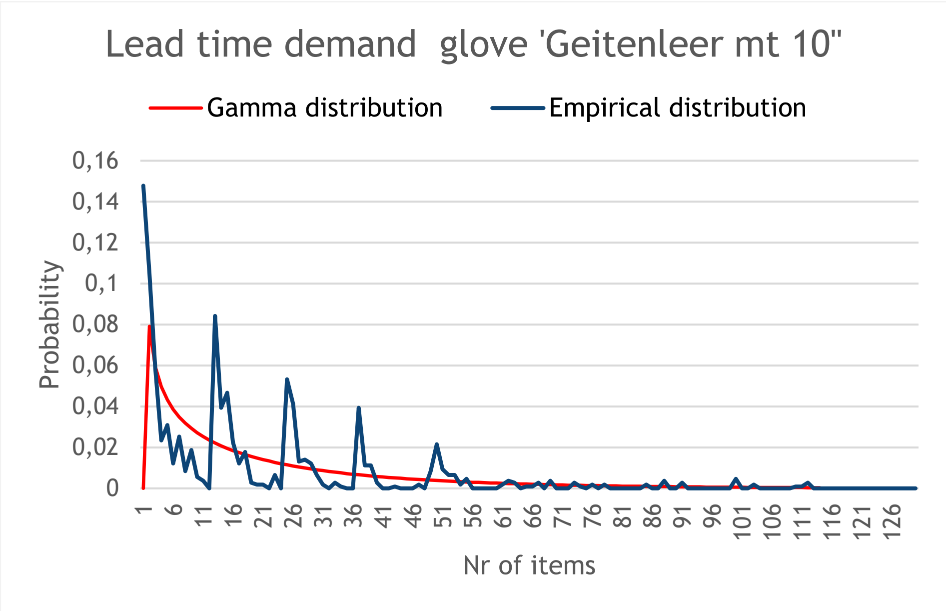

Figure 16: Demand pattern glove

To ensure a proper fit, the reorder points are calculated using the Expected Shortage Per Replenishment Cycle to see the difference in performance when using the empirical probabilities and the suggested distribution. For this specific example, both distributions give the same reorder point for the given target fill rates. Therefore, the gamma distribution is a proper fit for this item. For the other items, this is also done, and it can be concluded that the given distribution does perform the same as the empirical probabilities, despite the peaks (in the tail). Proof of this validation can be found in Appendix C.

Lead time distribution

There are two different lead time agreements made with the supplier. For the non-logo items, the lead time is 2 days (48 hours) and for logo items, the lead time is 5 working days. However, this is not reliable as discussed before. Therefore, the lead times are also described as a random variable. To calculate this, the order date and the delivery date are compared and combined for all items together. So, there is no individual variable lead time for each item, but for each product group (logo or non-logo items). For the non-logo items, the lead time has an expected value of 3,63 days and a variance of 16,09 days, this results in a covariance of 1,105

The lead times for the logo items are distributed with an expected value of 8,96 days and a variance of 44,62 days, this results in a covariance of 0,745

4.2 Class determination and target fill rates

An ABC analysis is performed on the SKUs at BU South. Normally, it holds that 20% of the items account for 80% of the inventory values. For BU South this is not the case, 20% of the items are good for 61% of the inventory value. The top item is a mouth mask, which reflects the corona period. The other top items are gloves and a type of glasses, for which the demand is high, and some rain clothing which are expensive. See Figure 17 for the number of items per classification.

Figure 17: ABC classification graph

Since the criticality of an item says more about its importance, the staff at BU South is asked to classify the various items as I, II or III. Where I means: the item is critical, and when out of stock the employee cannot continue working and there is no substitute. II means: when the item is out of stock there is a substitute item with which the employee can continue his tasks but this is not desirable. III means: when the item is out of stock, the employee can continue their work and can wait for the next replenishment order to arrive. In Table 9 the division of items is visible. The criticality of the items does reflect the basic needs described in chapter 2, so mostly gloves, shoes and hearing caps.

Table 9: Criticality levels

CRITICALITY LEVEL	A ITEM	B ITEM	C ITEM	TOTAL
I	18	17	19	54
II	3	8	13	24
III	7	13	9	29
Total	28	38	41	107

As suggested in the literature in section 3.1, the two classifications methods are combined into AA, BB and CC classes. Resulting in the final classifications shown in Table 10. In appendix B, all the items are listed with their ABC class, criticality and their final class.

Table 10: Final Classifications

CLASS	NUMBER OF ITEMS
AA	32
BB	35
CC	35

Fill rates per class

Together with Company X, the following target fill rates (see Table 11) were chosen per class. In general, for C items the fill rates are somewhat lower since items will be lower in value and are not that important for the company. However, for Company X it is important to ensure the safety of the employees at all times and therefore CC items will also have a high target fill rate.

Table 11: Target fill rates per Class

CLASS	TARGET FILL RATE
AA	99%
BB	97%
CC	95%

4.3 Policies per class

Since BU South works with a weekly MRP run, the periodic review policies are used for all items. I decided to first use **the (R, s, Q) system for the AA items** since most of the AA items are gloves and those are ordered in prescribed quantities. **For both BB and CC items I will first use the (R, S) or (R, s, S) system. In chapter 5, the best system for these classes is chosen.** In the next chapter, I will also experiment with the different policies for different items and find out which fits the best.

Calculating parameters per policy

In Table 12, the formulations of the parameters per policy are described. The formulas from the previous chapter were used with some changes.

Since all items are not normally distributed, using the normal loss function to calculate the safety factor is not an option. So, the only possibility to calculate the reorder points and the order-up-to level is to use the ESPRC, see formula (10). Based on the lead time demand, the s or S are calculated. For the (R, S) policy this is not a problem. For the (R, s, Q) and (R, s, S) policies it works a bit differently. The reorder point (s*) is calculated using the theory in the previous chapter (see also Table 12), but this is for an (s, Q) system that does not take the review period into account. To solve this problem the undershoot is added to s* which leads to the correct reorder point (s).

Since the biggest issue lies with the uncertainty of the lead time, the lead time will be a random variable with the parameters discussed earlier. Therefore, the mean and variance of the demand over the lead time and review period will be adjusted according to the formula in Table 12.

Validation of the policies

The reorder points and other parameters were calculated using the historical data of the previous three years (2019, 2020 and 2021) as suggested in the previous section. To see how these, and the proposed policies are performing, they will be tested using the data from this previous year (2022). So, when does the policy order, for which quantity and how are the fill rates and total costs. This will be compared to the actual orders of last year for BU South, to see the differences. This is done in the next chapter.

To compare the availability of the items, the fill rate is used. As a reminder, the fill rate (P_2) is the fraction of demand that can be fulfilled directly from stock. However, the data from BU South only shows demand when directly fulfilled. Since they only register the issuance of items and not the backorders. To solve this problem **the ready rate is used to compare the policies.** The ready rate is the “fraction of time with positive demand” (Axsäter, 2006). The ready rate and fill rate are, however, only equivalent when demand is Normal or Poisson distributed and when the demand size is small. Axsäter explains that when the on-hand stock is positive, it can still be too low to fulfil the total requested items. So, the ready rate can be high but the fill rate is not since our demand size is most of the time more than 1 and discrete, the ready rate is not the most convenient service measure. But since it is impossible to calculate other service measures, the ready rate is still used to get an idea of the performance.

Table 12: Parameter formulations

(R, s, Q) and (R, s, S)		
s	$0.5 * \mu_R + s^*$ = undershoot + s^*	
s*	Using ESPRC = $\int_s^{\infty}(x - s^*)f(x)dx$, with f(x) = probability of lead time demand and $P_2 = 1 - \frac{ESPRC_{target}}{Q}$ to calculate the target ESPRC. s* is the reorder point if $\int_s^{\infty}(x - s^*)f(x)dx \leq ESPRC_{target}$	
Q	$EOQ = \sqrt{\frac{2AD}{h}}$ For some items the EOQ is rounded to the unit order size which is specified by the supplier	
S	s + Q	
(R, S)		
S	Using ESPRC = $\int_s^{\infty}(x - S)f(x)dx$ with f(x) = probability of demand and $P_2 = 1 - \frac{ESPRC_{target}}{\mu_R}$ to calculate the target ESPRC. S is the order-up-to level if $\int_s^{\infty}(x - S)f(x)dx \leq ESPRC_{target}$	
When including variable lead times	The same calculations are performed to calculate the reorder points and order-up-to levels, but the mean and variance of the lead time demand are adjusted to include the variable lead times.	
Mean		$E(D) * E(L)$
	For logo items	$E(D) * 8{,}96$
	For non-logo items	$E(D) * 3{,}63$
Variance		$E(L) * Var(D) + E(D)^2 * Var(L)$
	For logo items	$(8{,}96) * Var(D) + E(D)^2 * 44{,}62$
	For non-logo items	$(3{,}63) * Var(D) + E(D)^2 * 16{,}09$

4.4 Cost Parameters

To not only focus on the performance of the items by checking the desired fill rates, but the total relevant cost is also considered. Formula (11) of section 3.4 is partly used since some costs are hard to calculate and are not necessary to take into account. The cost of stock out will not be taken into consideration since this can be influenced by a lot of factors. We will however consider the ordering costs, holding costs and the cycle cost per SKU per year. Resulting in the following total relevant cost formula:

$$\boldsymbol{TRC = \sum_{i=1}^{N}\left(\frac{A_i D_i}{Q_i} + h_i SS_i + h_i \frac{Q_i}{2}\right)} \qquad (12)$$

There are no direct ordering costs when placing an order at the supplier. However, there are always indirect costs that come along when ordering. For example, the labour costs of running and checking the MRP run, contacting the supplier when changes need to be made or when delivery times are increasing, and the actual handling of unpacking the orders and booking an order in the system. Together with Company X, it has been decided that the ordering costs are approximately 10 euros per order. The holding costs per SKU depend on the value of the item and the annual holding costs rate. It is hard to calculate this rate but normally considered between 20% and 30% of the value of the item (McCue, 2020). Therefore, I decided to use a holding costs rate of 25%.

4.5 Experimental design

To see the impact of the high variability in the lead time and unreliability of the supplier, several experiments will be performed in the next chapter. With four scenarios the impact on the safety stock levels of an unreliable supplier is show, as well as the way of ordering and the matching costs. The following scenarios will be tested.

Scenario 1 – Actual variable lead times

For the first scenario, the safety stock is calculated using the variable lead time as it is now. Calculated with the data from the previous years. For both the logo items as the non-logo items, with an average lead time of respectively 9 and 3,6 days. As calculated in section 4.1

Scenario 2 – All items variable lead time of non-logo items

It would be interesting for Company X to know what would happen if all items were delivered as if they were non-logo items. This could be possible if logo items were in stock with the logo already attached to it. So, for Scenario 3 all items will be delivered with a lead time with mean 3,6 days and variance of 16,09.

Scenario 3 – Contractual lead times

With the third scenario the safety stock is calculated using the lead times as contractually agreed on with the supplier. Using a deterministic lead time of 5 days for the logo items and 2 days for the non-logo items. This is done in the first part of the next chapter.

Scenario 4 – All items 2-day contractual lead times

The last scenario will show the safety stock levels that are needed if all items are delivered in exactly 2 days.

4.6 Conclusion

The findings of this chapter can be summarized as follows:

- Using the suggested distribution does perform the same as the empirical distribution and is therefore a valid way to calculate the reorder point.
- The lead times are extremely variable, the covariance of the lead time of logo items is 0.745 and for non-logo items 1.105.
- The reorder points are calculated using the ESPRC for continuous policies and adjusted with adding the undershoot.
- The ready rate is used to compare the performance of my policies and the policies from BU South. This is not the desirable way, but there is no data available to use more appropriate measures, such as the fill rate.
- When calculating the total costs, the backorder costs are not taken into account since the cost of stock out are hard to calculate.
- Experiments will be done with 4 different scenarios to get an idea of the impact of an unreliable supplier.

CHAPTER 5 - POLICY PERFORMANCE AND EXPERIMENTS

5.1 Model test

As explained in the previous chapter, the suggested models need to be validated. The models are compared to the way BU South has ordered in the past year to see if the suggested policies perform better with the preferred availability. The total costs and the fill rates are the main factors when comparing the policies. The total costs are calculated using formula (12) and for the fill rate, the ready rate is used as explained in the previous chapter.

Side notes to BU South's policy.

There are some side notes to the performance of BU South. The first difference is the possibility to adjust the reorder points over time. When demand changes during the year because of unforeseen events or seasonality, BU South will adjust the reorder points to meet the changing demand. Since I modelled BU South's demand as stationary demand, our policy will not change the reorder point at a certain point in time. I, however, included this demand and set the reorder points as high as needed for all peaks and seasonality throughout the year.

The second difference is the high predictable demand for projects. In some cases, BU South will order items specifically for a project, or when requested by employees. Our policy is made to also fulfil this demand. However, since these peaks are high, stock out can occur and the fill rate will be lower. In this chapter a comparison is made with our models and what happens if this project demand is taken into account or not.

Comparing BU South and my policy (R, s, Q) and (R, S)

In chapter 4 I explained which policy is used for each classification. For AA items the (R, s, Q) policy and for the BB and CC items, the (R, S) or (R, s, S) policy is used. The chosen policies are based on literature. To ensure a proper fit for each item, I will also test the policies on each item individually and then make a decision.

For my policy, I used the set fill rates (explained in chapter 4) to calculate the reorder points and order-up-to levels that are used to calculate the total costs. The ready rates are therefore only to compare the performance and later the fill rates are discussed. In Table 13, the total costs and the ready rate are visible for both BU South's order policy and my policies over the previous year. It is directly visible that with my policy the costs are slightly lower and the ready rates also improved, but when looking at the (R, s, Q) and (R, S) policies individually**, the AA items do perform better than what BU South does now. The difference in costs is €3.316,82, which is a decrease of 23,4% on the same items. Unfortunately, the (R, S) system performs much worse on the BB and CC items, the costs are 40% higher than before.** The ready rate for the (R, S) items however is better than BU South. So, improvements can be made to lower the costs of these items.

Table 13: Comparison BU South vs my policies (R, s, Q) and (R, S)

		BU SOUTH	MY POLICY
(R, s, Q)	TC	**€ 14.494,98**	**€ 11.178,16**
AA items	RR 0,99 or higher	44 items	45 items
	RR 0,95-0,99	10 items	12 items
	RR below 0,95	5 items	2 items
(R, S)	TC	**€ 7.714,52**	**€ 10.808,88**
BB and CC items	RR 0,99 or higher	41 items	47 items
	RR 0,95 - 0,99	3 items	1 item
	RR below 0,95	4 items	0 items
All items summary	TC	**€ 22.209,50**	**€ 21.987,04**
	RR 0,99 or higher	85 items	92 items
	RR 0,95 - 0,99	13 items	13 items
	RR below 0,95	9 items	2 items

When looking more in-depth at the performance of the (R, S) policy, the biggest difference is the average On Hand Stock. For the items where the (R, S) system is suggested the average OHS decreased from 1977 to 1872: this is a decrease of only 5,31% but with 40% higher costs. So, when looking into the cost components (see Table 14), the ordering costs for my (R, S) policy are high. However, the other cost components are almost similar. This is because the order sizes are small when using the (R, S) system, the average order size is 4 for my policy and 15,9 for BU South their policy. This creates the same OHS but with more orders and therefore high costs. **So, the (R, S) system is not the right fit for most of the items**. For the average OHS, ready rate, fill rate and total costs per item see Appendix D.

Table 14: Cost components policies (R, s, Q) and (R, S) and BU South

	ORDERING COSTS	HOLDING COSTS	CYCLE COSTS	*TOTAL*
(R, s, Q) items	€ 1.800,00	€ 5.533,05	€ 3.845,11	€ 11.178,16
(R, S) items	€ 3.630,00	€ 4722,57	€ 2456,30	€ 10.808,88
TOTAL OF ALL ITEMS	**€ 5.430,00**	**€ 10.255,62**	**€ 6.301,41**	**€ 21.987,04**
BU SOUTH				
(R, s, Q) items	€ 3.000,00	€ 6.686,27	€ 4.808,71	€ 14.494,98
(R, S) items	€ 750,00	€ 4.267,31	€ 2.697,21	€ 7.714,52
TOTAL	**€ 3.750,00**	**€ 10.953,58**	**€ 7.505,92**	**€ 22.209,50**

Why does this happen? The biggest reason for the small order sizes is the demand pattern. With an (R, S) policy you order new items every time demand occurred in the past period. The order-up-to level is calculated with the average demand in the review period + the lead time to ensure no stock out in the cycle. Since our demand shows high peaks (high variability), the order-up-to level is set high to fulfil this high demand. However, our demand also shows many zero demand or small demand (1 unit) periods. So, when the order-up-to level is high and our demand is low in the period before ordering, the order size (S - OHS) is also small. So, there are many small orders to set the stock levels to the desired (high) order-up-to levels. This creates a lot of orders for the same average on-hand stock. Which is not desirable and the costs are high.

What can be the solution? There are three possible ways to solve this. The first one is to make the review period longer. The time between orders will be longer, the demand in this period will then be higher and therefore the orders will be larger. The second solution is to adjust the order up to level for the coming period, using forecasting to determine the demand in this period. The third possible solution is to also use a reorder point for the BB and CC items. Items are then only ordered when reaching a certain stock level, hopefully lowering the number of small orders.

The first and last solution will be explored in the next sections. The second solution, using forecasting to determine the coming demand and adjust the order up to levels to this demand, is not possible. Company X Is not able to forecast this demand properly.

Increasing the review period

In Figure 18 the cost components and total costs per review period length are displayed in a graph and for corresponding amounts see Table 15. It is visible that when the review period is larger than 4 weeks, the costs stagnate. When choosing for example a review period of 8 weeks, the total costs are € 8.149,37. This is an improvement of 24,6% when comparing it to a review period of 1 week, but the ordering costs are in this situation still €1.400, which is almost double the ordering costs of BU South. The average order size has increased from 4 to 7,6 items, which is an improvement.

So, working with a larger review period seems like a proper solution. However, the ordering costs are still high. It might also not be an ideal policy for Company X, since the demand variability is high and especially now when the number of projects is increasing fast after Covid, new and higher peaks of demand are expected. If an (R, S) system is used with a longer review period, there is less control when the stock levels are only reviewed once every month or every two months.

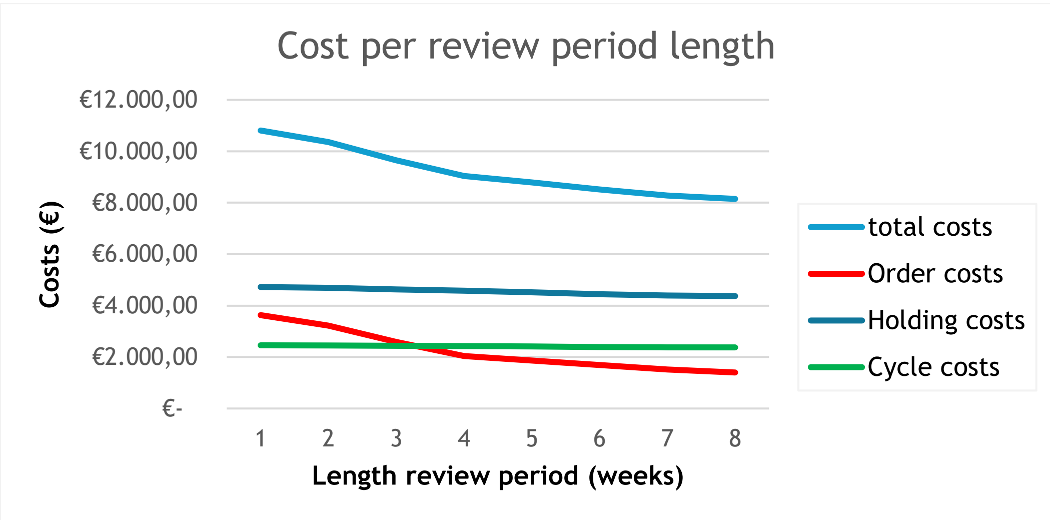

Figure 18: Costs components per review period length (graph)

Table 15: Costs components different lengths of review periods

	ORDERING COSTS	HOLDING COSTS	CYCLE COSTS	TOTAL COSTS
R = 1 week	€ 3.630,00	€ 4.722,57	€ 2.456,30	€ 10.808,88
R = 2 weeks	€ 3.220,00	€ 4.692,38	€ 2.448,20	€ 10.360,59
R = 3 weeks	€ 2.590,00	€ 4.628,32	€ 2.432,43	€ 9.650,75
R = 4 weeks	€ 2.040,00	€ 4.574,49	€ 2.422,76	€ 9.037,25
R = 5 weeks	€ 1.860,00	€ 4.523,25	€ 2.413,12	€ 8.796,37
R = 6 weeks	€ 1.690,00	€ 4.437,96	€ 2.383,25	€ 8.511,21
R = 7 weeks	€ 1.510,00	€ 4.393,46	€ 2.376,50	€ 8.279,96
R = 8 weeks	€ 1.400,00	€ 4.370,63	€ 2.378,74	€ 8.149,37

Another solution to lower the number of small orders is the use of a reorder point. If demand is then low in the review period, an order is only placed when demand reaches a certain point. **So, I tested the (R, s, S) policy for the BB and CC items and compared it to the (R, S) policy.**

Comparing the (R, S) and (R, s, S) systems for the BB and CC items

In Table 16 the costs of the (R, s, S) policy are displayed in comparison with the costs and the ready rates of the (R, S) policy and the performance of BU South for the same items. The total costs have decreased by € 4.238,- which is 39,2% comparing the (R, S) with a review period of 1 week and (R, s, S) system. The biggest problem that occurred with the (R, S) system is also solved since the ordering costs are lowered from € 3.630 to € 590 (see Table 17) and this results in an average order size of 17,75 items instead of the previous 4. However, the ready rates became slightly worse, but this and the actual fill rates are discussed in the next section. **Since the costs are lower and the ready rates are almost the same, I choose to work with the (R, s, S) policy instead of the (R, S)**. For more elaborate details per item see appendix D. **The total costs for all the items will be €17.749,04 when using (R, s, S) and (R, s, Q) systems.**

Table 16: Comparing BU South and my policy(R, S) with the ready rate

		BU SOUTH	(R, S) r = 1 WEEK	(R, S) r = 4 WEEKS	(R, S, S)
(R, S)	TOTAL COSTS	**€ 7.714,52**	**€ 10.808,88**	**€ 9.037,25**	**€ 6.570,88**
	RR 0,99 or higher	41 items	47 items	45 items	40 items
	RR 0,95 - 0,99	3 items	1 item	2 items	7 items
	RR below 0,95	4 items	0 items	1 item	1 item

Table 17: Cost components (R, S) and (R, s, S)

MY POLICY	ORDERING COSTS	HOLDING COSTS	CYCLE COSTS	*TOTAL*
(R, S) R = 1 week	€ 3630	€ 4722.57	€ 2.456,30	€ 10.808.88
(R, S) R = 4 weeks	€ 2040	€ 4574,49	€ 2.422,76	€ 9.037,25
(R, s, S)	€ 590	€ 3.737,78	€ 2.243,10	€ 6.570,88

(R, s, S) and (R, s, Q) difference per item

Since the policies are now chosen based on literature, I will check for each item individually if the right policy is chosen. I will base my choices on the ready rate and total costs, where meeting the target fill rate is the first priority and then costs. I first checked if it is possible to use the same policy for all items. Since 32% of the items have a fixed order quantity, an (R, s, S) system for all items is not possible. When using an (R, s, Q) policy for all items the total costs are €17.885,31. So, the costs are slightly higher (€136,10), but no extreme difference. When checking for each item the best possible strategy based on costs, the costs are €17.684,11, which results in a small improvement of €64,93 when comparing it to the suggested policies. Also, when looking at the ready rate, there are no big differences. The average ready rate when using the suggested policies is 0,9920, using only the (R, s, Q) system is, the ready rate is 0,9922 and when choosing the best policy for each item individually the average fill rate is 0,9919. See for an overview of the costs and ready rates in Table 18. **So, to conclude, using an (R, s, S) or (R, s, Q) policy on the items does not have a major influence on the total costs and the ready rate and therefore, I will stick to the suggested policies determined in chapter 4 by literature.**

Table 18: Costs and ready rate for different choices

	TOTAL COSTS	AVERAGE READY RATE
Suggested policy from literature	€ 17.749,04	0,9920
(R, s, Q) policy for all items	€ 17.885,31	0,9922
All items their best possible policy	€ 17.684,11	0,9919

Fill rates performance and sensitivity

As said before, the ready rate is not an accurate measure when demand per cycle is higher than one and was only used to compare and validate the working of the policies. Therefore, the performance of the fill rates is discussed now.

In Table 19 the performance on the fill rate is visible per class. The policies do not perform yet as they should. For some items, there is a valid reason why this happens, but some of them are out of my control. For example, items that are used occasionally in the previous three years and the last period almost every week with high peaks. For all the specific reasons per item see appendix E.

Table 19: Performance Fill rate (with project demand and target fill rates of 0,99, 0,97 and 0,95)

CLASS	TARGET FR MET (FR OF 0.95, 0.97 AND 0.99)
AA	30 items (81,1%)
BB	26 items (74,3%)
CC	28 items (80%)
Total	85 items
TC	**€ 17.749,04**

The biggest and challenging problem regarding meeting the target fill rates is peak demand that is higher than the reorder point. The probability of happening is small but when it happens it highly influences the fill rate. Therefore, it can occur that when using the Expected Shortage Per Replenishment Cycle to find the reorder point, the model will not take the peak demand into account since the probability of happening is too small (for some items a probability of 0,0018). When the target fill rate is higher, the model might include these peaks, since the ESPRC needs to be smaller. To test this, the target fill rate will be set to 0,99, 0,995 and 0,999 to see the sensitivity of this parameter to the actual fill rates and the total costs.

Table 20: Performance Fill rate (with project demand and target fill rates of 0,99, 0,995 and 0,999)

CLASS	TARGET FR MET (FR OF 0,95, 0,97 AND 0,99)	TARGET FR MET (FR 0,99)	TARGET FR MET (FR 0,995)	TARGET FR MET (FR 0,999)
AA (target FR 0,99)	30 items (81,1%)	30 items (81,1%)	33 items (89,2%)	37 items (100%)
BB (target FR 0,97)	26 items (74,3%)	29 items (82,9%)	30 items (85,7%)	33 items (94,3%)
CC (target FR 0,95)	28 items (80%)	31 items (88,6%)	32 items (91,4%)	34 items (97,1%)
TOTAL	85 items	90 items	95 items	104 items
TOTAL COSTS	**€ 17.749,04**	**€ 18.118,02**	**€ 19.023,47**	**€ 21.396,86**

In Table 20 the results are visible. The reorder points are calculated with the higher fill rates but are checked with the previously described target fill rates, (0,99 for class AA, 0,97 for class BB and 0,95 for class CC). Even with the highest fill rate, the costs are less than BU South. **So, for items that are performing bad, because of the high peak demand, using a higher fill rate is a good solution to reach the appropriate reorder point**. When adjusting only the target fill rates for the items which are performing low, there are only 3 items for which the target fill rates are still not met. This is due to the same reason as before and is not due to a bad choice in policy, parameters or something else that I could have changed.

Items that are sensitive to higher fill rates and peak demand are mostly gloves, which are fast-moving. Also, some clothing which have peak demand and are seasonal. **So, I would suggest using a fill rate of 0,995 or 0,999 to calculate the reorder point for all those items, to ensure that when demand peaks, it can be always fulfilled.** In appendix G it is visible for each item what the used fill rate is.

The final performance of my policy is visible in Table 21. The costs decreased by 14,8% compared to BU South. The performance per item and their reorder points are displayed in Appendix G.

Table 21: Final costs components (OHS = actual stock in BU South)

ITEMS WITH POLICY	ORDERING COSTS	HOLDING COSTS	CYCLE COSTS	TOTAL COSTS
(R, s, Q)	€ 1.880,00	€ 6.113,26	€ 3.999,70	€ 11.992,95
(R, s, S)	€ 640,00	€ 3.937,61	€ 2.338,88	€ 6.916,49
TOTAL COSTS	**€ 2.520,00**	**€ 10.050,87**	**€ 6.338,57**	**€ 18.909,45**

The total amount of € 18.909,45 from Table 21 is calculated when using the actual OHS at BU South at the beginning of the year. These costs represent what would happen if BU South would have implemented my policy from the beginning of the tested year. **In Table 22 the total costs of € 10.434,57 are calculated if the OHS at the start of the year is the same as my calculated reorder point**. So, in this scenario, BU South already implemented my strategy and the OHS is levelled out. The total costs are then € 10.434,57, which is a decrease in costs of 53% compared to BU South. When comparing it to my own policy (Table 21 and Table 22) the holding and cycle costs have decreased by respectively 65% and 47%. This means that the stock levels were extremely high for some items.

Table 22: Cost components OHS = my reorder point

ITEMS WITH POLICY	ORDERING COSTS	HOLDING COSTS	CYCLE COSTS	TOTAL COSTS
(R, s, Q)	€ 2.440,00	€ 2.420,18	€ 2.308,78	€ 7.168,95
(R, s, S)	€ 1.210,00	€ 1.009,09	€ 1.046,53	€ 3.265,62
Total costs	**€ 3.650,00**	**€ 3.429,27**	**€ 3.355,30**	**€ 10.434,57**

Project demand

In the previous section, we discussed using higher fill rates to calculate the reorder points to deal with peak demand. Another possible solution to deal with this, is to fulfil the project demand not from the same stock. Then when a project starts, items should be ordered specifically for this project.

The total inventory costs decrease by 22,4% when not taking project demand into account, see Table 23. As a reminder, these costs are only covering the inventory costs and not the actual spend on the items. The items for the project still need to be bought. For 57 items the total costs decrease, for 36 items the cost stays the same and for 14 items the cost increase. As expected, the costs decreased for items with high peaks such as fast-moving gloves and seasonal t-shirts. For the shoes the costs are not changing since the wear of shoes is not affected by projects. The items for which the total inventory costs increased are mostly slow movers. The holding and cycle costs has increased for all the cases. This is due to slightly less demand (the project demand is removed) with the same reorder points and order quantities. Since those items are slow moving, a decrease in demand can result in a way longer cycle period. In Appendix F the cost changes are visible per item.

Table 23: Costs components Start OHS = s)

ITEMS WITH POLICY	ORDERING COSTS	HOLDING COSTS	CYCLE COSTS	TOTAL COSTS
(R, s, Q)	€ 1.410,00	€ 1.404,44	€ 1.574,19	**€ 4.388,63**
(R, s, S)	€ 1.410,00	€ 1.024,17	€ 1.275,70	**€ 3.709,86**
TC without projects	**€ 2.820,00**	**€ 2.428,61**	**€ 2.849,89**	**€ 8.098,49**
TC with projects	€ 3.650,00	€ 3.429,27	€ 3.355,30	€ 10.434,57

With these outcomes, one would suggest not taking the project demand into account when calculating the parameters. However, in practice, this implies that project peak demand should be known in advance. In most cases this is true, but there is still a chance of unforeseen circumstances. Customers of Company X might need direct assistance when, for example, an installation breaks down. This depends also on the type of location, at some locations more maintenance and service tasks are performed. Therefore, I would suggest taking peak and project demand into account or seeing for each location individually what fits best.

5.2 Experiments with the variable lead time

In the previous section, the reorder points are calculated using the contracted lead times. However, in chapters 1 and 2, it became clear that the supplier of the items is not as reliable as it should be and in this next section, experiments are done to see the effect of the variable lead times on the reorder points and costs. The policies are tested using the reorder point as the start OHS and not the actual stock levels of BU South. This is done to test it in a more general way since we saw in the previous section that the influence on the costs of overstocking in BU South is high.

Experimental setting

Since the lead time is variable, the lead time demand itself is variable. To take this into account the reorder points should also adjust to this situation. These are calculated as before but with the changed mean and variance of the lead time demand, calculated as described in Table 12

After calculating the new reorder points, the policies are again evaluated with the demand of the previous one-year period. Every time an order is placed, the system generates a lead time for that specific order. Therefore, the lead times are a random variable which are distributed, as previously explained, with the following parameters: for logo items, the expected value is 8,96 days and the variance is 44,62 days and for non-logo items, the expected value is 3,63 days and the is variance 16,09 days.

Since the lead time is randomly generated, a Monte Carlo simulation is used to ensure that the results are valid. The simulation tool that I used is Monte Carlito (Auer, 2012). To test the right number of trials, the simulation is run with 100, 200 and 500 trials for a selection of 21 items which have peak demand. The run time was respectively 4.7, 16 and 38.2 minutes. The mean squared error of the total costs was respectively 0.03, 0.016 and 0.006. It decided to use 200 trials, otherwise the runtime would be too long when running it for all 107 items multiple times to find the right parameters.

<u>Limitations – notes</u>

This way of simulating does not fully reflect the actual situation, since in real life the lead times will not fluctuate that much per order. Most of the time the lead time will be higher for a certain period for a specific item. For example, when the supplier has issues with their own suppliers.

Experiment results

In Table 24 the results are displayed for the scenarios. The target fill rates are met in all cases. When taken the variable lead time into account the costs are on average 42,8% higher than with the contracted lead times. When changing the lead times for the logo items to 2 days, there is no big impact on the costs.

Table 24: Experiment results per scenario

SCENARIO	TOTAL COSTS
1 – Actual variable lead times	**€ 14.900,94**
For the first scenario, the safety stock is calculated using the variable lead time as it is now. Calculated with the data from the previous years. For both the logo items as the non-logo items, with an average lead time of respectively 9 and 3,6 days. As calculated in section 4.1.	
2 – All items variable lead time of non-logo items	**€ 14.696,70**
It would be interesting for Company X to know what would happen if all items were delivered as if they were non-logo items. This could be possible if logo items were in stock with the logo already attached to it. So, for Scenario 2 all items will be delivered with a lead time with mean of 3,6 days and a variance of 16,09 days.	
3 – Contractual lead times (2 and 5 days)	**€ 10.434,57**
In the third scenario, the safety stock is calculated using the lead times as contractually agreed on with the supplier. Using a deterministic lead time of 5 days for the logo items and 2 days for the non-logo items.	
4 – All items 2-day contractual lead time	**€ 9.656,44**
The last scenario will show the safety stock levels that are needed if all items are delivered in exactly 2 days.	

Scenario 5 – suggested situation

It is not necessary to take the variable lead time into account for all items when calculating the reorder points. Some items are less critical or are performing not as bad. So, for Scenario 5 the most accurate and preferred situation is simulated.

> Items for which a variable lead time is used are: all items that have criticality level I, which are basic needs such as gloves and shoes since they need to be always available. Logo items are also included since the delivery performance are unreliable. This covers 66% of all items and these are all class AA items with some additional items, For the rest of the items the contracted lead time is used (2 days)

The total cost of this scenario is € 12.593,23. Which is still 20.7% higher than when the supplier is reliable. However, there is still an improvement in costs of 43.3% when comparing it to the performance of BU South.

Scenario 6 – dedicated stock for logo items at the supplier

The last scenario is a combination of all scenarios. The difference with scenario 5 is the lead time of the logo items. At this point, the logo items are delivered too late and as explained in section 2.2, also delivering in five days is in some cases too long. Therefore, together with Company X, it is decided to see the performance if logo items are also delivered within 2 days (contracted). **This means dedicated logo stock is needed at the supplier for this scenario**. In this scenario, the variable lead time is used since delivery performance are still not reached. So, with an expected lead time of 3,63 days. To make it clearer:

> Variable lead time of 3,63 days for items which are: AA items, with criticality "I" and logo items, which covers 53% of the items.
>
> Contracted deterministic lead time of 2 days: the rest of the items.

The total cost of this scenario is € 13.181,39. Comparing these costs to BU South's performance the total costs would decrease by 40,7%. However, when working with dedicated stock at the supplier, the difference in total costs is higher than without (scenario 5 vs scenario 6). This is because the average OHS is higher. Which makes sense; orders are delivered faster; lead time are less variable and therefore stock out occurs less. So**, to conclude; using a dedicated stock at the supplier while also having stock at the location is not sufficient.** A reason to work with dedicated stock at the supplier could be the increase in availability for locations where there is not stock at the location. This is discussed in the next chapter. Where I will also explain more elaborate why having stock at the supplier might not be the best solution based on costs.

For all the reorder points of the scenarios see Appendix H.

5.3 Conclusion

The findings of this chapter can be summarized as follows:

- The (R, S) policy is not useful since demand sizes are fluctuating too much which creates many small orders.
- Using the (R, s, Q) and (R, s, S) policies resulted in an improvement in costs of 14,8% when BU South implemented these policies one year ago.
- When BU South had implemented these policies years ago the costs would have improved by 53%.
- For items with high peak demand, such as gloves and some t-shirts, use a target fill rate of 0,995 or higher to calculate the reorder point.
- Including the project demand does decrease the total cost of inventory. But taking the project demand into account might still be a good idea for locations where project demand is not known.
- The costs of inventory increase by 42.8% when the variable lead times are taken into account to calculate the reorder points. This increase shows the impact of an unreliable supplier.
- When supplier reliability is considered deciding the reorder points, scenario 5 (variable lead time for AA items, items with criticality I and logo items) would be the best solution. Resulting in a cost reduction of 43,3% compared to BU South.
- When deciding to implement scenario 6 and to work with dedicated logo stock at the supplier, the cost reduction is 40,7% compared to BU South but this is not the best solution. A more elaborate explanation is given in the next chapter.

CHAPTER 6 - IMPLEMENTATION AND FURTHER STEPS

This chapter focuses on the further steps to take and the implementation of the models. In the first section, the steps that need to be taken to implement and improve the inventory management of the other locations are described. In the second section, the possible options to solve, or at least to improve the variable lead time are discussed, as well as the (possible) dedicated stock at the supplier. In the last section, I will suggest some solutions to reduce the level of Maverick Buying at the locations, especially at Business Unit North.

6.1 Implementation of inventory management at the other locations

In this section, some concrete steps are described to implement the inventory models at all the locations. To start working with proper calculated reorder points and to implement a new way of working, some things need to be addressed. First, is the implementation itself. How Company X should organize the changes and which steps should be taken. Second, the locations need to know how to deal with items without any historical data. At the beginning of the implementation, reorder points, order-up-to levels and order quantities need to be determined with approximations. The last issue that is discussed in this section is the evaluation of the policies, how and how often should they adjust their parameters.

How to implement the new way of working?

When starting with the implementation, the **first step is choosing the way of controlling the inventory**. For most locations, this will be SAP, as it should be implemented at all locations in the coming year. In an ideal situation, this ERP system should be used in its entirety and therefore inventory should be ordered using the MRP-run. However, for smaller locations, this might not be ideal and implementation costs a lot of time and effort for a small number of orders each year. This is something Company X (and its locations individually) should decide itself. Whatever system they are going to use**, it should keep track of demand data properly for the coming period**. Since this is the most important information that is needed to later determine the right reorder points. **In the first period of the implementation, this demand data is not available yet and estimates for the reorder points should be made.** How to determine these approximations is explained in the next section. After a certain period, the demand data is enough and **the reorder points and order quantities can be calculated and changed**. They should be adjusted in such a way that the performance goals are met. For the first period, those goals can be the target fill rates that are set or the number of orders. The total costs are somewhat harder to set as a beginning goal since they are never tracked before and are therefore not comparable. However, the total costs of BU South can definitely be taken as an upper bound, since they are the biggest locations. How to evaluate and adjust the parameters is explained in one of the next sections.

Employee motivation and education

Axsäter (2006) explains that the most important factor of a successful implementation is the behaviour of the personnel involved. They all must be instructed and trained in inventory operating procedures. Especially the motivation to keep records accurate to be able to evaluate the performance since "A performance evaluation is needed both for creating motivation for efficient application of the system and for being able to adjust the control when various changes in the operating conditions occur" (Axsäter, 2006).

Another important factor is the knowledge and education of the employees. Axsäter (2006) clarifies that the need for education concerns not only the initial implementation phase. Because too often an inventory control system becomes progressively worse when a key person leaves the company and the person taking over does not have adequate training. The most important part of education should concern, according to Axsäter, the basic principles and assumptions of the inventory models that are used. Personnel should also know how the system is affected by changing different parameters. Because when clearly understanding how the control system works, it is both challenging and stimulating to work to focus on improved system control.

How to deal with items with no historical data?

Since only BU South tracks their inventory levels, for the other locations there is no historical demand data. Therefore, some guidelines are made to determine the reorder points for the first period when they start the implementation. After this first period, proper calculations can be made to determine the actual reorder point for each item at each location. **At the beginning, the order quantity can be calculated using the EOQ formula with the same parameters as BU South**: ordering costs of €10, - and the holding cost rate of 25%. For the annual demand per year, the demand from last year (2021) can be used or the demand from today to a year ago.

Since shoes are the biggest reason for Maverick Buying, Company X and I, therefore, decided to place some inventory of shoes at all locations. Since these items are totally new to some of the locations, **I would suggest using a reorder point of 1 or 2 for shoes that are requested often and a reorder point of zero if shoes are only demanded a maximum of 10 times a year.** Having shoes in stock at all locations will roughly cost about €6.550 per year. These costs are calculated using the total shoe demand of BU South and the matching costs and those are scaled to the total shoe demand of all locations (Bought by the supplier and Maverick Buying). The used ratios are visible in Appendix L

For the rest of the items, I made a decision tree in which indications of the reorder points are visible per item group. These are just rough estimates that I made with the outcome of chapter 5 and are only a guideline. I saw, for example, in BU South there are no shoes with a reorder point above 2. So, for bigger locations I suggest a reorder point of 1 or 2 and for the smaller locations a reorder point of 1 or 0. The locations can also choose to stick to their own way of working (described in chapter 2) and only gather demand data to then calculate the best reorder points later with the suggested policies and formulas. The decision tree is visible in appendix I.

How to evaluate the parameters?

After the first part of the implementation phase, the reorder points should be calculated according to the suggested models. It is hard to say after what period the demand data is sufficient. **I would say as a rule of thumb, take demand data of one year for slow-moving and seasonal items and for fast-moving items data from half a year.**

When the reorder points are calculated, it is important to evaluate and adjust them occasionally. However, parameter adjustments should be conducted slowly while continuously monitoring the outcome (Axsäter, 2006). Since adjustments affect both the short and long run. For example, when the target fill rates are not met or lead times are getting longer, the reorder points should be increased. This will result in many new orders in a short period since for many items the reorder point is reached directly or relatively soon after changing them. When decreasing the reorder point, changes in orders are slower visible. So, Axsäter concluded that "**Changes in the inventory control will nearly always first**

result in a higher total stock" since "the effects of the increased reorder points can be observed earlier, the total stock will increase in the short run." The locations should be aware of this when evaluating the changes and monitoring the performance. It is therefore also important "to **adjust the control continuously and under careful supervision**.". The employees must understand "that it can take a relatively long time until the system reaches a steady state. It is not uncommon that changes in the inventory control, **due to insufficient understanding of these effects, can create a situation that is completely opposite of what was intended.**" (Axsäter, 2006).

6.2 Dealing with lead time variability

As earlier explained in section 3.1, every effort should be made to reduce the lead time variability. Since, as seen in chapter 5, the costs at the locations can increase by approximately 40% when reorder points need to be adjusted to an unreliable supplier. In this section, several solutions are given.

Bullwhip effect

One of the most well-known effects of (variable) long lead times and variability in demand is the bullwhip effect. This effect describes the phenomenon that the variability in demand increases when moving upstream in the supply chain (Metters, 1996). This creates more fluctuations in order quantities at the next chain in the supply chain. When also dealing with variable lead times, the "retailer" (in our situation the Company X locations), will **order higher quantities** to prevent stock outs, where therefore the supplier itself needs to order more at its own supplier. Which creates a strong bullwhip effect. Researchers have done several studies on this effect and they all lead to one of the most important factors; the lack of sharing information in the supply chain. Chen, Drezner, Ryan and Simichi-levi (2000) concluded that centralizing customer demand information can significantly reduce the bullwhip effect. Especially with longer lead times: "the retailer must use more demand data in order to reduce the effect.". The biggest problem lies within the fact **that the supplier does not have the actual end-item demand data** and for Company X specifically **the forecasting of the big projects is lacking,** which is precisely the cause of the high variability in demand at the locations.

Vendor- managed Inventory (VMI)

A solution to decrease lead times and the lack of (end-item) demand information in the upstream firms in the supply chain is to work with Vendor-managed Inventory (VMI). In this situation, the replenishments of the inventory are continuously managed by the supplier (Waller, Johnson, & Davis , 1999). The supplier of the PPE is then personally responsible for the availability of the items at the locations. It will solve the problem of peak demand since: "Many suppliers are attracted to VMI because it mitigates uncertainty of demand" … "VMI helps dampen the peaks and valleys of demand, allowing smaller buffers of inventory." (Waller et al., 1999). Since the supplier does have **more insight into demand patterns at the locations (end-item demand)**, they are able to **forecast demand more precisely**. The time between replenishments is also more likely to decrease and therefore **order quantities (or replenishment quantities) are smaller,** which reduces the bullwhip effect as described in the previous section.

For Company X, VMI can also be helpful when looking at Maverick Buying. The supplier is then able to respond directly to demand changes and other needs. Especially for shoes, for which the level of Maverick Buying is the highest. The supplier can place shoes of all shapes and sizes at the locations and Company X only pays for the ones that they use. It will also benefit the supplier since they can increase their shoe revenue by almost 50% since all shoes are then bought from the supplier instead of somewhere else.

However, the implementation of VMI is at this moment somewhat impossible for Company X. The contracted supplier is not willing to cooperate since their company structure is not suited for VMI. It will also result in some higher contract costs, which Company X needs to pay since the supplier then need to put more effort in Company X as a customer. So, another plan needs to be made to reduce the bullwhip effect and the variability in the lead times.

Other solutions for variable lead times

As explained before the biggest causes of the bullwhip effect are the lack of end-item demand data, lack of (shared) forecasting and high order quantities. Since VMI is not an option, for now, other solutions will be addressed to tackle these problems.

To solve **the lack of forecasting and end-item demand**, clear communication and working closely together are needed between Company X and the supplier. Company X should communicate the bigger projects that are coming and give more insights into the actual demand on the locations. Company X and the supplier are then able to make forecasts together and plan the best strategy for both parties. However, it became clear in chapter 2 that only BU South tracks their inventory and therefore the locations themselves do not have their own end-item demand, only the orders are known for both parties. After implementing the inventory policies and way of working at all the locations, the demand data is known after a while and should be communicated to the supplier.

To ensure proper forecasts, the departments of Company X need to collaborate more. The communication between the sales department and the supply chain manager needs to be improved, so the supply chain manager can make proactive decisions on placing more stock at certain locations. When the forecasting of demand is improved, less safety stock is needed and therefore the inventory costs can lower even more.

The **high order quantities** are in some cases easy to adjust. Especially for logo items, when ordering lower quantities, it is easier for the supplier to deliver faster. Since there is an extra step (attaching the logo to the item), smaller orders are easier to manage. My suggested order quantities are for some items already lower than BU South orders at this moment. A trade-off should be made, ordering smaller quantities means more orders in the same period. Since Company X, as well as other companies, is focussing on reaching their sustainability goals, the number of orders and shipments should be minimized. However, since they use a periodic review policy, every week an order is placed anyway. So, it does not affect the number of orders since only the number of items on the order increase when ordering smaller amounts more often.

Performance-based contracting

In the previously explained solutions, Company X must cooperate a lot to create the best working supply chain. But in the end, it is the supplier that is not performing as it should. To motivate the supplier to strive for performance excellence, a performance-based contract (PBC) might help. PBC "focuses on the outputs and quality of service provision and may tie at least a portion of a contractor's payment as well as any contract extension or renewal to their achievements” (Martin, 2007). It “can facilitate supply chain coordination and collaboration to realize end customer outcomes by aligning incentives among supply chain actors (Randall, Terrance, & Joe, 2010).

At this moment, the contract does not include such performance-based payments, which does not motivate the supplier to meet the service levels. When implementing such a contract, it is necessary to measure the performance with several KPIs, which should be clearly defined. For Company X, possible KPIs could be the number of orders delivered on time, the item fill rate, the order fill rate, the quality of the items and many more. At the end of the year, a bonus can be obtained when the supplier meets the predefined KPIs and a penalty when they underperformed. This seems a reasonable solution to motivate the supplier or to take into account when contracting a new supplier. However, when measuring KPIs, monitoring them is one of the important aspects. At this moment proper performance data is not available or monitored, from either the side of Company X or the supplier. So, when working with a performance-based contract, monitoring must be possible.

Dedicated logo stock at the supplier

In section 5.2 it became clear that it is not profitable to work with stock at the supplier and the location at the same time, to only ensure faster delivery. It is indeed faster delivered, but this does not affect the availability or costs positively.

To ensure faster and higher availability at the locations without stock, two solutions are possible. Solution 1: Place stock at all the locations and no stock at the supplier. Solution 2: Place no (or some) stock at the locations and dedicated stock at the supplier, where items are ordered directly from the supplier and only for the quantities that are needed at that moment.

In the contract that Company X and the supplier agreed on, there are now no extra costs involved when deciding to place some stock at the supplier. So, the holding costs and cycle costs are not for the account of Company X, only the ordering costs. However, this can change when deciding to place more stock at the supplier than the supplier expected. So, for now I used the actual contract agreements, but Company X should keep in mind that the supplier might include holding costs in the future. The second thing to keep in mind, and is contracted, is that all stocked items need to be ordered at least once every 6 months. Otherwise, items that are left need to be bought from the supplier at the end of the 6 months.

To compare the solutions a comparison is made between the costs of having an item on stock at a location and the costs of ordering every single item from the supplier. **When looking at the logo items in BU South, there are only 4 items for which it is cheaper to work with single-item orders, those are the parkas**. This is due to the fact they are expensive, and the demand is low. When looking at the other items, it is cheaper to work with stock at the locations themselves. It is hard to validate these results for all locations since the data is not available. It is also hard to determine if these ordering costs reflect reality since it might happen that people order several different items at once.

So, **my suggestion will be to place parkas with logo at the supplier and place t-shirts and sweaters at the locations**. Company X could choose to still place some small stock parkas at locations where demand is high (BU South and Hengelo) since it is important to ensure the safety of the employee. Reorder points for the stock at the location should then be calculated using the variable lead times. For the other locations, ordering directly from the dedicated stock at the supplier is the best solution. So, the dedicated stock is only for the smaller locations. This will decrease the total costs and changes of overstocking.

Another possibility, which fits more in Company X its new policy, is to place items with criticality III only at the supplier. Company X wants to reduce the use of these items since they do not directly contribute to the safety of the employee. T-shirts and sweaters are only used underneath the overalls and do not have a safety norm. Company X also wants to monitor the use of those items, which is easier if the items are ordered directly at the supplier via a portal with a personal account (MijnPBM). Having stock at the supplier also reduces the chances of overstocking, because when having a shared stock, the throughput time is lower and the chances of not using the items are small. Especially in the situation where Company X is now; they get a new owner soon and it is not clear yet if logos are changing etcetera.

Reorder points and order-up-to levels at the supplier

The level of dedicated stock will be calculated for two different situations. In the first situation, only the parkas are in stock at the supplier for the smaller locations. In the second scenario, all logo items are in stock at the supplier, and available for all locations. For both situations, the items are personally ordered via the portal. The level of the dedicated stock will be calculated using the base stock system. This system uses end-item demand to calculate the order-up-to level and reorder points the same way as for one location (Silver et al., 2017). The end-item demand data from all locations are then combined. When all end-item demand data is known, the mean and variance of the total demand can easily be calculated. In theory, the standard deviation of the total demand is then lower than the sum of the standard deviation of the individual demand, this is called the risk pooling effect. Risk pooling occurs when one can aggregate demand across locations (Simchi-Levi, 2013). However, this end-item data is not available yet for all locations. Therefore, rough estimates are made, where the distributions of BU South are used to get an idea of the right reorder points and order-up-to levels. To simulate the risk pooling effect, the demand peaks are lowered manually. The same total demand is used but where previously a peak occurred, the demand is more spread out over the week. When the policies and way of working are implemented at all locations, better data is gathered, and the actual risk pooling effect can be calculated. For the reorder points and order-up-to levels of the dedicated stock at the supplier see Appendix J and K and for the ratios that are used see Appendix L.

6.3 Maverick Buying BU North

When starting this research, Company X thought one of the bigger reasons for Maverick Buying was the poor availability of items at the contracted supplier. However, it became clear after some research (chapter 2), that this is not the main reason. Especially at BU North, there are other reasons like: items are **easier and faster accessible, no need to level up their own inventory management and the service at the non-contracted supplier is more personal**. Another important aspect is the poor relationship between BU North and the central management, BU North can take well-intended advice as criticism, and they are not eager to change. This describes as Casual Maverick Buying as explained in section 2.3.

Solutions in literature for Maverick Buying

To reduce the level of casual Maverick Buying, there are some solutions. Karjalainen (2009) explains that Casual MB could be reduced by **educating employees about the total costs of ownership,** and by showing strong purchasing leadership. Wimbush and Shepard (1994) also explains that **supervisors determine how organizational policies are perceived within their unit**. This means that Maverick Buying can be influenced by local management. When business procurement managers on the locations are positive about the contracted supplier and motivate the buyers to purchase the items there, this might help. This might also improve the relationship with the central management.

There are other general solutions for Maverick Buying such as e-procurement, the procurement card and rewards and sanctions. In my opinion, these solutions would not help. Especially rewards and sanctions, since according to Karjaleinen (2009) “the incentives should be aligned correctly, as misaligning them could result in the employee’s or unit’s best interest being different from that of the organization and the principal-agent problem would get deepened.” Then the relationship with the central management can get more difficult over time if they get the feeling that they are closely watched.

Other solutions for Maverick Buying

In my opinion the first thing on the menu for reducing Maverick Buying in BU North is improving the relationship between the departments. Also, Incentives need to be clear and both parties, location BU North and the central management, need to address their issues. **Working together needs to be one of the first objectives.**

The second thing is improving their inventory management. If they would work the same way as BU South does, with a weekly MRP run, it could already improve the easy and faster availability of the items at their location. In the beginning, this will be a big step. As explained before, motivation and education are the most important factor in a successful implementation. So, therefore the first step, talking and getting the objectives straight, is extremely important. So, I would take it slow. **But when the implementation is done successful, managing their inventory will become easier over time. Therefore, they do not need to get their supplier elsewhere, since they are always available with the slightest effort**.

As explained in the beginning of this chapter, **Vendor Managed Inventory is also a possible solution** to reduce Maverick Buying. It makes more items fast accessible, and it might also solve the last-mentioned reason for MB: the service at the non-contracted supplier is more personal. When occasionally, an employee of the supplier is visiting the location for a replenishment, **this more personal feel might also be attained.**

The last possible solution could be **splitting the orders**. When an order cannot be delivered within the contracted time, the most important items should already be delivered. Especially items that are important.

6.4 Conclusion

Implementation

- The most important task at the beginning of the implementation is keeping track of the demand per item and setting the starting reorder points and order quantities.
- Employee motivation and education are important factors for the success of the inventory system.
- Changes in inventory control will always result in a higher total stock. Those changes need to be done continuously and under careful supervision otherwise, it might result in the opposite of what was intended.

Dealing with an unreliable supplier and dedicated stock

- VMI is a good solution to solve the lack of end-item demand at the supplier, the level of Maverick Buying and the order quantities will be smaller, which decreases the bullwhip effect.
- Performance based contracting can motive the supplier to improve their delivery performance.
- Only for the parkas it is profitable to place dedicated stock at the supplier, for the rest of the items placing some stock at the locations is the best option to increase the availability of the items.

Maverick Buying

- Placing shoe stock at all locations would cost approximately 6.550,- euros.
- Improving the inventory management on the locations, will ensure easy accessibility of items at the locations itself and therefore decreasing the level of MB.
- Splitting orders and delivering items separately can also be an option to consider.
- Rewards and sanctions are in my opinion not the right way.

CHAPTER 7 - CONCLUSION AND RECOMMENDATIONS

7.1 Conclusion

In the beginning three problems where found. Where two of them are sub problems, those are the high level of Maverick Buying and the unreliable supplier. The main problem is formulated in the following research question:

"How should Company X allocate its PPE stock in the supply chain to ensure the satisfaction and safety of the employee while reducing (extra hidden) costs?"

To answer this question, first a proper inventory system was made based on the data of Business Unit South. The following conclusions are based on these systems:

- **The availability of 104 of the 107 items was brought to the desired fill rate with a reduction in costs of 43,3% compared to the situation now, for which the total cost is € 12.593,23.** Those inventory costs are calculated taking the delivery performance of the unreliable supplier into account, to be able to have enough items in stock to always ensure the availability of the items.
- **When the supplier would have delivered as contracted, the costs could have been € 10.434,57. Meaning that it costs Company X 20,7% more when the supplier does not perform well.**
- Taking project demand into account can lead to 20% more costs.

We researched other ways to deal with the unreliable supplier by looking at a possible dedicated stock of logo items since the delivery performance of those items is lacking the most. We came to the conclusions:

- **It is not ideal to place logo stock, both at the supplier and the location, to only ensure faster delivery.**
- **When placing stock at the supplier and not at the locations, it is only profitable for Parka's** since the inventory costs are less than the ordering costs when all items are ordered separately.
- **For the other logo items, sweaters and t-shirts, placing stock only at the locations themselves** is the best solution when looking at costs.
- Literature suggests looking into VMI and Performance-based contracting.

Regarding Maverick Buying the following conclusions are made:

- Placing shoes at all locations would cost approximately €6.550.
- Other solutions for Maverick Buying are for example, also VMI.

7.2 Recommendations

To ensure the safety of the employees and to increase the availability of the items at the locations while reducing Maverick Buying and other hidden costs, I would recommend Company X the following:

- **implementing one way of working regarding inventory management at all locations.** When the availability of the items is sufficient at the location itself, the level of Maverick Buying will become less since there is no need to go somewhere else. The short-term impact of an unreliable supplier will also become less since locations then know how to deal with it.

- **When implementing the inventory models the focus should be on data gathering** since the data of most of the locations was not sufficient to analyse. When the quality of the data is improved, the parameters can be calculated more precisely.
- **Looking into performance-based contracting to ensure the higher delivery performance of the supplier.** This will probably decrease the lead time and therefore the inventory costs at the locations will also decrease.
- **Placing shoe stock at all locations.** This will increase the availability of shoes at the locations and therefore, Maverick Buying is less likely since the shoes are as fast available as at a supplier next door.
- **Placing t-shirts and sweaters at the locations to cover the 5-day unreliable lead time.**
- **Placing Parkas with the logo already attached to them at the supplier to serve all smaller locations.**
- **Taking the project demand into account at locations where ad hoc projects occur often.** for locations where project demand is known upfront, this is not needed and can save money.

7.3 limitations

There are several limitations to this research. First, the quality of the data, we only had access to the data of one location. Therefore, a proper multi-echelon analysis was not possible to conduct. This would have given a better understanding of for example the attainted risk pooling effect. The data from BU South provided us with information about when an item is issued, therefore there we had no insights in the backorders.

We did not take seasonality into account and modelled our demand as stationary demand. This causes probably higher reorder points than needed for periods where demand is low due to, for example, weather. Our costs could therefore maybe even be lower than calculated.

The lead time variability is not calculated per item, but for all items together. Therefore there is no difference made between items that are poorly delivered and items that are well delivered in the last year. The lead time variability is also the same for all periods. In real life, lead times are most of the time longer and more variable for only a period when, for example, the supplier has internal problems.

The backorder costs are not considered since those costs are hard to calculate. This results in costs that are not influenced by the availability of the item. When taken them into account, the availability of the item not only influenced the fill rate but also the costs and would have given a more elaborate point of view.

The ordering costs are calculated for each SKU individually. In real life this is not the case, items are combined in one order every week. When comparing the policies this does not affect the outcome, but when calculating the order costs when ordering directly form the supplier it does.

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APPENDICES

Appendix A: Specific items Maverick Buying

	Amount	Available at the contracted supplier?	Note
Business Unit North	**€ 61.800**		
Hand protection	€ 43.447		
Hyflex 11-531	€ 21.051	At preferred supplier	Performance at supplier 82,7%
Hyflex 11-801	€ 1.414	At preferred supplier	Performance at supplier 88%
other Hyflex	€ 6.112		
Other	€ 14.870		
Footwear	€ 12.433		
Brand Grisport	€ 2.012	At preferred supplier	Delivery performance 50%, but no standard shoe for Company X
Jalatta/jalaska	€ 2.005	Not at preferred supplier	
Brand Emma	€ 1.345	At preferred supplier	Performance where low for some items, at this moment performance even worse than 2021
Other	€ 7.071		
Eye Protection	€ 4.090		
not traceable which types			
Business Unit South	**€ 9.512**		
Hand protection	€ 3.967		
Brand Tegera (Welding gloves)	€ 1.100	At preferred supplier	Not sure about specific items. Performance was low for some types.
Hyflex 11-816	€ 960	At preferred supplier, only bought by BU South (Heerlen)	Performance of preferred supplier 12,5%
Other	€ 1.907		
Footwear	€ 5.222		
Not traceable which types			
Business Unit West	**€ 5.811**		
Rain clothing	€ 3.980	In direct need	
Flame resistant jackets/pants	€ 3.980		

Goes Vlissingen	**€ 3.634**		
Hand protection	€ 900		
Isolated gloves Klasse 0 ATPV	€ 420	Not at preferred supplier, needed for specific specialization	
Isolated gloves Level C	€ 417	Not at preferred supplier, needed for specific specialization	
Footwear	€ 2.435		
Emma boot Mendoza	€ 1.157	At preferred supplier	Performance where low and low spend for the rest of Company X.
Jalatta/jalaska	€ 1.129	Not at preferred supplier	
other	€ 149		

Appendix B: Items and their classifications

Item description	ABC	Criticality	Criticality class	final class	Distribution
Laars Emma Mento S3 mt 41D	C	I	CI	BB	Neg Binomial
Laars Emma Mento S3 mt 42 D	B	I	BI	AA	Neg Binomial
Laars Emma Mento S3 mt 43 D	B	I	BI	AA	Neg Binomial
Laars Emma Mento S3 mt 44 D	C	I	CI	BB	Poisson
Laars Emma Mento S3 mt 45D	C	I	CI	BB	Poisson
Veiligh. schoen hoog Emma Billy mt 41	B	I	BI	AA	Neg Binomial
Veiligh. schoen hoog Emma Billy mt 42	B	I	BI	AA	Poisson
Veiligh. schoen hoog Emma Billy mt 43	A	I	AI	AA	Neg Binomial
Veiligh. schoen hoog Emma Billy mt 44	B	I	BI	AA	Poisson
Veiligh. schoen hoog Emma Billy mt 45	B	I	BI	AA	Neg Binomial
Veiligh. schoen hoog Emma Billy mt 41	B	I	BI	AA	Neg Binomial
Veiligh. schoen hoog Emma Lukas mt42	C	I	CI	BB	Poisson
Veiligh. schoen hoog Emma Lukas mt43	C	I	CI	BB	Poisson
Veiligh. schoen hoog Emma Lukas mt44	C	I	CI	BB	Poisson
Veiligh. schoen hoog Emma Lukas mt45	C	I	CI	BB	Poisson
Veiligh. schoen hoog Nestor mt41 D	B	I	BI	AA	Poisson
Veiligh. schoen hoog Nestor mt42 D	A	I	AI	AA	Neg Binomial
Veiligh. schoen hoog Nestor mt43 D	B	I	BI	AA	Neg Binomial
Veiligh. schoen hoog Nestor mt44 D	B	I	BI	AA	Poisson
Veiligh. schoen hoog Nestor mt45 D	B	I	BI	AA	Neg Binomial
Winterlaars Emma Merula S3 mt 41 D	B	I	BI	AA	Neg Binomial
Winterlaars Emma Merula S3 mt 42 D	A	I	AI	AA	Neg Binomial
Winterlaars Emma Merula S3 mt 43 D	A	I	AI	AA	Neg Binomial
Winterlaars Emma Merula S3 mt 44 D	B	I	BI	AA	Poisson
Winterlaars Emma Merula S3 mt 45 D	B	I	BI	AA	Neg Binomial
Binnenvoering 7760 maat EEL marine Fleece	B	II	BII	BB	Neg Binomial
Binnenvoering 7760 maat EL marine Fleece	B	II	BII	BB	Neg Binomial
Binnenvoering 7760 maat L marine Fleece	B	II	BII	BB	Neg Binomial
Binnenvoering 7760 maat M marine Fleece	B	II	BII	BB	Neg Binomial
Binnenvoering 7760 maat S marine Fleece	B	II	BII	BB	Neg Binomial
Parka 7223 maat EEL Hedland - Company X logo	B	II	BII	BB	Neg Binomial
Parka 7223 maat EL Hedland - Company X logo	A	II	AII	AA	Neg Binomial
Parka 7223 maat L Hedland - Company X logo	A	II	AII	AA	Neg Binomial
Parka 7223 maat M Hedland - Company X logo	A	II	AII	AA	Neg Binomial
Parka 7223 maat S Hedland - Company X logo	B	II	BII	BB	Neg Binomial
T-shirt korte mouw Company X logo maat EEL	B	III	BIII	CC	Neg Binomial
T-shirt korte mouw Company X logo maat EL	B	III	BIII	CC	Neg Binomial
T-shirt korte mouw Company X logo maat L	B	III	BIII	CC	Neg Binomial
T-shirt korte mouw Company X logo maat M	B	III	BIII	CC	Neg Binomial
Sweater Company X logo maat EEL	B	III	BIII	CC	Neg Binomial
Sweater Company X logo maat EL	A	III	AIII	BB	Neg Binomial
Sweater Company X logo maat L	A	III	AIII	BB	Neg Binomial
Sweater Company X logo maat M	A	III	AIII	BB	Neg Binomial

T-shirt lange mouw Company X logo maat EEL	B	III	BIII	CC	Neg Binomial
T-shirt lange mouw Company X logo maat EL	B	III	BIII	CC	Neg Binomial
T-shirt lange mouw Company X logo maat L	B	III	BIII	CC	Neg Binomial
T-shirt lange mouw Company X logo maat M	B	III	BIII	CC	Neg Binomial
Armbeschermer Fireblade FS14 geel 35 cm	C	II	CII	CC	Neg Binomial
Bivakmuts Intersafe FR/AS	B	II	BII	BB	Neg Binomial
Bril Goggle ultravision 9301-105	C	II	CII	CC	Neg Binomial
Bril I-VO 9160-265 blauw-oranje	A	I	AI	AA	Gamma/Lognormal
Col Intersafe FR/AS	A	III	AIII	BB	Neg Binomial
Gehoorkap Bilsom Clarity 1011142 28109	C	I	CI	BB	Neg Binomial
Gehoorkap Optime II H520p3E-110883	A	I	AI	AA	Neg Binomial
Gelaatscherm Perforama Nova scherm blank	C	II	CII	CC	Neg Binomial
Gelaatsscherm V4F voor helm Uvex airwing	C	I	CI	BB	Neg Binomial
HANDSCHOEN 5-VINGERS L.35 ROOD	C	I	CI	BB	Neg Binomial
Handschoen Alphatec 58-435 maat 10	C	I	CI	BB	Neg Binomial
Handschoen Alphatec 58-435 maat 8	C	I	CI	BB	Neg Binomial
Handschoen Alphatec 58-435 maat 9	C	I	CI	BB	Neg Binomial
Handschoen geitenleer Tegera Ejendalls10	A	I	AI	AA	Neg Binomial
Handschoen geitenleer Tegera Ejendalls11	C	I	CI	BB	Neg Binomial
Handschoen Hyflex 11-518 maat 10	A	I	AI	AA	Neg Binomial
Handschoen Hyflex 11-518 maat 8	A	I	AI	AA	Neg Binomial
Handschoen Hyflex 11-518 maat 9	A	I	AI	AA	Gamma/Lognormal
Handschoen Hyflex 11-531 maat 10	A	I	AI	AA	Gamma/Lognormal
Handschoen Hyflex 11-531 maat 8	B	I	BI	AA	Neg Binomial
Handschoen Hyflex 11-531 maat 9	A	I	AI	AA	Gamma/Lognormal
Handschoen Hyflex 11-537 maat 10	A	I	AI	AA	Gamma/Lognormal
Handschoen Hyflex 11-537 maat 8	A	I	AI	AA	Neg Binomial
Handschoen Hyflex 11-537 maat 9	A	I	AI	AA	Gamma/Lognormal
Handschoen HyFlex 11-630 Maat 10	C	I	CI	BB	Neg Binomial
Handschoen HyFlex 11-630 Maat 8	C	I	CI	BB	Neg Binomial
Handschoen HyFlex 11-630 Maat 9	C	I	CI	BB	Neg Binomial
Handschoen Hyflex 11-739 maat 10	B	I	BI	BB	Neg Binomial
Handschoen Hyflex 11-739 maat 8	C	I	CI	BB	Poisson
Handschoen Hyflex 11-739 maat 9	B	I	BI	BB	Neg Binomial
Handschoen Winterpro, Maat 08	C	III	CIII	CC	Neg Binomial
Handschoen Winterpro, Maat 09	B	III	BIII	CC	Neg Binomial
Handschoen Winterpro, Maat 10	B	III	BIII	CC	Neg Binomial
Handschoenen geitenleder maat 10	A	I	AI	AA	Gamma/Lognormal
Helm Uvex Airwing blauw incl Company X Logo	A	I	AI	AA	Neg Binomial
Kniebescherm Helly Hansen	C	II	CII	CC	Neg Binomial
Oordop Ear Classic geel	C	I	CI	AA	Gamma/Lognormal
Overzetbril 9161-014, transparant	C	II	CII	CC	Neg Binomial
Overzetbril Flexy	C	II	CII	CC	Neg Binomial
Regenbroek EL FR-LR41 koningsblauw	A	III	AIII	BB	Neg Binomial
Regenjas EL FR-LR48 koningsblauw	A	III	AIII	BB	Neg Binomial
Ruimzichtbril Atom blauw, polycarbonaat	C	II	CII	CC	Neg Binomial

Stofmasker FFP3 3M 9332	A	I	AI	AA	Gamma/Lognormal
Thermobroek lange onderbroek maat EEL	C	III	CIII	CC	Neg Binomial
Thermobroek lange onderbroek maat EL	C	III	CIII	CC	Neg Binomial
Thermobroek lange onderbroek maat L	C	III	CIII	CC	Neg Binomial
Thermobroek lange onderbroek maat M	C	III	CIII	CC	Neg Binomial
Thermoshirt lange mouw maat EEL	C	III	CIII	CC	Neg Binomial
Thermoshirt lange mouw maat EL	B	III	BIII	CC	Neg Binomial
Thermoshirt lange mouw maat L	C	III	CIII	CC	Neg Binomial
Thermoshirt lange mouw maat M	C	III	CIII	CC	Neg Binomial
Thermosokken Bata maat 39-42	B	III	BIII	CC	Neg Binomial
Thermosokken Bata maat 43-46	A	III	AIII	BB	Neg Binomial
Veiligh. bril Uvex Astrospec 2.0 9164187	C	II	CII	CC	Neg Binomial
Veiligheidsbril Carbovision	C	II	CII	CC	Neg Binomial
Vizier Atom blauw, polycarbonaat	C	II	CII	CC	Neg Binomial
Wegwerpoverall wit Tyvek Classic EEL	C	II	CII	CC	Neg Binomial
Wegwerpoverall wit Tyvek Classic EL	C	II	CII	CC	Neg Binomial
Wegwerpoverall wit Tyvek Classic L	C	II	CII	CC	Neg Binomial
Zweetband G22, G2000, G3000	C	III	CIII	CC	Neg Binomial

Appendix C: Proof of the use of empirical data vs a distribution for the reorder point

Item Description	s empirical	s distributed	Distribution used
Laars Emma Mento S3 mt 41D	1	1	Neg Binomial
Laars Emma Mento S3 mt 42 D	1	1	Neg Binomial
Laars Emma Mento S3 mt 43 D	1	1	Neg Binomial
Laars Emma Mento S3 mt 44 D	1	1	Poisson
Laars Emma Mento S3 mt 45D	1	1	Poisson
Veiligh. schoen hoog Emma Billy mt 41 XD	1	1	Neg Binomial
Veiligh. schoen hoog Emma Billy mt 42 XD	1	1	Poisson
Veiligh. schoen hoog Emma Billy mt 43 XD	1	1	Neg Binomial
Veiligh. schoen hoog Emma Billy mt 44 XD	1	1	Poisson
Veiligh. schoen hoog Emma Billy mt 45 XD	1	1	Neg Binomial
Veiligh. schoen hoog Emma Lukas mt41 XXD	1	1	Poisson
Veiligh. schoen hoog Emma Lukas mt42 XXD	1	1	Poisson
Veiligh. schoen hoog Emma Lukas mt43 XXD	1	1	Poisson
Veiligh. schoen hoog Emma Lukas mt44 XXD	1	1	Poisson
Veiligh. schoen hoog Emma Lukas mt45 XXD	1	1	Poisson
Veiligh. schoen hoog Nestor mt41 D	1	1	Poisson
Veiligh. schoen hoog Nestor mt42 D	1	1	Neg Binomial
Veiligh. schoen hoog Nestor mt43 D	1	1	Neg Binomial
Veiligh. schoen hoog Nestor mt44 D	1	1	Poisson
Veiligh. schoen hoog Nestor mt45 D	1	1	Neg Binomial
Winterlaars Emma Merula S3 mt 41 D	1	1	Neg Binomial
Winterlaars Emma Merula S3 mt 42 D	1	1	Neg Binomial
Winterlaars Emma Merula S3 mt 43 D	1	1	Neg Binomial
Winterlaars Emma Merula S3 mt 44 D	1	1	Poisson
Winterlaars Emma Merula S3 mt 45 D	1	1	Neg Binomial
Binnenvoering 7760 maat EEL marine fleece	1	1	Neg Binomial
Binnenvoering 7760 maat EL marine Fleece	1	1	Neg Binomial
Binnenvoering 7760 maat L marine Fleece	1	1	Neg Binomial
Binnenvoering 7760 maat M marine Fleece	1	1	Neg Binomial
Binnenvoering 7760 maat S marine Fleece	1	1	Neg Binomial
Parka 7223 maat EEL Hedland - Company X logo	1	1	Neg Binomial
Parka 7223 maat EL Hedland - Company X logo	4	4	Neg Binomial
Parka 7223 maat L Hedland - Company X logo	7	6	Neg Binomial
Parka 7223 maat M Hedland - Company X logo	10	8	Neg Binomial
Parka 7223 maat S Hedland - Company X logo	1	1	Neg Binomial
T-shirt korte mouw Company X logo maat EEL	1	1	Neg Binomial
T-shirt korte mouw Company X logo maat EL	2	2	Neg Binomial
T-shirt korte mouw Company X logo maat L	4	4	Neg Binomial
T-shirt korte mouw Company X logo maat M	1	1	Neg Binomial
Sweater Company X logo maat EEL	1	1	Neg Binomial
Sweater Company X logo maat EL	3	3	Neg Binomial
Sweater Company X logo maat L	3	3	Neg Binomial
Sweater Company X logo maat M	4	4	Neg Binomial

T-shirt lange mouw Company X logo maat EEL	1	1	Neg Binomial
T-shirt lange mouw Company X logo maat EL	2	1	Neg Binomial
T-shirt lange mouw Company X logo maat L	1	1	Neg Binomial
T-shirt lange mouw Company X logo maat M	1	1	Neg Binomial
Armbeschermer Fireblade FS14 geel 35 cm	1	1	Neg Binomial
Bivakmuts Intersafe FR/AS	1	1	Neg Binomial
Bril Goggle ultravision 9301-105	1	1	Neg Binomial
Bril I-VO 9160-265 blauw-oranje	14	15	Gamma
Col Intersafe FR/AS	1	1	Neg Binomial
Gehoorkap Bilsom Clarity 1011142 28109	1	1	Neg Binomial
Gehoorkap Optime II H520p3E-110883	16	14	Neg Binomial
Gelaatscherm Perforama Nova scherm blank	1	1	Neg Binomial
Gelaatsscherm V4F voor helm Uvex airwing	1	1	Neg Binomial
HANDSCHOEN 5-VINGERS L.35 ROOD	1	1	Neg Binomial
Handschoen Alphatec 58-435 maat 10	1	1	Neg Binomial
Handschoen Alphatec 58-435 maat 8	1	1	Neg Binomial
Handschoen Alphatec 58-435 maat 9	1	1	Neg Binomial
Handschoen geitenleer Tegera Ejendalls10	10	10	Gamma
Handschoen geitenleer Tegera Ejendalls11	1	1	Neg Binomial
Handschoen Hyflex 11-518 maat 10	14	15	Gamma
Handschoen Hyflex 11-518 maat 8	12	12	Gamma
Handschoen Hyflex 11-518 maat 9	21	22	Gamma
Handschoen Hyflex 11-531 maat 10	26	35	Gamma
Handschoen Hyflex 11-531 maat 8	14	10	Neg Binomial
Handschoen Hyflex 11-531 maat 9	23	24	Gamma
Handschoen Hyflex 11-537 maat 10	21	22	Gamma
Handschoen Hyflex 11-537 maat 8	10	9	Neg Binomial
Handschoen Hyflex 11-537 maat 9	25	30	Gamma
Handschoen HyFlex 11-630 Maat 10	1	1	Neg Binomial
Handschoen HyFlex 11-630 Maat 8	1	1	Neg Binomial
Handschoen HyFlex 11-630 Maat 9	1	1	Neg Binomial
Handschoen Hyflex 11-739 maat 10	1	1	Neg Binomial
Handschoen Hyflex 11-739 maat 8	1	1	Neg Binomial
Handschoen Hyflex 11-739 maat 9	1	1	Neg Binomial
Handschoen Winterpro, Maat 08	1	1	Neg Binomial
Handschoen Winterpro, Maat 09	1	1	Neg Binomial
Handschoen Winterpro, Maat 10	1	1	Neg Binomial
Handschoenen geitenleder maat 10	26	34	Gamma
Helm Uvex Airwing blauw incl Company X Logo	31	26	Neg Binomial
Kniebescherm Helly Hansen	1	1	Neg Binomial
Oordop Ear Classic geel	1	1	Gamma
Overzetbril 9161-014, transparant	1	1	Neg Binomial
Overzetbril Flexy	1	1	Neg Binomial
Regenbroek EL FR-LR41 koningsblauw	3	3	Neg Binomial
Regenjas EL FR-LR48 koningsblauw	5	5	Neg Binomial
Ruimzichtbril Atom blauw, polycarbonaat	1	1	Neg Binomial

Stofmasker FFP3 3M 9332	73	86	Gamma
Thermobroek lange onderbroek maat EEL	1	1	Neg Binomial
Thermobroek lange onderbroek maat EL	1	1	Neg Binomial
Thermobroek lange onderbroek maat L	1	1	Neg Binomial
Thermobroek lange onderbroek maat M	1	1	Neg Binomial
Thermoshirt lange mouw maat EEL	1	1	Neg Binomial
Thermoshirt lange mouw maat EL	1	1	Neg Binomial
Thermoshirt lange mouw maat L	1	1	Neg Binomial
Thermoshirt lange mouw maat M	1	1	Neg Binomial
Thermosokken Bata maat 39-42	1	1	Neg Binomial
Thermosokken Bata maat 43-46	1	1	Neg Binomial
Veiligh. bril Uvex Astrospec 2.0 9164187	1	1	Neg Binomial
Veiligheidsbril Carbovision	1	1	Neg Binomial
Vizier Atom blauw, polycarbonaat	1	1	Neg Binomial
Wegwerpoverall wit Tyvek Classic EEL	1	1	Neg Binomial
Wegwerpoverall wit Tyvek Classic EL	1	1	Neg Binomial
Wegwerpoverall wit Tyvek Classic L	1	1	Neg Binomial
Zweetband G22, G2000, G3000	1	1	Neg Binomial

Appendix D: Comparison my policies (R, s, Q) and (R,S) with BU South

(R, s, Q)	Class	Target FR	Ready Rate BU South	RR my policies	FR my policies	Avg OHS BU South	Avg OHS my policies	TC BU South	TC my policies
Laars Emma Mento S3 mt 42 D	AA	0,99	0,91	1,00	1	2	3	€ 133,40	€ 107,45
Laars Emma Mento S3 mt 43 D	AA	0,99	0,96	1,00	1	2	4	€ 101,71	€ 131,17
Veiligh. schoen hoog Emma Billy mt 41 XD	AA	0,99	0,99	1,00	1	2	4	€ 102,21	€ 89,86
Veiligh. schoen hoog Emma Billy mt 42 XD	AA	0,99	1,00	1,00	1	2	4	€ 113,66	€ 89,86
Veiligh. schoen hoog Emma Billy mt 43 XD	AA	0,99	0,99	1,00	1	2	4	€ 172,32	€ 91,13
Veiligh. schoen hoog Emma Billy mt 44 XD	AA	0,99	0,99	1,00	1	2	4	€ 162,21	€ 109,86
Veiligh. schoen hoog Emma Billy mt 45 XD	AA	0,99	0,95	1,00	1	1	4	€ 57,47	€ 98,59
Veiligh. schoen hoog Emma Lukas mt41 XXD	AA	0,99	1,00	1,00	1	1	3	€ 57,47	€ 81,25
Veiligh. schoen hoog Nestor mt41 D	AA	0,99	1,00	1,00	1	2	3	€ 62,33	€ 60,79
Veiligh. schoen hoog Nestor mt42 D	AA	0,99	0,93	0,99	0,9	2	4	€ 190,07	€ 117,72
Veiligh. schoen hoog Nestor mt43 D	AA	0,99	0,98	1,00	1	2	4	€ 171,67	€ 107,72
Veiligh. schoen hoog Nestor mt44 D	AA	0,99	1,00	1,00	1	2	4	€ 112,33	€ 87,72
Veiligh. schoen hoog Nestor mt45 D	AA	0,99	0,95	1,00	1	1	3	€ 86,93	€ 62,33
Winterlaars Emma Merula S3 mt 41 D	AA	0,99	1,00	1,00	1	3	4	€ 158,17	€ 130,44
Winterlaars Emma Merula S3 mt 42 D	AA	0,99	0,99	1,00	1	4	4	€ 262,15	€ 138,17
Winterlaars Emma Merula S3 mt 43 D	AA	0,99	1,00	1,00	1	4	4	€ 273,23	€ 138,17
Winterlaars Emma Merula S3 mt 44 D	AA	0,99	1,00	1,00	1	4	4	€ 231,30	€ 128,17
Winterlaars Emma Merula S3 mt 45 D	AA	0,99	1,00	1,00	1	3	4	€ 138,17	€ 130,44
Parka 7223 maat EL Hedland - Company X logo	AA	0,99	1,00	1,00	1	15	12	€ 357,77	€ 357,71
Parka 7223 maat L Hedland - Company X logo	AA	0,99	1,00	1,00	1	18	10	€ 347,83	€ 278,34
Parka 7223 maat M Hedland - Company X logo	AA	0,99	1,00	1,00	1	23	13	€ 496,88	€ 357,77
Armbeschermer Fireblade FS14 geel 35 cm	CC	0,95	0,96	1,00	1	15	15	€ 26,16	€ 18,72
Bril Goggle ultravision 9301-105	CC	0,95	1,00	1,00	1	14	12	€ 37,12	€ 32,04
Bril I-VO 9160-265 blauw-oranje	AA	0,99	1,00	1,00	1	57	54	€ 210,27	€ 117,61
Gehoorkap Optime II H520p3E-110883	AA	0,99	1,00	1,00	1	37	29	€ 272,30	€ 201,89
Handschoen Alphatec 58-435 maat 10	BB	0,97	1,00	1,00	1	47	40	€ 81,99	€ 54,90

Handschoen Alphatec 58-435 maat 8	BB	0,97	1,00	1,00	1	17	10	€ 40,82	€ 13,73
Handschoen Alphatec 58-435 maat 9	BB	0,97	1,00	0,98	0,94897959	55	22	€ 89,02	€ 33,73
Handschoen geitenleer Tegera Ejendalls10	AA	0,99	1,00	1,00	1	190	91	€ 263,84	€ 301,97
Handschoen geitenleer Tegera Ejendalls11	BB	0,97	1,00	0,99	0,94642857	21	13	€ 81,98	€ 38,13
Handschoen Hyflex 11-518 maat 10	AA	0,99	1,00	0,97	0,95938104	140	102	€ 272,89	€ 286,39
Handschoen Hyflex 11-518 maat 8	AA	0,99	0,87	0,94	0,913371	87	30	€ 183,59	€ 117,49
Handschoen Hyflex 11-518 maat 9	AA	0,99	1,00	0,98	0,97787295	127	72	€ 357,00	€ 218,96
Handschoen Hyflex 11-531 maat 10	AA	0,99	1,00	0,99	0,98855508	141	84	€ 299,12	€ 183,88
Handschoen Hyflex 11-531 maat 8	AA	0,99	1,00	1,00	1	42	46	€ 86,94	€ 95,70
Handschoen Hyflex 11-531 maat 9	AA	0,99	1,00	0,99	0,9808	154	86	€ 282,14	€ 169,50
Handschoen Hyflex 11-537 maat 10	AA	0,99	1,00	0,96	0,95600476	141	72	€ 276,02	€ 183,30
Handschoen Hyflex 11-537 maat 8	AA	0,99	0,99	0,98	0,93495935	72	65	€ 196,84	€ 125,63
Handschoen Hyflex 11-537 maat 9	AA	0,99	0,99	1,00	1	107	79	€ 165,23	€ 209,63
Handschoen HyFlex 11-630 Maat 10	BB	0,97	0,99	0,89	0,36697248	76	31	€ 270,30	€ 157,00
Handschoen HyFlex 11-630 Maat 8	BB	0,97	1,00	1,00	1	89	53	€ 285,43	€ 190,40
Handschoen HyFlex 11-630 Maat 9	BB	0,97	1,00	1,00	1	80	32	€ 238,72	€ 114,96
Handschoen Hyflex 11-739 maat 10	BB	0,97	1,00	0,99	0,91428571	21	18	€ 91,97	€ 69,27
Handschoen Hyflex 11-739 maat 8	BB	0,97	1,00	1,00	1	91	89	€ 392,45	€ 376,80
Handschoen Hyflex 11-739 maat 9	BB	0,97	1,00	1,00	1	42	17	€ 137,01	€ 71,97
Handschoen Winterpro, Maat 08	CC	0,95	1,00	0,99	0,82352941	15	9	€ 17,79	€ 32,98
Handschoen Winterpro, Maat 09	CC	0,95	0,96	1,00	1	10	15	€ 65,74	€ 22,98
Handschoen Winterpro, Maat 10	CC	0,95	0,99	0,99	0,75714286	17	18	€ 52,78	€ 35,57
Handschoenen geitenleder maat 10	AA	0,99	1,00	0,99	0,99236641	517	185	€ 278,20	€ 132,60
Helm Uvex Airwing blauw incl Company X Logo	AA	0,99	1,00	1,00	1	48	46	€ 180,26	€ 166,18
Oordop Ear Classic geel	AA	0,99	1,00	1,00	1	518	494	€ 109,34	€ 18,53
Stofmasker FFP3 3M 9332	AA	0,99	1,00	1,00	1	3582	2948	€ 4.805,60	€ 4.200,90
Thermosokken Bata maat 39-42	CC	0,95	1,00	0,99	0,99264706	35	35	€ 89,78	€ 49,87
Thermosokken Bata maat 43-46	BB	0,97	1,00	0,99	0,94444444	37	34	€ 123,76	€ 52,57
Veiligh. bril Uvex Astrospec 2.0 9164187	CC	0,95	1,00	0,98	0,30208333	29	25	€ 60,45	€ 37,23
Wegwerpoverall wit Tyvek Classic EEL	CC	0,95	0,99	0,81	0,32214765	35	13	€ 99,20	€ 130,13
Wegwerpoverall wit Tyvek Classic EL	CC	0,95	0,88	1	1	25	30	€ 82,57	€ 58,95

Wegwerpoverall wit Tyvek Classic L	CC	0,95	1,00	1	1	30	14	€ 57,04	€ 30,40
								€ 14.450,89	€ 11.247,10
(R, S)	Class	Target FR	Ready Rate BU South	RR my policies	FR my policies	Avg OHS BU South	Avg OHS my policies	TC BU South	TC my policies
Laars Emma Mento S3 mt 41D	BB	0,97	0,97	1,00	1	1	2	€ 72,48	€ 116,21
Laars Emma Mento S3 mt 44 D	BB	0,97	0,93	1,00	1	1	2	€ 62,48	€ 106,21
Laars Emma Mento S3 mt 45D	BB	0,97	0,97	1,00	1	1	2	€ 42,48	€ 86,21
Veiligh. schoen hoog Emma Lukas mt42 XXD	BB	0,97	1,00	1,00	1	1	2	€ 42,48	€ 45,00
Veiligh. schoen hoog Emma Lukas mt43 XXD	BB	0,97	1,00	1,00	1	1	2	€ 42,48	€ 112,50
Veiligh. schoen hoog Emma Lukas mt44 XXD	BB	0,97	1,00	1,00	1	1	2	€ 42,48	€ 92,00
Veiligh. schoen hoog Emma Lukas mt45 XXD	BB	0,97	1,00	1,00	1	1	2	€ 42,48	€ 70,83
Binnenvoering 7760 maat EEL marine fleece	BB	0,97	1,00	1,00	1	25	25	€ 373,59	€ 373,59
Binnenvoering 7760 maat EL marine Fleece	BB	0,97	1,00	1,00	1	26	17	€ 381,14	€ 254,04
Binnenvoering 7760 maat L marine Fleece	BB	0,97	1,00	1,00	1	22	16	€ 288,95	€ 239,10
Binnenvoering 7760 maat M marine Fleece	BB	0,97	1,00	1,00	1	25	19	€ 366,20	€ 283,93
Binnenvoering 7760 maat S marine Fleece	BB	0,97	1,00	1,00	1	24	17	€ 318,84	€ 254,04
Parka 7223 maat EEL Hedland - Company X logo	BB	0,97	1,00	1,00	1	24	19	€ 626,05	€ 566,37
Parka 7223 maat S Hedland - Company X logo	BB	0,97	1,00	1,00	1	22	13	€ 566,43	€ 387,51
T-shirt korte mouw Company X logo maat EEL	CC	0,95	1,00	0,99	1	36	27	€ 87,69	€ 203,45
T-shirt korte mouw Company X logo maat EL	CC	0,95	1,00	1,00	1	47	50	€ 84,94	€ 204,27
T-shirt korte mouw Company X logo maat L	CC	0,95	1,00	1,00	1	45	40	€ 82,38	€ 316,54
T-shirt korte mouw Company X logo maat M	CC	0,95	0,92	1,00	1	35	30	€ 57,40	€ 208,09
Sweater Company X logo maat EEL	CC	0,95	1,00	1,00	1	26	15	€ 121,40	€ 201,31
Sweater Company X logo maat EL	BB	0,97	1,00	1,00	1	37	30	€ 236,11	€ 278,02
Sweater Company X logo maat L	BB	0,97	1,00	1,00	1	26	20	€ 169,39	€ 247,14
Sweater Company X logo maat M	BB	0,97	0,98	0,98	1	22	23	€ 108,44	€ 396,35
T-shirt lange mouw Company X logo maat EEL	CC	0,95	1,00	1,00	1	24	58	€ 56,02	€ 264,86
T-shirt lange mouw Company X logo maat EL	CC	0,95	0,86	1,00	1	34	30	€ 42,29	€ 172,88
T-shirt lange mouw Company X logo maat L	CC	0,95	1,00	0,96	1	41	22	€ 81,12	€ 297,88
T-shirt lange mouw Company X logo maat M	CC	0,95	1,00	0,90	0,93814433	40	16	€ 97,44	€ 216,77

Bivakmuts Intersafe FR/AS	BB	0,95	1,00	1,00	1	18	35	€ 40,13	€ 182,14
Col Intersafe FR/AS	BB	0,97	1,00	1,00	1	17	34	€ 81,50	€ 342,43
Gehoorkap Bilsom Clarity 1011142 28109	BB	0,95	1,00	1,00	1	8	5	€ 63,75	€ 142,50
Gelaatscherm Perforama Nova scherm blank	CC	0,97	1,00	1,00	1	8	5	€ 61,96	€ 90,69
Gelaatsscherm V4F voor helm Uvex airwing	BB	0,97	1,00	1,00	1	54	44	€ 198,43	€ 150,98
HANDSCHOEN 5-VINGERS L.35 ROOD	BB	0,95	0,88	1,00	1	6	4	€ 30,94	€ 58,75
Kniebescherm Helly Hansen	CC	0,97	1,00	1,00	1	8	8	€ 101,55	€ 284,63
Overzetbril 9161-014, transparant	CC	0,97	1,00	1,00	1	13	14	€ 10,82	€ 41,38
Overzetbril Flexy	CC	0,97	1,00	1,00	1	9	9	€ 20,25	€ 20,25
Regenbroek EL FR-LR41 koningsblauw	BB	0,97	1,00	1,00	1	143	143	€ 1.393,18	€ 1.393,18
Regenjas EL FR-LR48 koningsblauw	BB	0,97	1,00	1,00	1	50	52	€ 476,13	€ 919,74
Ruimzichtbril Atom blauw, polycarbonaat	CC	0,97	1,00	1,00	1	27	17	€ 143,13	€ 95,63
Thermobroek lange onderbroek maat EEL	CC	0,97	1,00	1,00	1	8	9	€ 30,00	€ 42,50
Thermobroek lange onderbroek maat EL	CC	0,97	1,00	1,00	1	18	12	€ 52,50	€ 102,71
Thermobroek lange onderbroek maat L	CC	0,97	1,00	1,00	1	45	45	€ 168,75	€ 168,75
Thermobroek lange onderbroek maat M	CC	0,97	1,00	1,00	1	21	21	€ 78,75	€ 78,75
Thermoshirt lange mouw maat EEL	CC	0,97	1,00	1,00	1	4	14	€ 0,01	€ 74,54
Thermoshirt lange mouw maat EL	CC	0,97	1,00	1,00	1	16	13	€ 57,45	€ 76,62
Thermoshirt lange mouw maat L	CC	0,95	1,00	1,00	1	14	13	€ 43,72	€ 136,48
Thermoshirt lange mouw maat M	CC	0,95	1,00	1,00	1	36	36	€ 134,87	€ 134,87
Veiligheidsbril Carbovision	CC	0,95	1,00	1,00	1	26	26	€ 146,25	€ 146,25
Vizier Atom blauw, polycarbonaat	CC	0,95	1,00	1,00	1	25	20	€ 141,25	€ 112,50
Zweetband G22, G2000, G3000	CC	0,95	1,00	1,00	1	13	13	€ 17,50	€ 17,50
						1175	1093	€ 7.985,99	€ 10.808,88
Total costs								**€ 22.436,88**	**€ 22.055,97**

Appendix E: Reasons for low fill rate per item

Item description	Critical class	Target FR	FR my policies	Reason
Handschoen Hyflex 11-518 maat 10	I	0,99	0,96	Demand way higher than previous year
Handschoen Hyflex 11-518 maat 8	I	0,99	0,98	Demand way higher than previous year
Handschoen Hyflex 11-518 maat 9	I	0,99	0,95	Demand way higher than previous year
Handschoen Hyflex 11-537 maat 10	I	0,99	0,96	Peak demand in 5 days, higher than Q
Handschoen Hyflex 11-537 maat 8	I	0,99	0,95	Demand peaks higher than s
T-shirt korte mouw Company X logo maat EEL	III	0,95	0,92	s is lower than average demand peaks and seasonal
T-shirt korte mouw Company X logo maat M	III	0,95	0,85	s is lower than average demand peaks and seasonal
Sweater Company X logo maat L	III	0,97	0,91	s is lower than average demand peaks and seasonal
Sweater Company X logo maat M	III	0,97	0,80	coincidence, OHS 1 item too high to order, a lot of demand in next cycle (review period)
T-shirt lange mouw Company X logo maat EEL	III	0,95	0,94	s is lower than average demand peaks and seasonal
Bivakmuts Intersafe FR/AS	II	0,97	0,88	s is lower than average demand peaks and seasonal
HANDSCHOEN 5-VINGERS L.35 ROOD	I	0,97	0,91	Coincidence, half of the total demand in 4 days and s=1
Handschoen HyFlex 11-630 Maat 10	I	0,97	0,47	Demand way higher than previous year
Handschoen Hyflex 11-739 maat 10	I	0,97	0,91	s is lower than average demand peaks
Handschoen Winterpro, Maat 08	III	0,95	0,88	s is lower than average demand peaks and seasonal
Handschoen Winterpro, Maat 10	III	0,95	0,80	s is lower than average demand peaks and seasonal
Thermosokken Bata maat 43-46	III	0,97	0,83	s is lower than average demand peaks and seasonal
Veiligh. bril Uvex Astrospec 2.0 9164187	II	0,95	0,31	demand always 1 or 2 items, at a certain point 40 items (project)
Wegwerpoverall wit Tyvek Classic EEL	II	0,95	0,43	Demand way higher than previous year

Appendix F: Difference in costs when taking project demand not into account

Item Description	Change in cost (%)
Regenjas EL FR-LR48 koningsblauw	-72,57%
Wegwerpoverall wit Tyvek Classic EEL	-71,90%
Handschoen Hyflex 11-739 maat 10	-67,14%
Handschoen Alphatec 58-435 maat 8	-65,40%
T-shirt lange mouw Company X logo maat EEL	-65,22%
Wegwerpoverall wit Tyvek Classic EL	-63,19%
Handschoen Hyflex 11-531 maat 10	-57,32%
Bivakmuts Intersafe FR/AS	-55,87%
Handschoen geitenleer Tegera Ejendalls11	-53,04%
Handschoen Alphatec 58-435 maat 9	-51,61%
Helm Uvex Airwing blauw incl Company X Logo	-51,45%
Handschoen Hyflex 11-531 maat 9	-49,92%
Handschoen Hyflex 11-537 maat 10	-49,64%
Handschoen geitenleer Tegera Ejendalls10	-47,50%
HANDSCHOEN 5-VINGERS L.35 ROOD	-46,04%
Thermoshirt lange mouw maat L	-45,64%
Parka 7223 maat M Hedland - Company X logo	-45,42%
Handschoen Hyflex 11-518 maat 10	-44,24%
Veiligh. bril Uvex Astrospec 2.0 9164187	-43,25%
Gehoorkap Optime II H520p3E-110883	-40,31%
Handschoen Winterpro, Maat 08	-39,20%
Handschoen Hyflex 11-537 maat 9	-38,05%
T-shirt korte mouw Company X logo maat M	-37,68%
T-shirt korte mouw Company X logo maat L	-35,98%
Handschoenen geitenleder maat 10	-34,58%
Handschoen Alphatec 58-435 maat 10	-34,22%
T-shirt korte mouw Company X logo maat EL	-32,98%
Handschoen Hyflex 11-531 maat 8	-31,35%
Binnenvoering 7760 maat M marine Fleece	-31,25%
Gelaatscherm Perforama Nova scherm blank	-29,91%
Gelaatsscherm V4F voor helm Uvex airwing	-29,44%
Overzetbril 9161-014, transparant	-29,29%
Regenbroek EL FR-LR41 koningsblauw	-29,03%
Handschoen HyFlex 11-630 Maat 10	-28,34%
Handschoen Hyflex 11-518 maat 9	-28,21%
Bril Goggle ultravision 9301-105	-26,94%
T-shirt korte mouw Company X logo maat EEL	-26,91%
Handschoen Winterpro, Maat 10	-26,83%
Handschoen HyFlex 11-630 Maat 9	-25,12%

Bril I-VO 9160-265 blauw-oranje	-24,79%
Parka 7223 maat L Hedland - Company X logo	-23,06%
Binnenvoering 7760 maat S marine Fleece	-21,41%
Sweater Company X logo maat M	-20,91%
Thermosokken Bata maat 43-46	-20,44%
Thermosokken Bata maat 39-42	-19,77%
Handschoen Hyflex 11-518 maat 8	-19,64%
Veiligh. schoen hoog Nestor mt42 D	-17,74%
Handschoen Hyflex 11-537 maat 8	-15,67%
Parka 7223 maat EL Hedland - Company X logo	-14,99%
Binnenvoering 7760 maat EL marine Fleece	-14,32%
Sweater Company X logo maat L	-9,82%
Sweater Company X logo maat EEL	-8,93%
Winterlaars Emma Merula S3 mt 43 D	-6,75%
Oordop Ear Classic geel	-4,46%
Gehoorkap Bilsom Clarity 1011142 28109	-2,45%
Stofmasker FFP3 3M 9332	-2,15%
T-shirt lange mouw Company X logo maat L	-1,31%
Laars Emma Mento S3 mt 41D	0,00%
Laars Emma Mento S3 mt 44 D	0,00%
Laars Emma Mento S3 mt 45D	0,00%
Veiligh. schoen hoog Emma Lukas mt42 XXD	0,00%
Veiligh. schoen hoog Emma Lukas mt43 XXD	0,00%
Veiligh. schoen hoog Emma Lukas mt44 XXD	0,00%
Binnenvoering 7760 maat EEL marine Fleec	0,00%
Parka 7223 maat EEL Hedland - Company X logo	0,00%
Parka 7223 maat S Hedland - Company X logo	0,00%
Handschoen HyFlex 11-630 Maat 8	0,00%
Handschoen Hyflex 11-739 maat 9	0,00%
Overzetbril Flexy	0,00%
Thermobroek lange onderbroek maat EEL	0,00%
Thermobroek lange onderbroek maat EL	0,00%
Thermobroek lange onderbroek maat L	0,00%
Thermoshirt lange mouw maat EEL	0,00%
Thermoshirt lange mouw maat EL	0,00%
Thermoshirt lange mouw maat M	0,00%
Veiligheidsbril Carbovision	0,00%
Vizier Atom blauw, polycarbonaat	0,00%
Zweetband G22, G2000, G3000	0,00%
Laars Emma Mento S3 mt 42 D	0,00%
Laars Emma Mento S3 mt 43 D	0,00%
Veiligh. schoen hoog Emma Billy mt 41 XD	0,00%
Veiligh. schoen hoog Emma Billy mt 42 XD	0,00%

Veiligh. schoen hoog Emma Billy mt 43 XD	0,00%
Veiligh. schoen hoog Emma Billy mt 44 XD	0,00%
Veiligh. schoen hoog Emma Billy mt 45 XD	0,00%
Veiligh. schoen hoog Emma Billy mt 41 XD	0,00%
Veiligh. schoen hoog Nestor mt41 D	0,00%
Veiligh. schoen hoog Nestor mt43 D	0,00%
Veiligh. schoen hoog Nestor mt44 D	0,00%
Veiligh. schoen hoog Nestor mt45 D	0,00%
Winterlaars Emma Merula S3 mt 42 D	0,00%
Winterlaars Emma Merula S3 mt 44 D	0,00%
Winterlaars Emma Merula S3 mt 45 D	0,00%
T-shirt lange mouw Company X logo maat EL	1,38%
Armbeschermer Fireblade FS14 geel 35 cm	4,21%
Col Intersafe FR/AS	5,36%
Veiligh. schoen hoog Emma Lukas mt45 XXD	5,69%
Sweater Company X logo maat EL	6,16%
Handschoen Winterpro, Maat 09	6,31%
Ruimzichtbril Atom blauw, polycarbonaat	10,71%
Handschoen Hyflex 11-739 maat 8	11,96%
Wegwerpoverall wit Tyvek Classic L	12,29%
T-shirt lange mouw Company X logo maat M	12,67%
Kniebescherm Helly Hansen	13,46%
Thermobroek lange onderbroek maat M	20,00%
Winterlaars Emma Merula S3 mt 41 D	35,53%
Binnenvoering 7760 maat L marine Fleece	54,47%

Appendix G: Final results policy with project demand

Item description	Class	Policy	Target FR	FR used for s	s	Q or S	Fill rate	Total costs
Laars Emma Mento S3 mt 41D	BB	(R, s, S)	0,97	0,97	1	2	1,00	€ 108,69
Laars Emma Mento S3 mt 42 D	AA	(R, s, Q)	0,99	0,99	1	3	1,00	€ 107,45
Laars Emma Mento S3 mt 43 D	AA	(R, s, Q)	0,99	0,99	1	3	1,00	€ 131,17
Laars Emma Mento S3 mt 44 D	BB	(R, s, S)	0,97	0,97	1	1	1,00	€ 106,21
Laars Emma Mento S3 mt 45D	BB	(R, s, S)	0,97	0,97	1	2	1,00	€ 98,69
Veiligh. schoen hoog Emma Billy mt 41 XD	AA	(R, s, Q)	0,99	0,99	1	4	1,00	€ 89,86
Veiligh. schoen hoog Emma Billy mt 42 XD	AA	(R, s, Q)	0,99	0,99	1	4	1,00	€ 89,86
Veiligh. schoen hoog Emma Billy mt 43 XD	AA	(R, s, Q)	0,99	0,99	1	5	1,00	€ 91,13
Veiligh. schoen hoog Emma Billy mt 44 XD	AA	(R, s, Q)	0,99	0,99	1	4	1,00	€ 109,86
Veiligh. schoen hoog Emma Billy mt 45 XD	AA	(R, s, Q)	0,99	0,99	1	3	1,00	€ 98,59
Veiligh. schoen hoog Emma Lukas mt41 XXD	AA	(R, s, Q)	0,99	0,99	1	3	1,00	€ 98,59
Veiligh. schoen hoog Emma Lukas mt42 XXD	BB	(R, s, S)	0,97	0,97	1	2	1,00	€ 62,50
Veiligh. schoen hoog Emma Lukas mt43 XXD	BB	(R, s, S)	0,97	0,97	1	3	1,00	€ 105,83
Veiligh. schoen hoog Emma Lukas mt44 XXD	BB	(R, s, S)	0,97	0,97	1	3	1,00	€ 68,13
Veiligh. schoen hoog Emma Lukas mt45 XXD	BB	(R, s, S)	0,97	0,97	1	2	1,00	€ 76,88
Veiligh. schoen hoog Nestor mt41 D	AA	(R, s, Q)	0,99	0,99	1	3	1,00	€ 60,79
Veiligh. schoen hoog Nestor mt42 D	AA	(R, s, Q)	0,99	0,999	2	4	1,00	€ 143,12
Veiligh. schoen hoog Nestor mt43 D	AA	(R, s, Q)	0,99	0,99	1	4	1,00	€ 107,72
Veiligh. schoen hoog Nestor mt44 D	AA	(R, s, Q)	0,99	0,99	1	4	1,00	€ 87,72
Veiligh. schoen hoog Nestor mt45 D	AA	(R, s, Q)	0,99	0,99	1	4	1,00	€ 62,33
Winterlaars Emma Merula S3 mt 41 D	AA	(R, s, Q)	0,99	0,99	1	3	1,00	€ 130,44
Winterlaars Emma Merula S3 mt 42 D	AA	(R, s, Q)	0,99	0,99	1	4	1,00	€ 138,17
Winterlaars Emma Merula S3 mt 43 D	AA	(R, s, Q)	0,99	0,99	1	4	1,00	€ 138,17
Winterlaars Emma Merula S3 mt 44 D	AA	(R, s, Q)	0,99	0,99	1	4	1,00	€ 128,17
Winterlaars Emma Merula S3 mt 45 D	AA	(R, s, Q)	0,99	0,99	1	3	1,00	€ 130,44
Binnenvoering 7760 maat EEL marine Fleec	BB	(R, s, S)	0,97	0,97	1	3	1,00	€ 373,59

Binnenvoering 7760 maat EL marine Fleece	BB	(R, s, S)	0,97	0,97	1	4	1,00	€ 254,04
Binnenvoering 7760 maat L marine Fleece	BB	(R, s, S)	0,97	0,97	1	5	1,00	€ 239,10
Binnenvoering 7760 maat M marine Fleece	BB	(R, s, S)	0,97	0,97	1	5	1,00	€ 283,93
Binnenvoering 7760 maat S marine Fleece	BB	(R, s, S)	0,97	0,97	1	4	1,00	€ 254,04
Parka 7223 maat EEL Hedland - Company X logo	BB	(R, s, S)	0,97	0,97	1	3	1,00	€ 566,37
Parka 7223 maat EL Hedland - Company X logo	AA	(R, s, Q)	0,99	0,99	4	4	1,00	€ 357,71
Parka 7223 maat L Hedland - Company X logo	AA	(R, s, Q)	0,99	0,99	6	4	1,00	€ 278,34
Parka 7223 maat M Hedland - Company X logo	AA	(R, s, Q)	0,99	0,99	8	4	1,00	€ 357,77
Parka 7223 maat S Hedland - Company X logo	BB	(R, s, S)	0,97	0,97	1	3	1,00	€ 387,51
T-shirt korte mouw Company X logo maat EEL	CC	(R, s, S)	0,95	0,99	9	34	1,00	€ 61,51
T-shirt korte mouw Company X logo maat EL	CC	(R, s, S)	0,95	0,95	4	36	1,00	€ 64,51
T-shirt korte mouw Company X logo maat L	CC	(R, s, S)	0,95	0,95	6	39	1,00	€ 46,43
T-shirt korte mouw Company X logo maat M	CC	(R, s, S)	0,95	0,99	13	41	1,00	€ 71,75
Sweater Company X logo maat EEL	CC	(R, s, S)	0,95	0,95	2	14	1,00	€ 73,57
Sweater Company X logo maat EL	BB	(R, s, S)	0,97	0,97	4	16	1,00	€ 124,80
Sweater Company X logo maat L	BB	(R, s, S)	0,97	0,99	7	16	1,00	€ 110,99
Sweater Company X logo maat M	BB	(R, s, S)	0,97	0,99	10	22	0,98	€ 106,53
T-shirt lange mouw Company X logo maat EEL	CC	(R, s, S)	0,95	0,99	12	29	1,00	€ 57,88
T-shirt lange mouw Company X logo maat EL	CC	(R, s, S)	0,95	0,95	3	40	1,00	€ 46,64
T-shirt lange mouw Company X logo maat L	CC	(R, s, S)	0,95	0,99	9	42	1,00	€ 62,29
T-shirt lange mouw Company X logo maat M	CC	(R, s, S)	0,95	0,99	7	34	0,98	€ 57,94
Armbeschermer Fireblade FS14 geel 35 cm	CC	(R, s, S)	0,95	0,95	2	30	1,00	€ 19,30
Bivakmuts Intersafe FR/AS	BB	(R, s, S)	0,97	0,99	3	32	1,00	€ 26,52
Bril Goggle ultravision 9301-105	CC	(R, s, S)	0,95	0,95	1	10	1,00	€ 32,04
Bril I-VO 9160-265 blauw-oranje	AA	(R, s, Q)	0,99	0,99	22	80	1,00	€ 117,61
Col Intersafe FR/AS	BB	(R, s, S)	0,97	0,97	2	22	1,00	€ 36,61
Gehoorkap Bilsom Clarity 1011142 28109	BB	(R, s, S)	0,97	0,999	2	10	1,00	€ 52,81
Gehoorkap Optime II H520p3E-110883	AA	(R, s, Q)	0,99	0,99	16	20	1,00	€ 201,89
Gelaatscherm Perforama Nova scherm blank	CC	(R, s, S)	0,95	0,95	1	6	1,00	€ 33,99
Gelaatsscherm V4F voor helm Uvex airwing	BB	(R, s, S)	0,97	0,97	2	10	1,00	€ 150,98
HANDSCHOEN 5-VINGERS L.35 ROOD	BB	(R, s, S)	0,97	0,97	1	9	0,91	€ 18,75

Handschoen Alphatec 58-435 maat 10	BB	(R, s, S)	0,97	0,97	2	24	1,00	€ 54,90
Handschoen Alphatec 58-435 maat 8	BB	(R, s, S)	0,97	0,97	1	12	1,00	€ 13,73
Handschoen Alphatec 58-435 maat 9	BB	(R, s, S)	0,97	0,995	6	36	0,99	€ 42,19
Handschoen geitenleer Tegera Ejendalls10	AA	(R, s, Q)	0,99	0,99	14	48	1,00	€ 301,97
Handschoen geitenleer Tegera Ejendalls11	BB	(R, s, S)	0,97	0,999	5	24	1,00	€ 47,20
Handschoen Hyflex 11-518 maat 10	AA	(R, s, Q)	0,99	0,995	27	48	1,00	€ 310,14
Handschoen Hyflex 11-518 maat 8	AA	(R, s, Q)	0,99	0,995	24	60	0,99	€ 180,71
Handschoen Hyflex 11-518 maat 9	AA	(R, s, Q)	0,99	0,995	43	108	0,99	€ 235,45
Handschoen Hyflex 11-531 maat 10	AA	(R, s, Q)	0,99	0,999	104	96	1,00	€ 323,09
Handschoen Hyflex 11-531 maat 8	AA	(R, s, Q)	0,99	0,99	12	48	1,00	€ 95,70
Handschoen Hyflex 11-531 maat 9	AA	(R, s, Q)	0,99	0,995	46	108	1,00	€ 187,02
Handschoen Hyflex 11-537 maat 10	AA	(R, s, Q)	0,99	0,999	70	96	1,00	€ 255,61
Handschoen Hyflex 11-537 maat 8	AA	(R, s, Q)	0,99	0,995	19	72	1,00	€ 151,96
Handschoen Hyflex 11-537 maat 9	AA	(R, s, Q)	0,99	0,99	39	96	1,00	€ 209,63
Handschoen HyFlex 11-630 Maat 10	BB	(R, s, S)	0,97	0,97	1	12	0,47	€ 47,12
Handschoen HyFlex 11-630 Maat 8	BB	(R, s, S)	0,97	0,97	1	12	1,00	€ 190,40
Handschoen HyFlex 11-630 Maat 9	BB	(R, s, S)	0,97	0,97	1	12	1,00	€ 114,96
Handschoen Hyflex 11-739 maat 10	BB	(R, s, S)	0,97	0,99	6	12	1,00	€ 77,74
Handschoen Hyflex 11-739 maat 8	BB	(R, s, S)	0,97	0,97	1	12	1,00	€ 376,80
Handschoen Hyflex 11-739 maat 9	BB	(R, s, S)	0,97	0,97	2	24	1,00	€ 71,97
Handschoen Winterpro, Maat 08	CC	(R, s, S)	0,95	0,995	3	12	1,00	€ 40,76
Handschoen Winterpro, Maat 09	CC	(R, s, S)	0,95	0,95	2	36	1,00	€ 23,84
Handschoen Winterpro, Maat 10	CC	(R, s, S)	0,95	0,999	15	36	1,00	€ 63,68
Handschoenen geitenleder maat 10	AA	(R, s, Q)	0,99	0,99	47	192	0,99	€ 132,60
Helm Uvex Airwing blauw incl Company X Logo	AA	(R, s, Q)	0,99	0,99	30	35	1,00	€ 166,18
Kniebescherm Helly Hansen	CC	(R, s, S)	0,95	0,95	2	28	0,98	€ 36,32
Oordop Ear Classic geel	AA	(R, s, Q)	0,99	0,99	13	500	1,00	€ 18,53
Overzetbril 9161-014, transparant	CC	(R, s, S)	0,95	0,95	1	14	1,00	€ 10,82
Overzetbril Flexy	CC	(R, s, S)	0,95	0,95	1	6	1,00	€ 20,25
Regenbroek EL FR-LR41 koningsblauw	BB	(R, s, S)	0,97	0,97	4	11	1,00	€ 1.393,18
Regenjas EL FR-LR48 koningsblauw	BB	(R, s, S)	0,97	0,97	7	15	1,00	€ 208,77

Ruimzichtbril Atom blauw, polycarbonaat	CC	(R, s, S)	0,95	0,95	1	11	1,00	€ 95,63
Stofmasker FFP3 3M 9332	AA	(R, s, Q)	0,99	0,99	138	330	1,00	€ 4.200,90
Thermobroek lange onderbroek maat EEL	CC	(R, s, S)	0,95	0,95	1	12	1,00	€ 30,00
Thermobroek lange onderbroek maat EL	CC	(R, s, S)	0,95	0,95	1	15	1,00	€ 32,50
Thermobroek lange onderbroek maat L	CC	(R, s, S)	0,95	0,95	1	12	1,00	€ 168,75
Thermobroek lange onderbroek maat M	CC	(R, s, S)	0,95	0,95	1	8	1,00	€ 78,75
Thermoshirt lange mouw maat EEL	CC	(R, s, S)	0,95	0,95	1	7	1,00	€ 22,49
Thermoshirt lange mouw maat EL	CC	(R, s, S)	0,95	0,95	1	15	1,00	€ 37,46
Thermoshirt lange mouw maat L	CC	(R, s, S)	0,95	0,95	1	11	1,00	€ 29,98
Thermoshirt lange mouw maat M	CC	(R, s, S)	0,95	0,95	1	9	1,00	€ 134,87
Thermosokken Bata maat 39-42	CC	(R, s, S)	0,95	0,95	3	60	1,00	€ 52,52
Thermosokken Bata maat 43-46	BB	(R, s, S)	0,97	0,999	16	70	1,00	€ 90,18
Veiligh. bril Uvex Astrospec 2.0 9164187	CC	(R, s, S)	0,95	0,95	2	30	0,31	€ 25,13
Veiligheidsbril Carbovision	CC	(R, s, S)	0,95	0,95	1	3	1,00	€ 146,25
Vizier Atom blauw, polycarbonaat	CC	(R, s, S)	0,95	0,95	1	11	1,00	€ 112,50
Wegwerpoverall wit Tyvek Classic EEL	CC	(R, s, S)	0,95	0,999	65	25	0,97	€ 193,89
Wegwerpoverall wit Tyvek Classic EL	CC	(R, s, S)	0,95	0,95	2	50	1,00	€ 62,81
Wegwerpoverall wit Tyvek Classic L	CC	(R, s, S)	0,95	0,95	1	25	1,00	€ 30,40
Zweetband G22, G2000, G3000	CC	(R, s, S)	0,95	0,95	1	15	1,00	€ 17,50
Total costs								**€ 18.909,45**

Appendix H: Reorder points and costs per scenario

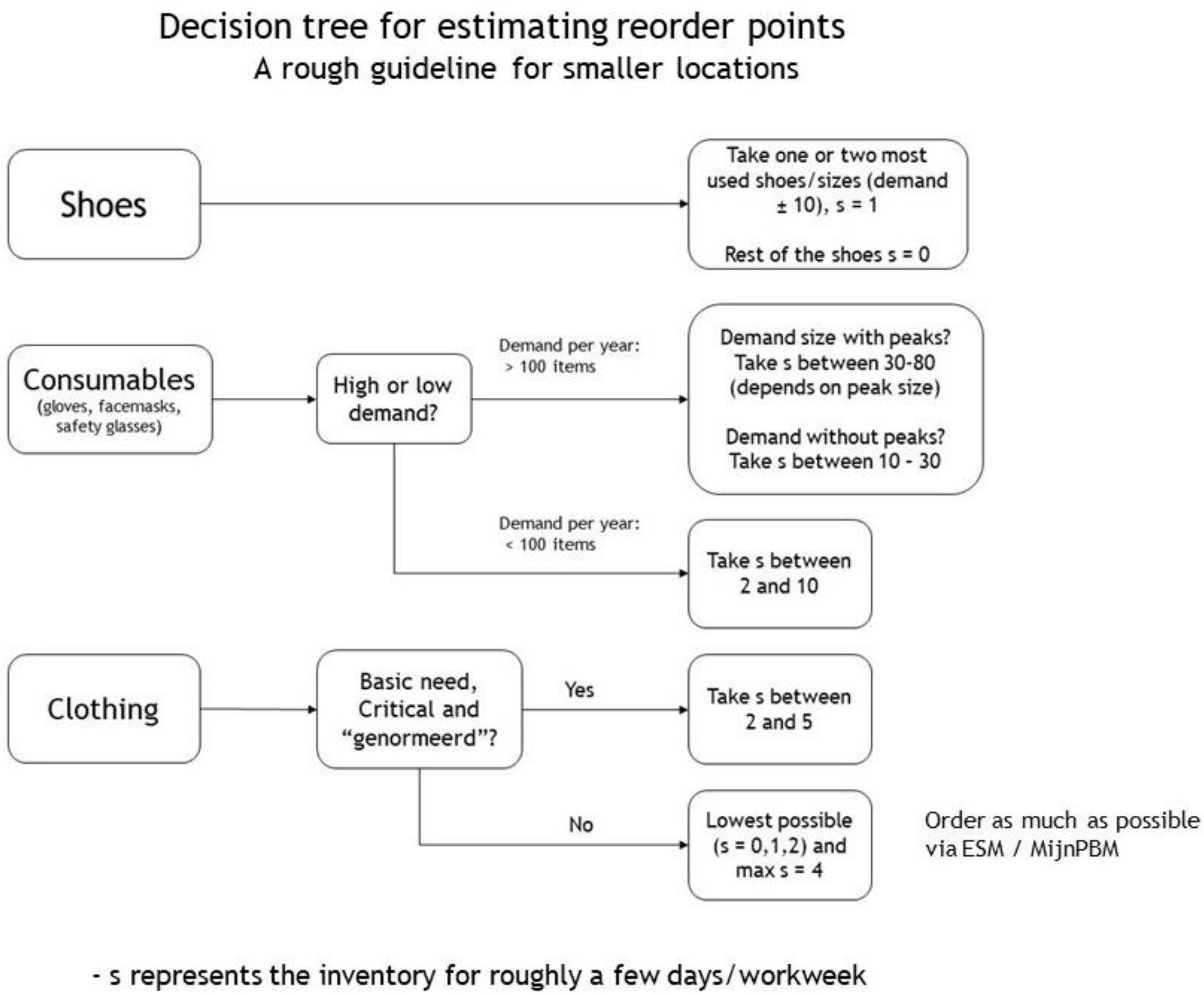
	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
	€ 14.900,94	€ 14.696,70	€ 10.434,57	€ 9.656,44	€ 12.593,23	€ 13.181,39
Laars Emma Mento S3 mt 41D	1	1	1	1	1	1
Laars Emma Mento S3 mt 42 D	1	1	1	1	1	1
Laars Emma Mento S3 mt 43 D	1	1	1	1	1	1
Laars Emma Mento S3 mt 44 D	1	1	1	1	1	1
Laars Emma Mento S3 mt 45D	1	1	1	1	1	1
Veiligh. schoen hoog Emma Billy mt 41 XD	1	1	1	1	1	1
Veiligh. schoen hoog Emma Billy mt 42 XD	1	1	1	1	1	1
Veiligh. schoen hoog Emma Billy mt 43 XD	1	1	1	1	1	1
Veiligh. schoen hoog Emma Billy mt 44 XD	1	1	1	1	1	1
Veiligh. schoen hoog Emma Billy mt 45 XD	1	1	1	1	1	1
Veiligh. schoen hoog Emma Lukas mt41 XXD	1	1	1	1	1	1
Veiligh. schoen hoog Emma Lukas mt42 XXD	1	1	1	1	1	1
Veiligh. schoen hoog Emma Lukas mt43 XXD	1	1	1	1	1	1
Veiligh. schoen hoog Emma Lukas mt44 XXD	1	1	1	1	1	1
Veiligh. schoen hoog Emma Lukas mt45 XXD	1	1	1	1	1	1
Veiligh. schoen hoog Nestor mt41 D	1	1	1	1	1	1
Veiligh. schoen hoog Nestor mt42 D	3	3	2	2	3	3
Veiligh. schoen hoog Nestor mt43 D	1	1	1	1	1	1
Veiligh. schoen hoog Nestor mt44 D	1	1	1	1	1	1
Veiligh. schoen hoog Nestor mt45 D	1	1	1	1	1	1
Winterlaars Emma Merula S3 mt 41 D	1	1	1	1	1	1
Winterlaars Emma Merula S3 mt 42 D	1	1	1	1	1	1
Winterlaars Emma Merula S3 mt 43 D	2	2	1	1	2	2
Winterlaars Emma Merula S3 mt 44 D	1	1	1	1	1	1
Winterlaars Emma Merula S3 mt 45 D	1	1	1	1	1	1

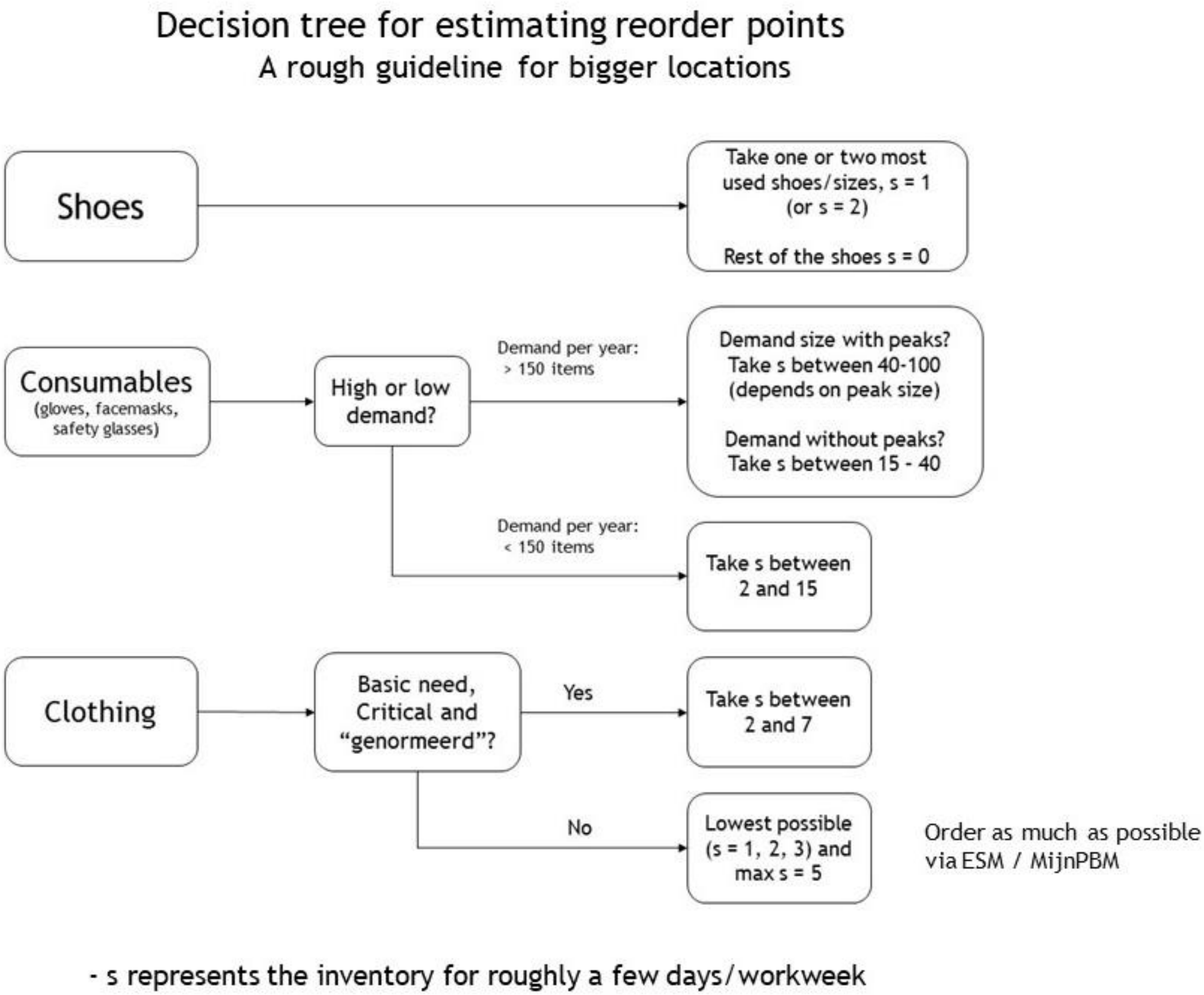
Binnenvoering 7760 maat EEL marine Fleece	1	1	1	1	1	1
Binnenvoering 7760 maat EL marine Fleece	1	1	1	1	1	1
Binnenvoering 7760 maat L marine Fleece	1	1	1	1	1	1
Binnenvoering 7760 maat M marine Fleece	1	1	1	1	1	1
Binnenvoering 7760 maat S marine Fleece	1	1	2	2	2	2
Parka 7223 maat EEL Hedland - Company X logo	2	1	1	1	2	1
Parka 7223 maat EL Hedland - Company X logo	4	3	4	2	4	3
Parka 7223 maat L Hedland - Company X logo	6	4	6	3	6	4
Parka 7223 maat M Hedland - Company X logo	8	6	8	4	8	6
Parka 7223 maat S Hedland - Company X logo	1	1	1	1	1	1
T-shirt korte mouw Company X logo maat EEL	11	6	9	2	11	6
T-shirt korte mouw Company X logo maat EL	8	3	4	3	8	3
T-shirt korte mouw Company X logo maat L	10	3	6	9	10	3
T-shirt korte mouw Company X logo maat M	17	11	13	9	17	11
Sweater Company X logo maat EEL	3	2	2	2	3	2
Sweater Company X logo maat EL	6	3	4	2	6	3
Sweater Company X logo maat L	9	6	7	4	9	6
Sweater Company X logo maat M	14	9	10	8	14	9
T-shirt lange mouw Company X logo maat EEL	12	7	8	2	12	7
T-shirt lange mouw Company X logo maat EL	7	3	3	6	7	3
T-shirt lange mouw Company X logo maat L	12	8	9	3	12	8
T-shirt lange mouw Company X logo maat M	11	6	7	3	11	6
Armbeschermer Fireblade FS14 geel 35 cm	2	2	2	2	2	2
Bivakmuts Intersafe FR/AS	20	20	3	3	3	3
Bril Goggle ultravision 9301-105	1	1	8	8	8	8
Bril I-VO 9160-265 blauw-oranje	41	41	22	22	41	41
Col Intersafe FR/AS	14	14	2	2	2	2
Gehoorkap Bilsom Clarity 1011142 28109	3	3	2	2	3	3
Gehoorkap Optime II H520p3E-110883	26	26	16	16	26	26
Gelaatscherm Perforama Nova scherm blank	1	1	3	3	3	3
Gelaatsscherm V4F voor helm Uvex airwing	3	3	7	7	3	3

HANDSCHOEN 5-VINGERS L.35 ROOD	1	1	1	1	1	1
Handschoen Alphatec 58-435 maat 10	2	2	2	2	2	2
Handschoen Alphatec 58-435 maat 8	1	1	1	1	1	1
Handschoen Alphatec 58-435 maat 9	11	11	6	6	11	11
Handschoen geitenleer Tegera Ejendalls10	26	26	14	14	26	26
Handschoen geitenleer Tegera Ejendalls11	8	8	5	5	8	8
Handschoen Hyflex 11-518 maat 10	45	45	27	27	45	45
Handschoen Hyflex 11-518 maat 8	41	41	24	24	41	41
Handschoen Hyflex 11-518 maat 9	87	87	43	43	87	87
Handschoen Hyflex 11-531 maat 10	163	163	104	104	163	163
Handschoen Hyflex 11-531 maat 8	60	60	22	22	60	60
Handschoen Hyflex 11-531 maat 9	82	82	46	46	82	82
Handschoen Hyflex 11-537 maat 10	82	82	70	70	82	82
Handschoen Hyflex 11-537 maat 8	28	28	19	19	28	28
Handschoen Hyflex 11-537 maat 9	72	72	39	39	72	72
Handschoen HyFlex 11-630 Maat 10	8	8	5	5	8	8
Handschoen HyFlex 11-630 Maat 8	1	1	1	1	1	1
Handschoen HyFlex 11-630 Maat 9	1	1	6	6	1	1
Handschoen Hyflex 11-739 maat 10	12	12	8	8	12	12
Handschoen Hyflex 11-739 maat 8	1	1	1	1	1	1
Handschoen Hyflex 11-739 maat 9	2	2	2	2	2	2
Handschoen Winterpro, Maat 08	5	5	3	3	3	3
Handschoen Winterpro, Maat 09	2	2	2	2	2	2
Handschoen Winterpro, Maat 10	18	18	15	15	15	15
Handschoenen geitenleder maat 10	85	85	47	47	85	85
Helm Uvex Airwing blauw incl Company X Logo	45	45	30	30	45	45
Kniebescherm Helly Hansen	2	2	2	2	2	2
Oordop Ear Classic geel	13	13	13	13	13	13
Overzetbril 9161-014, transparant	1	1	1	1	1	1
Overzetbril Flexy	1	1	1	1	1	1
Regenbroek EL FR-LR41 koningsblauw	8	8	4	4	4	4

Regenjas EL FR-LR48 koningsblauw	12	12	7	7	7	7
Ruimzichtbril Atom blauw, polycarbonaat	1	1	1	1	1	1
Stofmasker FFP3 3M 9332	200	200	138	138	200	200
Thermobroek lange onderbroek maat EEL	1	1	1	1	1	1
Thermobroek lange onderbroek maat EL	1	1	1	1	1	1
Thermobroek lange onderbroek maat L	1	1	1	1	1	1
Thermobroek lange onderbroek maat M	1	1	1	1	1	1
Thermoshirt lange mouw maat EEL	1	1	1	1	1	1
Thermoshirt lange mouw maat EL	1	1	1	1	1	1
Thermoshirt lange mouw maat L	2	2	2	2	2	2
Thermoshirt lange mouw maat M	1	1	1	1	1	1
Thermosokken Bata maat 39-42	3	3	3	3	3	3
Thermosokken Bata maat 43-46	25	25	16	16	16	16
Veiligh. bril Uvex Astrospec 2.0 9164187	2	2	2	2	2	2
Veiligheidsbril Carbovision	1	1	1	1	1	1
Vizier Atom blauw, polycarbonaat	1	1	1	1	1	1
Wegwerpoverall wit Tyvek Classic EEL	74	74	65	65	65	65
Wegwerpoverall wit Tyvek Classic EL	12	12	25	25	12	12
Wegwerpoverall wit Tyvek Classic L	1	1	1	1	1	1
Zweetband G22, G2000, G3000	1	1	1	1	1	1

Appendix I: Decision trees




Decision tree for estimating reorder points
A rough guideline for bigger locations
Shoes
Take one or two most used shoes/sizes, s = 1 (or s = 2)
Rest of the shoes s = 0
Consumables (gloves, facemasks, safety glasses)
High or low demand?
Demand per year: > 150 items
Demand size with peaks? Take s between 40-100 (depends on peak size)
Demand without peaks? Take s between 15 - 40
Demand per year: < 150 items
Take s between 2 and 15
Clothing
Basic need, Critical and "genormeerd"?
Yes
Take s between 2 and 7
No
Lowest possible (s = 1, 2, 3) and max s = 5
Order as much as possible via ESM / MijnPBM
- s represents the inventory for roughly a few days/workweek

Appendix J: Dedicated logo stock at the supplier (s, S) system (all logo items)

Item description	Reorder point	Order-Up-To level	Order quantity
Sweater Santino Roland EEL	6	14	8
Sweater Santino Roland EL	9	17	8
Sweater Santino Roland L	9	19	10
Sweater Santino Roland M	9	17	8
Sweater Santino Roland s	3	11	8
T-shirt Santino Joy EEL	12	31	19
T-shirt Santino Joy EL	14	36	22
T-shirt Santino Joy L	20	40	20
T-shirt Santino Joy M	18	35	17
T-shirt Santino Joy S	3	15	12
Parka Sioen Hedland EEEL	1	2	1
Parka Sioen Hedland EEL	3	6	3
Parka Sioen Hedland EL	3	7	4
Parka Sioen Hedland L	5	9	4
Parka Sioen Hedland M	4	8	4
Parka Sioen Hedland s	1	4	3
T-shirt Santino James EEL	7	22	15
T-shirt Santino James EL	10	27	17
T-shirt Santino James L	14	31	17
T-shirt Santino James M	13	27	14
T-shirt Santino James S	3	15	12

Appendix K: Dedicated logo stock at the supplier (s, S) system (Parka's)

Item description	Reorder point	Order-Up-To level	Order quantity
Parka Sioen Hedland EEEL	1	2	1
Parka Sioen Hedland EEL	3	5	2
Parka Sioen Hedland EL	3	6	3
Parka Sioen Hedland L	5	8	3
Parka Sioen Hedland M	3	6	3
Parka Sioen Hedland s	1	2	1

Appendix L: Ratio's used for estimating costs and demand for the other locations

Estimation of extra Costs when placing shoes at all	
Total demand BU South	240
Total from stock BU South	206
Ratio from stock	**0,8583**
Total shoe demand bought at supplier (all other locations)	386
Total shoes with Maverick Buying	236
Total all other locations	622
possible from stock	622 * 0,8583 = 532
Ratio BU South from stock and Possible from stock at other locations	532 / 206 = **2,58**
Total costs BU South	€ 2.533,43
Estimate costs other locations	2.533,43 * 2,58 = **€ 6.540**

Multiplier demand		
Mean All locations = mean BU South * multiplier Variance all locations = Variance BU South * $\sqrt{\boldsymbol{multiplier}}$		
	Multiplier (all locations)	Multiplier (without BU South and Hengelo)
Parka 7223 maat EEL Hedland - Company X logo	1,85	0,85
Parka 7223 maat EL Hedland - Company X logo	1,9	0,9
Parka 7223 maat L Hedland - Company X logo	2,12	1,07
Parka 7223 maat M Hedland - Company X logo	2,05	1
Parka 7223 maat S Hedland - Company X logo	1,1	0,1
T-shirt korte mouw Company X logo maat EEL	1,66	0,66
T-shirt korte mouw Company X logo maat EL	1,63	0,63
T-shirt korte mouw Company X logo maat L	1,37	0,37
T-shirt korte mouw Company X logo maat M	1,53	0,53
Sweater Company X logo maat EEL	2,14	0,55
Sweater Company X logo maat EL	1,684	0,68
Sweater Company X logo maat L	1,98	0,98
Sweater Company X logo maat M	1,51	0,5

Appendix M: Calculation of the Total Relevant Costs

$$TRC = Nr\ of\ orders * orderingcosts + \left(avg\ OHS - \left(\frac{avg\ Order\ size}{2}\right)\right) * holdingcosts + \left(\frac{avg\ Order\ size}{2}\right) * holdingcosts$$

Appendix N: Maverick Buying Dashboard for the Business Procurement Managers

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