Optimizing the Inventory Control Policy Within an Electronics Production Company

Master thesis

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Optimizing the Inventory Control Policy Within an Electronics Production Company

Final Report

Industrial Engineering & Management
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Management Summary

This research is conducted at Hortec Electronics. Hortec Electronics is located in Oldenzaal and is specialized in the development and production of printed circuit boards. The focus of this research is on reducing the inventory values (i.e., the monetary value of the inventories in the warehouse). The current total inventory value is 30% of the revenue. The management of Hortec considers this too high. The inventory value per item is calculated by multiplying the inventory level with the item price. The total inventory value is a summation of the inventory values over all items. Reducing the inventory value leads to less capital utilization and higher liquidity. The current purchasing strategy is solely based on experience, instead of using decision rules. A clear decision-making process for the purchasing strategy is desired so that no experience is needed and the inventory values can be reduced. With this goal in mind, the following main research question is composed:

How to control the raw materials inventory within Hortec to reduce the inventory value while satisfying the service level?

The inventory of the raw materials is investigated because the raw materials have the highest impact on the total inventory value. The total inventory value is approximately €1,075,000 and the inventory value for all raw materials are approximately €750,000. So the raw materials account for almost 70% of the total inventory value. The raw materials can be used in production or still located in the warehouse. The focus of this research is on the latter, because the raw materials used in production contributes to the revenue. The inventory value of the raw materials located in the warehouse is more than €500,000

As said before, the purchasing strategy is based on experience. No guidelines are provided when and how much to order. For some orders, the items are purchased when the order arrives. For other orders, the items are already purchased in advance. The items that are purchased in advance are purchased by gut feeling. The demand and price of an item are taken into account. For expensive items, only the quantities needed are purchased. For cheaper items, larger quantities are ordered to get quantity discounts. A trade-off between these decisions is currently not taken into account.

Within Hortec, a distinction is made within three order types, first production runs (FPRs), annual orders, and general orders. This research mainly focuses on the purchasing strategy related to the annual orders. With annual orders, the customer communicates a global demand planning for one year. It is unknown when a customer wants to receive the products and in what quantity. For these orders, Hortec needs to purchase raw materials in advance. The inventory value of raw materials for annual orders is approximately €250,000.

To determine when and how much to purchase, different inventory control policies are investigated. The four most common policies are the (s,Q), (s,S), (R,s,Q), and (R,S)-policies. The policies can be categorized under the continuous or periodic review and a fixed or variable lot size. Those four policies are static. The control parameters of static policies do not depend on the factors resulting in predictable variation in demand, such as trend or seasonality. When these factors have a high impact (e.g., only sales in the summer), one can choose for a dynamic policy to include predictable changes in demand. In contrast to the static policy, a dynamic policy has parameters that can have different values for different periods. For example, when an item is sold more in the summer, the corresponding parameters are higher in the summer than in the other periods.

Table 0.1: Policy of each category

	X	Y	Z
A	(R,s,S)	(s_k,S)	(s,S) & (s_k,S)
B	(R,S)	(s_k,Q)	(s,Q) & (s_k,Q)
C	(s,Q)	(s,Q)	(s,Q) & (s_k,Q)

During this research, 675 raw materials are investigated. First, they are classified according to the ABC-XYZ classification. The ABC-XYZ classification is based on the annual usage value and the demand uncertainty. The classification is used to determine the most appropriate inventory control policy per class. For some classes, multiple inventory control policies are considered to see which one performs better. The considered policies for each class can be found in Table 0.1.

The control parameters are calculated using demand forecast and cycle service levels. The demand is forecasted in the R software, using historical demand data. The cycle service levels are chosen between 80% and 99%, depending on the classification category.

After the control parameters are calculated, a simulation study is carried out to see how the proposed policies performed. The results per class can be found in Table 0.2. For the items with high demand variability, the dynamic policy only works better for the AZ-items, items with high annual usage and high variability. When the best performing policy per category is considered, the proposed policy can reduce the total inventory value with almost €33,000, which is a reduction of approximately 13% of the total inventory value. All categories with X-items show a negative change in inventory value. The main cause of the increase in inventory value when applying the proposed policy is the demand forecast. When the demand forecast is optimized, the policies will perform better.

Table 0.2: Total change in inventory value

Classification category	Change in inventory value
AX-items	-€319
AY-items	€6043
AZ-items	€2799 (static) €6640 (dynamic)
BX-items	-€4276
BY-items	€6031
BZ-items	€5829 (static) €4768 (dynamic)
CX-items	-€1014
CY-items	€3966
CZ-items	€9691 (static) €9484 (dynamic)
Total	€32591

Since the dynamic policy did not perform as good as the static policy for the Z-items, the static policy is also evaluated for the Y-items. The static worked better than the dynamic for both the AY- and BY-items. Using a static policy for those items, the inventory value can be reduced with almost €50,000. This is a reduction in inventory value of almost 20%. The selected inventory control policies and the corresponding inventory value reductions can be found in Table 0.3.

In the end, the proposed model is verified and validated to check whether it is realistic and representative of the current situation. To calculate the control parameters, a demand forecast is needed. The accuracy of the demand forecast is tested using four forecasting accuracy measured. Furthermore, a sensitivity analysis is performed to see how the proposed model reacts to changes.

Table 0.3: Best policy for each category

	X	Y	Z
A	(R,s,S)	(s,S)	(s_k,S)
B	(R,S)	(s,Q)	(s,Q)
C	(s,Q)	(s,Q)	(s,Q)

To conclude, the implementation of the inventory control policies proposed in this theses can reduce 10% to 20% of the inventory value of the raw materials analyzed during research.

Acknowledgements

Dear reader,

This report is the final result of my research conducted at Hortec Electronics to finish the Production & Logistics Management specialization of the Industrial Engineering and Management Master's degree at University of Twente.

I would like to thank all the people at the company for their contribution to this research. A special thanks to Lars Zwanenburg for being able to conduct my research at the company and supervising me. Furthermore, I would like to thank Erik Hoomans from who I learned a lot about the current situation within Hortec.

Moreover, I want to thank my supervisors of the university, Engin Topan and Wouter van Heeswijk. Even though they were very busy teaching courses and supervising other students, they always found the time to help me and give meaningful feedback.

Lastly, I want to thank my family and friend who supported me during this research. Especially the ones who proofread my thesis.

I wish you a lot of pleasure in reading my Master Thesis,

Anouk Scholten

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Acronyms

BOM bill of materials.

CMA centered moving average.

EOQ economic order quantity.

FPR first production run.

IMA internal merchandise authorization.

MAD mean absolute deviation.

MAPE mean absolute percentage error.

MOQ minimum order quantity.

MSE mean squared error.

MTO make-to-order.

MTS make-to-stock.

PCB printed circuit board.

RMA return merchandise authorization.

SMD surface-mounted device.

SMT surface-mounted technology.

TH through-hole.

WIP work-in-progress.

1 Introduction

The electronics industry is growing fast. Because of the rapid growth, the electronics industry can be a very competitive market which can be challenging for companies. Companies have to deal with customization, which includes a high amount of raw materials, especially in the electronics industry. Because of this, inventory management has become an important element that determines the achievement of important goals, such as achieving a high customer service level and having low cost at the same time (Babiloni et al., 2010). Competitive pressure made many firms review their production-inventory practices. These practices especially concern maintaining low inventory levels and determining when it is optimal to hold finished goods inventory (Arreola-Risa and DeCROIX, 1998).

This research is conducted at Hortec. Hortec is a production company located in Oldenzaal (NL) and is specialized in the development and assembly of electronic devices. The management of Hortec wants to review its production-inventory practices since high inventory values were observed. Hortec has to deal with a large variety of raw materials because their products are highly customized. Large varieties of raw materials make inventory practices difficult. Therefore, the focus of this research is to investigate the processes concerned with the inventory value and find a way to reduce their inventories. At the moment, decisions about when and how much to order are based on gut feelings and experience. The solution of this research should include a clear decision-making process to make these kind of decisions.

This first chapter introduces the research subject and elaborates on the research plan. Section 1.1 introduces Hortec, the company where this research is conducted. Section 1.2 describes the research motivation and Section 1.3 clarifies the problem. In Section 1.4, the scope and limitations of this research will be described. The research objective and the research questions are defined in Sections 1.5 and 1.6 respectively. The deliverables of this research are mentioned at the end of Section 1.6.

1.1 The company - Hortec

Hortec is a production company founded in 1998, located in Oldenzaal (NL), and employs approximately 25 people at the moment. Hortec is specialized in the development and production of printed circuit boards (PCBs). A PCB serves as a carrier for electronic components. Hortec can either supply subsystems or fully tested and finished electronic systems. Furthermore, they can support the customer during the entire product life cycle. Hortec distinguishes itself from its competitors by combining flexibility, quality, and knowledge.

The company produces customized products by using a make-to-order (MTO) policy. This means that they start producing after an order arrives (Mihiotis, 2014). Besides that, they start purchasing when an order is received. The disadvantage of this way of working is the long lead times. On the other hand, this way of working has the advantages that they can quickly adapt to the wishes of the customer and that little to no inventory is required.

The production process of Hortec consists of machine assembly, so-called surface-mounted technology (SMT) assembly, and conventional hand assembly, so-called through-hole (TH) assembly. SMT is a method in which the components are mounted or placed directly onto the surface of a PCB. In contrast to TH-assembly, which is used for components that are inserted into holes of a PCB and soldered to pads on the opposite side. This is either done by manual assembly (hand placement) or by the use of automated insertion mount machines. A simplified version of this process is visualized in Figure 1.1. Within Hortec, most of the PCBs need both SMT- and TH-assembly. The surface-mounted device (SMD) components are first assembled. After that, the through-hole technique is used for components not suitable for SMT such as large transformers (see Figure 2.2a) and heatsinked power semiconductors. Years ago, TH-assembly was the most common way. However, SMT is becoming more ubiquitous nowadays. Together with the customer, Hortec determines which components are SMT and which TH.

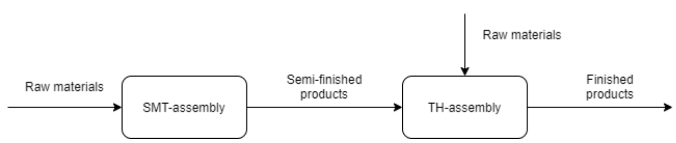


Figure 1.1: Simplified SMD- and TH-assembly process

1.2 Research motivation

Hortec is committed to improving its competitive position for its clients who want to distinguish themselves in technology and quality. This is done by combining flexibility, quality, and knowledge in the development and assembly of electronics.

As illustrated in Table 1.1, Hortec has grown significantly in the last couple of years. Although Hortec has grown, it operates more or less in the same way as a couple of years ago. Purchasing decisions are made on gut feelings and experience instead of standard practices. The management of Hortec is wondering if they can improve the way they operate and/or get more clear and standard decision making process. An advantage of the MTO-policy Hortec applies is low inventory levels. However, the management of Hortec experiences an inventory value that is too high, which is surprising because of the MTO-policy. Optimizing the inventory value leads to less capital utilization and higher liquidity. The cause(s) for the high inventory will be analyzed in Chapter 2. Table 1.1 shows that the inventory value has increased over the years. At the moment, the inventory value is around 1.1 million euros.

The management already experienced a high inventory value in 2011. The causes for the high inventories were investigated at that time but unfortunately did not make a difference. In fact, the inventory value has increased since then. In 2011, the inventory value was 18% of the revenue, which is way lower than the current percentage of around 30%.

Table 1.1: Revenue, inventory value, and service level per year (in million euros)

Year	2012	2013	2014	2015	2016	2017	2018	2019
Revenue	1.88	2.76	2.62	3.09	3.57	3.27	2.92	3.90
Inventory value	0.514	0.645	0.853	0.765	0.869	0.838	1.027	1.191
Service level		92.8%	97.5%	92.4%	77.6%	95.7%	90.0%	84.5%

Within the inventory, a distinction can be made between raw materials, semi-finished products, and finished products. Due to the high inventory levels, there is little insight into the inventory. This is the main reason the management wants to gain more insight into the inventory.

1.3 Problem statement

The main problem Hortec has experienced is that the inventory value is too high. In this section, the causes of the problem are described. These causes are also visualized in the problem bundle which can be found in Appendix A.1.

The first cause of the high inventory value is the **minimum order quantity (MOQ)**. An MOQ is an ordering requirement imposing that the amount of units orders has to be at least a certain quantity (Park and Klabjan (2015)). A lot of suppliers make use of an MOQ, especially for small and cheap items. Because of the MOQ, items are on average longer in stock. Besides, it can lead to excess inventory, because not all materials are needed later on.

The second cause of the high inventory value is the **alignment of production steps**. Each order includes different production steps, which are not always properly aligned. This has two causes. The first cause is that some production steps have a fixed lead time of one or more days. In reality, the lead time is only a couple of hours. Sometimes, this fixed lead time is needed because, for example, the product needs to dry. However, most of the time this is not the case. When the fixed lead time is not required, the difference between the fixed lead time and the actual time needed is automatically waiting time. Because of this, the production lead time increases, resulting in more work-in-progress (WIP). The second cause is the changeover time at the first production stage, SMT. The changeover time is on average one day, whereas the production time is on average one week. Because of the long changeover time, the batch-size at this stage is bigger than the batch-size at the TH-production. This means that a lot of parts are waiting for the next production stage and therefore a higher WIP.

The third cause is the **first production run (FPR)**. FPRs are customer orders which contain products Hortec makes for the first time. This means that there are some uncertainties accompanied by FPRs. Most of the time, there are more materials purchased than needed. Besides, the wrong item(s) may be purchased which are stored in the warehouse. This results in excess inventory. The warehouse personnel does not know if the excess inventory needs to be stocked again or can be discarded. Therefore all materials are placed in the warehouse (on a random location).

The fourth cause are the **annual orders**. Annual orders are a service Hortec provides where the customer communicates a global demand planning for one year. However, it is unknown when a customer wants to receive the products. When the orders need to be delivered is communicated a short period before their desired delivery date. This period can vary from one day to two months. Because Hortec has long lead times (approximately 10-12 weeks), it is not possible to start purchasing when the official order arrives. Therefore, Hortec keeps inventory for these customers. The safety stock Hortec uses is based on experience and MOQs, instead of using demand forecasting. The annual orders are planned based on the global demand planning of the customer. The end-products of annual order could be in stock since the actual planning could differ from the global planning.

The fifth cause is that a **customer shifts the delivery date**. Besides FPRs and annual orders, Hortec has general orders. General orders should have a fixed delivery date. However, a customer may shift this date. Because of this, the planning needs to be adjusted to the new date. Most of the time, the materials are already purchased and sometimes even delivered. So when a customer shifts the delivery date, the materials are longer in stock.

The sixth cause is the **non-stationary demand**. Non-stationary means that the stochastic process is not constant over time. So a non-stationary process does not possess a fixed mean and/or variance (Box and Tiao, 1965). Trend and seasonality are possible causes for non-stationary demand (Tunc et al., 2011). To deal with non-stationary demand in inventory control, dynamic policies are needed. Unfortunately, the current inventory control policy is not dynamic and is not robust to non-stationary demand. This causes the raw materials to be longer in stock.

Table 1.2: Types of orders and their characteristics

Order type	FPRs	Annual orders	General orders
Delivery date	Fixed	Variable	Fixed
Order quantity	Fixed	Variable	Fixed
Raw materials needed	Unknown	Known	Known
Impact on sales	Low	Moderate	Moderate
Overall uncertainty	Moderate	High	Low

1.4 Scope and limitations

It is clear from Section 1.3 that many different aspects affect the inventory level at Hortec. To make sure this research can be conducted in the given time-frame, the scope needs to be determined. Below, the aspects that are outside the scope are discussed.

As can be seen from Table 1.2 and mentioned in Section 1.3, one type of order is FPR. FPRs have some additional production steps in comparison to the other two types of orders. These additional production steps have little to no impact on the inventory. Therefore, only the production process of annual and general orders is part of this research. The raw material purchasing policy of the FPR orders will be investigated during this research.

When a product does not function properly, it may be possible that the customer sends the PCB back to Hortec to be repaired (return merchandise authorization (RMA)). Also, when a product does not pass the test during production and cannot be repaired immediately, it becomes an internal merchandise authorization (IMA). To conduct this research within the restricted time and because the inventory value of these products is negligible, RMAs and IMAs are outside the scope.

Within Hortec, a distinction is made between active and non-active inventory. Active inventory is inventory that has been used at least once in the last three years. Non-active inventory is inventory that has not been used in the last three years and has been amortized. However, non-active inventory is still located in the warehouses. The inventory problem of Hortec has nothing to do with space, but with the monetary value of the inventory. Therefore, only the active inventory is investigated during this research.

Hortec produces products that sometimes have to be coated or varnished. These processes are outsourced. This is a production step with a fixed planned lead time. Because this production step is a blackbox, it is outside the scope of this research. Further in this research, coating or varnishing is a production step with a fixed lead time.

1.5 Research objective

The goal of this research is to decrease the inventory value. The high inventory within Hortec has three direct causes. Those will be explained below and are visualized in the problem bundle in Appendix A.1. The first cause is the raw materials that are longer in stock. The second cause is the excess inventory and the third cause is that the WIP is higher than needed. The focus of this research will be on the first cause because we assume that the raw materials have the highest impact on the total inventory value. The raw materials are longer in stock due to annual orders, the customer changes the delivery date, the safety buffers before and after production, and the non-stationary demand. These causes need to be investigated in Chapter 2.

Moreover, the current inventory control policy needs to be investigated. As well as how to improve this policy to reduce the inventory. However, reducing the inventory may harm the service level. Because the service level is already lower than desired, the inventory needs to be reduced using a smart method. To do this, the raw materials inventory control policy needs to be investigated and come up with a smart solution to reduce the inventory but at the same time does not reduce the service level. Therefore, the research objective is defined as follows:

Determine how the control of the raw materials inventory within Hortec can be adapted to reduce the inventory value while satisfying the service level.

1.6 Research questions

The research objective in Section 1.5 leads to the following main research question:

How to control the raw materials inventory within Hortec to reduce the inventory value while satisfying the service level?

To answer this question, multiple research questions have been established. These research questions are grouped under the different chapters of this thesis.

1. What is the current production-inventory strategy and the corresponding performance of Hortec?

   As concluded in Section 1.2, the inventory value is too high. Therefore, in Chapter 2, the inventory control policy, the planning strategy, and the effects of these strategies will be analyzed. Hortec claims to use the MTO-policy. However, this is questionable since the inventory level is too high. Besides, annual orders can have finished goods inventory, which is not the case in the MTO-policy. Hortec has to deal with supply and demand uncertainty, which is also clear from the problem bundle in Appendix

A.1. It needs to be investigated how Hortec currently deals with this uncertainty. To answer this research question, multiple sub-questions are designed:

(a) What inventory-production model is currently used by Hortec: make-to-stock or make-to-order?

(b) How are the raw materials currently classified?

(c) What raw materials inventory control policy is currently applied within Hortec?

(d) How are the supply and demand uncertainty incorporated in the current inventory control policy?

(e) What impact has the inventory of the raw materials, semi-finished products, and the finished product on the total inventory?

(f) What are the causes of high inventory and what impact do different causes have on the total inventory?

2. What methods are suggested in the literature to reduce the inventory value?

   After the current situation analysis, a literature study needs to be done to investigate how the inventory value can be reduced. This literature study can be found in Chapter 3 and it should include which inventory control policies are available. Besides, how the corresponding control parameters can be calculated needs to be determined and how non-stationary demand can be included in the inventory control needs to be investigated. To calculate the control parameters, demand needs to be modeled using forecasts. Since Hortec does not use demand forecasting at the moment, this also needs to be studied. In order to answer this research question, multiple sub-questions are designed:

   (a) What classification methods are available in the literature?

   (b) What inventory control policies are available in the literature?

   (c) How do the control parameters of the inventory control policies need to be determined?

   (d) What methods are described in the literature that deal with non-stationary demand?

   (e) How can the demand be modeled from using forecasts?

3. What is the most suitable inventory control policy for Hortec and how can it be designed?

   In Chapter 4, inventory control policies most suitable for Hortec will be designed. To do this, first the raw materials need to be classified and the demand need to be forecasted. With this, the most suitable inventory control policies and the corresponding control parameters can be determined. Furthermore, how to implement the inventory control policy within Hortec needs to be investigated. In order to answer this research question, multiple sub-questions are designed:

(a) How are the raw materials of annual orders classified with the new classification method?

(b) What policy is suitable for each classification?

(c) How can the existing data be used to determine the control parameters of the inventory control policy?

(d) How can demand forecasting be used to determine the control parameters of the inventory control policy?

4. What is the effect and improvement of the proposed inventory control policy after implementation?

The proposed inventory control policy has to be tested to investigate what the improvement of the implemented policy is. For this, the results of both the current and proposed policy need to be compared and evaluated. This is done in Chapter 5 with the use of a simulation study. With the results of the different policies, the most suitable inventory control policy needs to be chosen for each classification category. Furthermore, it needs to be checked whether the results are reasonable. In order to answer this research question, multiple sub-questions are designed:

(a) Which raw material inventory control policy is most suitable for each classification category?

(b) How is the performance of the proposed policy in comparison with the current policy?

(c) How can the designed simulation study be validated?

(d) Is the proposed policy close to reality and does it take all restrictions into account?

(e) How robust is the proposed policy?

(f) How can the inventory control policy be implemented within Hortec so that it can be used efficiently?

Deliverables
After this research, a proposal to implement an inventory control policy which is the result of the solution design in Chapter 4, will be delivered. Furthermore, a master thesis will be written which includes the answers on the above-mentioned questions and recommendations to reduce the inventory.

2 Current situation

This chapter elaborates on the current situation at Hortec and answers the first research question: "*What is the current production-inventory strategy and the corresponding performance of Hortec?*". In Section 2.1, the current production process is described. The purchasing and planning strategies are described in Sections 2.2 and 2.3 respectively. The different types of orders are covered in Section 2.4. In Section 2.5, the current performance of Hortec is investigated. The conclusion of this chapter can be found in Section 2.6.

2.1 Current production process

As mentioned in Section 1.1, Hortec can realize both SMT-assembly and TH-assembly. Most of the PCBs need both types of assembly. Within Hortec, separate production orders are created for SMT- and TH-production. In Figure 2.1, the production process within Hortec is graphically shown. The whole process can be divided into three smaller processes: Sales/purchasing, warehouse, and production. In Sections 2.1.1-2.1.3, these three processes are explained.

To detect where an order is in the production process, Hortec uses statuses (e.g., when an order is in SMD-production, it either has the status 38 or 41, depending on whether all materials (raw materials) needed are present or not). These statuses and their description can be found in Appendix A.2.

2.1.1 Sales/purchasing

The production process starts with a customer placing an order. When an order arrives, a sales order is created by the sales department. This is done in Isah, the ERP system Hortec uses. After that, two production orders are created. One for the SMD-production and one for TH-production. Then, the raw materials are purchased. The purchasing department communicates the delivery date of the raw materials with sales, so the sales department can confirm the shipping date to the customer. The production orders are scheduled by the planning department. How the orders are scheduled is elaborated in Section 2.3.

2.1.2 Warehouse

When the raw materials are delivered, the warehouse personnel checks if the materials are needed for an order which is already picked. If this is the case, the material is stored in the corresponding picking bin. Otherwise, the materials are stored in warehouse 00 or 01, for SMD- and TH-components respectively.

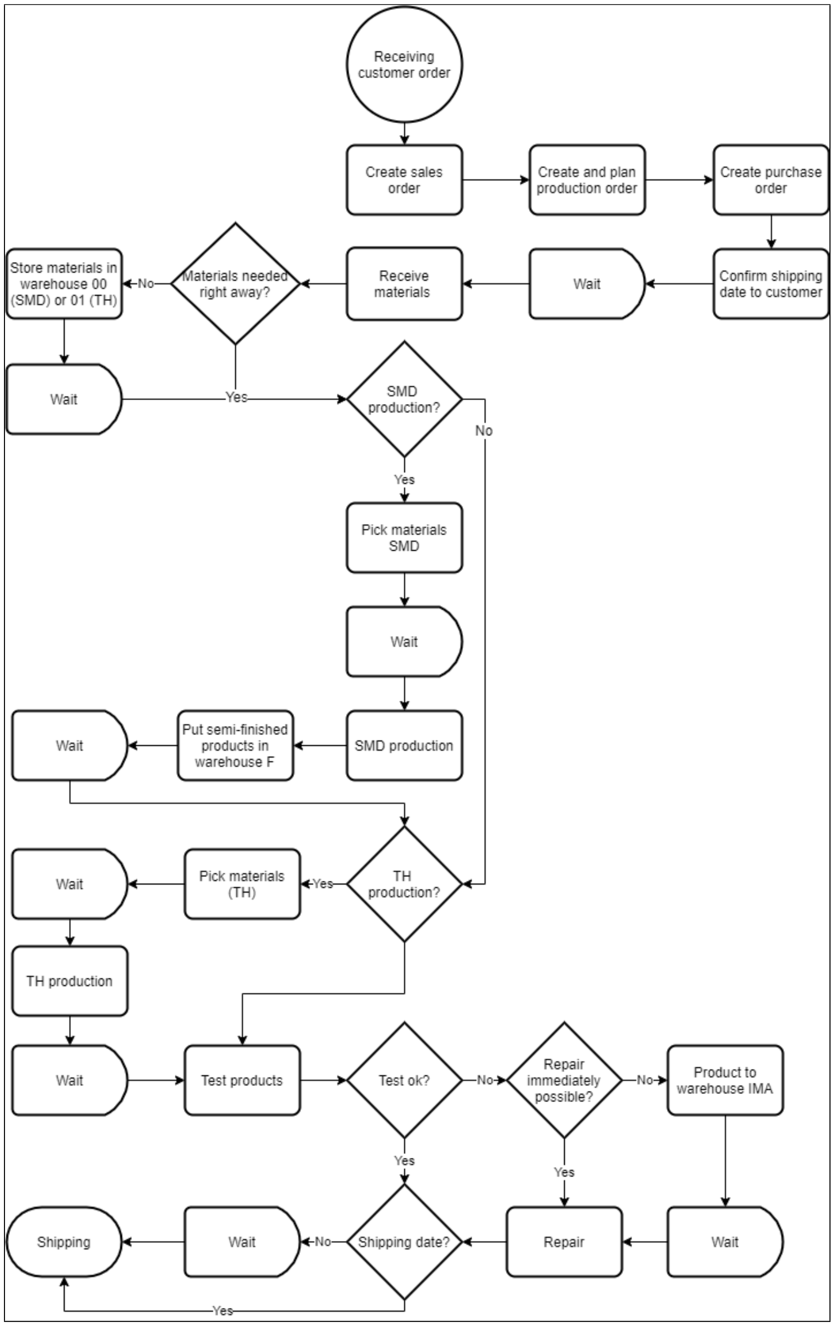


Figure 2.1: Flowchart of the production process within Hortec

2.1.3 Production

When a sales order needs SMD, the materials are picked. The materials wait in a bin until the production can start. When the order is finished at SMD-production, the semi-finished products are stored in warehouse F until the next production stage (TH-production) starts. When the sales order needs TH-production, the required materials are picked from warehouse 01 approximately one week before production starts. When the production is finished, the products are tested. If a product needs repair, it is repaired immediately when possible. If not, the product is stored in warehouse 01 to be repaired later (IMA). When a product works properly, it is either shipped directly (when it is the shipping date) or waits in warehouse 01 to be shipped.

2.2 Purchasing

In this section, the purchasing strategy is described. First, in Section 2.2.1, the inventory control policy Hortec currently applies is explained. After that, in Section 2.2.2, the effects of the minimum order quantity (MOQ) are explained.

2.2.1 Current inventory control policy

Shortly after a customer order arrives, a purchase order may be created (see Figure 2.1). This means that Hortec uses a review period instead of a continuous review. The reviews are triggered by a customer order and therefore the review periods are not fixed. This type of inventory control is called transaction reporting (Silver et al., 1998).

In principle, the quantity purchased is the difference between the needed quantity and the amount already in inventory. However, some suppliers apply minimum order quantities, so a minimum quantity should be ordered. The MOQ is further explained in Section 2.2.2. Some supplier apply quantity discounts, which Hortec also sees as a sort of MOQ. So the order quantity can be fixed, but a variable order quantity is also possible.

In the current inventory control policy, the purchaser takes the characteristics of an item into account. Especially the demand and the price of an item. For example, when 100 pieces are needed but the demand of the item is high and there is a quantity discount when ordering more than 500 pieces, the purchaser may consider buying the 500 pieces. When the item is expensive, the purchaser will prefer to purchase the 100 pieces instead of getting a quantity discount. The idea behind this approach is good. However, it is very time consuming and done by experience.

2.2.2 Minimum order quantity (MOQ)

An MOQ is the lowest quantity the supplier is willing to sell. This can be due to practical reasons, to fit all items on a pallet. Other reasons why suppliers apply MOQs are to be more profitable. The purchaser within Hortec can most of the time purchase items at multiple suppliers. So where one supplier has MOQs and a lower price, another supplier does not have MOQs but probably a higher price. This is a trade-off the purchaser has to make.

As mentioned in Section 1.3, the MOQ of the supplier causes the (raw) materials to be longer in stock. For example, an item has an MOQ of 5000 but is only needed for one order where 1100 pieces are required. This means that the other 3900 pieces are waiting in the warehouse to be used. Most of the time, it is possible to purchase items separately for a higher price at a different supplier. However, for annual orders or products Hortec produces more often, the MOQ of the materials is purchased because this is cheaper. The choice within Hortec is solely based on the cost of the item instead of a trade-off between item cost and inventory cost.

Besides the fact that the MOQ causes materials to be longer in stock, it sometimes causes excess inventory. This is mostly the case with general orders. If 50 pieces are needed, 60 pieces may be purchased when this is cheaper due to the MOQ. The remaining pieces are placed in the warehouse.

2.3 Production planning

In this section, the most important factors concerned with the production planning are described. In Section 2.3.1, the planning strategy is explained. After that, the safety buffers Hortec uses to make sure the orders are delivered on time are covered in Section 2.3.2.

2.3.1 Tactical vs Operational planning

In essence, all production orders are planned at two moments. The first time is when the order arrives, this can be called "tactical planning". The second time is when the production start date is close and is an adjustment of the "tactical planning", this can be called the "operational planning". Below, these two will be explained.

Tactical planning
When a production order is created, the order is planned as soon as possible with the help of Isah. This is mainly done to make sure there is enough capacity. The orders are planned using the backward planning strategy. With backward planning, the last production step is scheduled first, working backward until all production steps are planned (Wiese et al., 2016). All production steps have a fixed lead time which is known by Isah. The completion date used by the

planning department is one week before the delivery date. This week is used as a buffer for unforeseen circumstances. This buffer is further elaborated in Section 2.3.2.

Unfortunately, the planning is sometimes shifted for various reasons. One reason is that the customer changes the delivery date. Another reason can be annual orders. Annual orders are orders of customers who communicate their yearly demand, but do not know yet when they want to receive the products. This is already explained in Section 1.3. When the annual order arrives, the planning department cuts the order in smaller orders and divides them over the year. But most of the time, this does not match with the moment the customer needs the products. More about annual orders can be found in Section 2.4.

Operational planning

When the start date of an order is near, the orders of the coming weeks are written down on a whiteboard at the production department. The planner in the production makes sure that all orders are produced in the right sequence. The planning is done by hand and by experience. Sometimes the delivery date of an order is taken into account and sometimes the planned start date. However, no (machine) scheduling or assignment of jobs to machines is done while planning.

2.3.2 Safety buffer

The planner of Hortec uses for all production orders a two-week buffer before and one-week buffer after the production. This means that the (raw) materials need to be delivered two weeks before the production starts. Furthermore, according to the planning, orders are ready one week before the orders need to be delivered.

Two-weeks buffer (raw) materials

Within Hortec, a two-week buffer is used before production to make sure that all (raw) materials needed are available. Hortec uses this two-week buffer, because not all suppliers are reliable. Table 2.1 shows what percentage of the purchase orders were delivered on time. So, the suppliers are reliable enough that the two-weeks buffer is not needed.

Table 2.1: Reliability suppliers

2017	2018	2019	2020
95.7%	92.9%	93.0%	96.9%

One-week buffer finished products

Besides a two-week buffer before production, Hortec also uses a one-week buffer for finished products. This buffer is used to make sure that the customer orders are delivered on time, even when there is a delay. Also, the one-week buffer is used to have more flexibility in the planning. The service level at Table 1.1 shows that not all orders are delivered on time. Moreover, a lot of the orders are not ready on time, this will be elaborated on in Section 2.5.3.

2.4 Types of orders

As mentioned in Section 1.3, the different types of orders have an impact on the inventory value. Below, the effect of the order types on the inventory is described.

First production run (FPR)
FPRs are orders for products Hortec makes for the first time. Because these products are new, it is not always clear what items are needed and in what quantity. Therefore FPRs are the reason why sometimes wrong items are purchased. When these items are delivered, it is clear that the items are not needed. However, cheap items are stocked in the warehouse because sending it back takes to much time.

Besides wrongly purchased materials, FPRs are the reason for some of the excess inventory. When a product is produced for the first time, sometimes extra pieces of certain (cheap) materials are purchased for unforeseen circumstances. When these extra pieces are not used in production, they are stocked in the warehouse.

Table 2.2: Number of FPRs and orders

Year	2016	2017	2018	2019	2020
#orders	818	606	610	517	79
#FPR	46	60	77	38	10

Talking to some employees of Hortec clarified that this occurred very occasionally and is not a major problem. Furthermore, as can be seen in Table 2.2, the number of FPRs is insignificant in comparison with the total number of orders.

Annual orders
In 2019, 24 of the 74 customers of Hortec places annual orders. In total, these 24 customers placed orders for 2.1 million turnover. This is 54.7% of the total turnover in 2019. Furthermore, these customers are good for an inventory value of more than €400,000, of which approximately €250,000 are for raw materials. Hortec did not know that the annual orders had such a big impact. Therefore this needs to be further investigated.

The hardest part of the annual orders is that Hortec does not know when an order will be placed. In other words, the demand is stochastic. Most of the time, Hortec knows the global demand planning of the customer, which is used to plan production orders. The purchase orders are created based on the production orders. As stated in Section 1.3, the actual demand planning can differ from the communicated demand planning. For example, it is possible that the global demand planning of a customer is evenly spread over the year, when in reality no order is placed during the first half year. When this happens, the (raw) materials, and end products if already produced, are in inventory for a long time.

General orders
For general orders, Hortec uses the MTO-policy. So after a customer order arrives, the production order(s) and purchase order(s) are created. Hence there is no “safety stock“ for these orders. In principle, these orders are not a cause for the high inventory. However, a customer may change the delivery date. When this happens, it may be possible that the (raw) materials are delivered as planned before and therefore are longer on stock than expected.

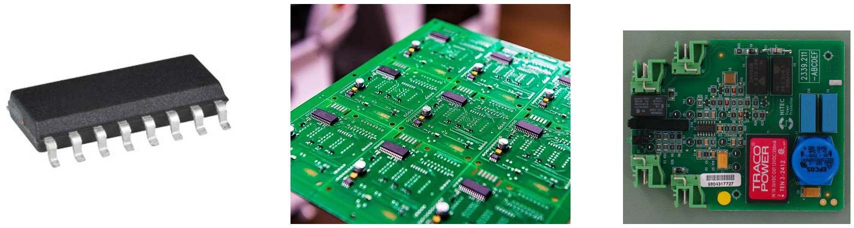
2.5 Current performance

In this section, the performance of the current production-inventory strategy of Hortec is elaborated. First, the current inventory levels are provided and explained in Section 2.5.1. After that, the usage of the inventory is described in Section 2.5.2. In other words, it is investigated when the items were used last and the last time they were purchased. In Section 2.5.3, the service levels are calculated and described.

2.5.1 Current inventory

Hortec distinguishes three types of inventory. The first type is called raw materials. Raw materials are components that are not yet assembled on a PCB. An example can be found in Figure 2.2a. The second type is called semi-finished products. This are PCBs with only SMD components assembled on it. Most of the time, Hortec does the SMD assembly itself. However, sometimes semi-finished products are purchased. An example can be found in Figure 2.2b. The third type is called finished products. Finished products are end products that are delivered to the customer. An example can be found in Figure 2.2c.

From Figure 2.3, it can be concluded that the inventory of finished and semi-finished products remained fairly the same over the years. The inventory of raw materials is increasing a bit over the years. A decrease is seen in 2018 and an increase in 2019. However, the inventory value of work-in-progress increased in 2018. This increase is further elaborated in Section 2.5.1. Below, each product category is investigated separately with the the help of information in Table 2.3, where the inventory is divided per order status and per product category.



(a) Raw material (b) Semi-finished product (c) Finished product

Figure 2.2: Different types of inventory

Raw materials
The raw materials account for almost 70 percent of the total inventory value and have therefore the highest impact. Table 2.3 shows that the majority of the raw materials is not yet linked to a status and is still stored in the warehouse. Around €30,000 is waiting in the warehouse to be used in production and approximately €100,000 is used in production of which approximately €50,000 in testing. In total, the raw materials account for more more than €700,000 of the total inventory value.

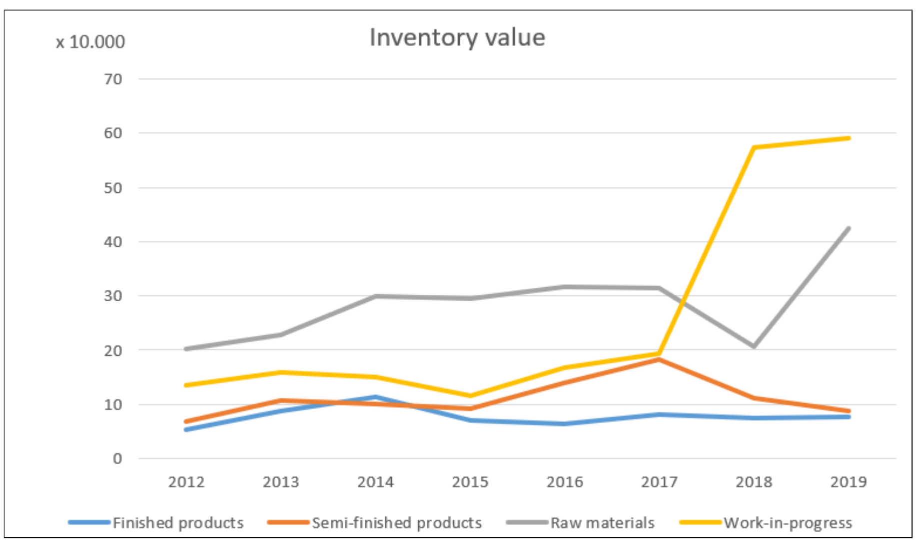


Figure 2.3: Inventory value per product category

Table 2.3: Inventory value per status per product category (in euros)

Order status	Finished products	Semi-finished products	Raw materials	Total
	72,000	103,000	535,000	709,000
24	2,000	-	4,000	5,000
25	4,000	9,000	13,000	26,000
27	6,000	-	3,000	9,000
29	-	21,000	19,000	40,000
38	-	-	19,000	19,000
40	2,000	6,000	8,000	16,000
41	-	-	10,000	10,000
42	-	47,000	25,000	72,000
43	-	-	54,000	54,000
44	34,000	1,000	9,000	44,000
45	12,000	24,000	18,000	55,000
47	4,000	3,000	5,000	12,000
60	-	2,000	2,000	5,000
90	-	-	-	-
95	-	-	-	-
Total	135,000	216,000	723,000	1,075,000

Semi-finished products
Table 2.3 shows that most of the semi-finished products are not yet linked to status. This means that they are waiting in warehouse F for a production order. These parts are waiting because the batch-size of the first production stage (SMD) is larger than the batch-size of the second production stage (TH). Furthermore, almost €50,000 of semi-finished products are already picked but still waiting for TH-production. The rest, which is around €75,000, is in production. In total, the semi-finished products account for €216,000 of the total inventory value.

Finished products
Again, most of the finished products are not linked to a status. This means that the products are waiting in the warehouse, ready to be shipped. Some finished products are needed in other finished products and are waiting in production or waiting for a test. In total, the finished products account for more than €135,000 of the total inventory value.

Work-in-progress (WIP)
In total, there are more than €200,000 of the raw materials, semi-finished products, and finished products in production. A reason for this high WIP inventory is that the different production steps are not aligned, causing a lot of waiting times. Furthermore, there is a strong increase in WIP in 2018. The reason for this increase was that one specific customer obtained some trouble and did not want to receive the products for some time, while they were already in produc-

tion. The products were delivered to the customer in the beginning of 2019. Because of this, the products were long in production.

2.5.2 Usage of the inventory

The second column of Table 2.4 shows in which year which amount of inventory was moved for the last time. From the €1,075,618 of total stock, €788,621 has been moved in this year (2020). Unfortunately, moved can mean multiple things. It can mean that the material has been used for production. But it is also possible that the warehouse personnel has moved it to another location within the warehouse.

Table 2.4: Inventory last mutated and purchased per year (in euros)

Year	last moved	last purchased
2015	€26	€71
2016	€1,514	€1,476
2017	€16,242	€16,389
2018	€36,868	€36,918
2019	€232,345	€259,919
2020	€788,621	€760,843

The last column of Table 2.4, shows in which year which amount of inventory was purchased for the last time. For example, more then €16,000 of inventory is stocked for the last time in 2017. Besides, more than 760 thousand euros has been stocked this year. Which means it is still needed. However, more than 250 thousand euros has been stocked in 2019. To get a better overview, in Table 2.5, the inventory of 2019 is divided over the months.

Table 2.5 shows that most of the materials are purchased at the end of 2019. But still 25% of the inventory value purchased in 2019 was purchased in the first half of this year.

The conclusion formed from Tables 2.4 and 2.5 is that most of the items, approximately 75%, are used in the last couple of months. However, the other 25% is already in stock for three months or more. It even raises the question why some items are in stock since more than € 50,000 of the inventory value has not moved after 2018, which is almost 5% of the total inventory value.

Table 2.5: Inventory purchased per month in 2019 (in euros)

Month	last purchased
January	€18,726
February	€12,350
March	€8,645
April	€4,630
May	€13,031
June	€9,871
July	€21,392
August	€15,396
September	€36,129
October	€31,288
November	€44,429
December	€44,026

2.5.3 Orders ready on time

Table 1.1 already showed that the service level of Hortec is not that high. In this section, the number of the orders are ready on time will be investigated. A distinction is made between the TH-assembly and the SMT-assembly. In Table 2.6, the percentage of orders on time of the conventional assembly is shown per year. In Appendix A.4, the percentages are shown per month. The goal of Hortec is to have at least 90% of the orders ready on time. However, this is never the case. The year 2018 has the highest percentage with 83% and 2016 the lowest with 22%.

Table 2.6: Orders ready on time TH-assembly

2016	2017	2018	2019	2020
22%	36%	83%	68%	43%

In Table 2.7, the percentage of orders on time of the SMD assembly is shown per year. In Appendix A.3, the percentages are shown per month. Just like the TH orders, the goal is to have at least 90% of the orders ready on time. The percentages of SMT are even lower than the percentages of TH-assembly. Once again, the year 2018 has the highest percentage. However, it is still low with 47%. 2019 has the lowest percentage of 28%.

Table 2.7: Orders ready on time SMT-assembly

2016	2017	2018	2019	2020
35%	38%	47%	28%	29%

2.6 Conclusion

In this chapter, the current situation within Hortec was investigated to get an understanding of the process and to answer the first research question. In this section, the first research question is answered by answering the corresponding sub questions.

What inventory-production model is currently used by Hortec: make-to-stock or make-to-order?
Within Hortec, a combination of the MTS- and MTO-policies are used. For the first production runs and general orders, Hortec uses a MTO policy. For annual orders, however, Hortec uses the MTS policy. The focus of this research will be on the latter, because the annual orders are the main cause of the high inventory. So from this moment on, we will only look at the raw materials of MTS orders.

How are the raw materials currently classified?
There is no specific classification method used within Hortec. However, the purchaser classifies items according to the item characteristics like demand and price of the item. This looks a lot like the ABC-classification (Silver et al., 1998), but it is all done by experience and not based on historical data and/or calculations. Therefore, in the literature study, the ABC-classification will be investigated more closely to see if this is a good classification method for Hortec.

What raw materials inventory control policy is currently applied within Hortec?
A production order triggers the purchase of items. When items are needed for a production order, these are purchased. This means that Hortec uses, instead of a fixed review period (e.g., one week), a variable review period called transaction reporting. Furthermore, the quantity purchased can be both fixed and variable. In principle, the quantity needed for the order is purchased, so a variable quantity. However, some suppliers apply MOQs, causing a fixed quantity to be purchased. Furthermore, some suppliers give quantity discounts when purchasing a larger quantity, which is a consideration for the purchaser.

How are the supply and demand uncertainty incorporated in the current inventory control policy?
Hortec uses a two-week buffer for raw materials to overcome the supply uncertainty. This buffer is used to make sure that all raw materials are available when they start producing. Because of the buffer, supply uncertainty is not a problem and will therefore not discussed further in this research.

To deal with demand uncertainty, the customer orders are evenly spread over the year. This means that Hortec does not make use of demand forecasting. Also, non-stationary demand is not taken into account. Non-stationary demand is partly explainable with trend and/or seasonality and this can be taken into account by using dynamic inventory control policies. So this needs to be further investigated to improve the raw materials inventory control.

What impact has the inventory of the raw materials, semi-finished products, and the finished product on the total inventory?
Most of the inventory value is because of the raw materials (approximately €750,000). Approximately one-third of the raw materials are for customers who place annual orders. Another one-third is customers who place general orders and the rest is not linked to a customer. The semi-finished products have after the raw materials the highest inventory value, with a value of more than €200,000. Approximately half of this value is stored in warehouse F, waiting for the second stage because the production batch-size in the first production stage is higher than at the second stage due to set-up costs. The rest of the value is used in production. The finished products have the lowest inventory value, with a value of approximately €135,000. Two third of this value is for annual orders and the rest for general orders. Half of the value is waiting in the warehouse to be shipped, the other half is used in production. Furthermore, there is approximately €250,000 WIP.

The raw materials are the focus of this research because in Section 1.5, the assumption was made that the raw materials have the highest impact on the total inventory value. Since the raw materials account for almost 70% of the total inventory value, it can be concluded that this assumption is correct.

What are the causes of high inventory and what impact do different causes have on the total inventory?
The high inventory is caused by different factors. The most important factors are the planning and the purchasing policy of the raw materials. The impact of these two will be explained below. Furthermore, purchasing items for FPR orders also have a small impact on the inventory.

The planning has an influence on especially the amount of WIP, which is pretty high. Furthermore, when a production order starts later than planned, raw materials are longer in stock. Also, the purchasing policy has an influence on the high inventory. No specific inventory control policy is used and all considerations and classifications of raw materials are made by feeling. Because of this, larger quantities are purchased to get quantity discounts and MOQs are purchased.

3 Literature study

This chapter gives an overview of the literature that is useful for this thesis and answers the second research question: *"What methods are suggested in the literature to reduce the inventory value?"*. In Section 3.1, some classification methods are explained. The classification methods are used to determine the appropriate control policies. The different inventory control policies and the corresponding control parameters are described in Section 3.2. The can-order system, a special control policy, is explained in Section 3.3. Section 3.4 describes how to deal with non-stationary demand and Section 3.5 explains how demand can be forecasted. In Section 3.6, this chapter is concluded by answering the sub-questions of the second research question. In Appendix A.5, additional literature can be found.

3.1 SKU classification

The goal of this research is to identify the best inventory control policy per item. In the ideal situation, all inventory control policies are investigated per item, to see which one performs best for each item. Hortec has a lot of different items, so this would be very time consuming. For practical reasons, we will apply classification to group different items. Each classification group will be linked to a particular inventory control policy.

In this section, three methods to classify SKUs are introduced. The first method is the ABC-analysis and will be described in Section 3.1.1. The ABC method is analyzed because this classification method is based on the annual usage value and the current inventory control policy is also based on the annual usage value. The second method is the XYZ-analysis, which will be elaborated on in Section 3.1.2. This method is analyzed because it is based on the demand uncertainty, which plays an important role in this research. In Section 3.1.3, the two methods are combined.

3.1.1 ABC-analysis

The ABC-analysis is a method to classify items based on the annual usage value (Silver et al., 1998). The goal of the ABC-analysis is to determine the amount of control effort each item needs. The annual usage value is calculated with Equation 1, where D_i is the annual demand and v_i is the item price of item i.

$$Annual\ usage\ value\ of\ item\ i = D_i \cdot v_i \tag{1}$$

The ABC-analysis is easy to use and simple to understand by an average materials manager. Relatively, there are a few items in class A but they form a relatively large amount of the annual usage value. On the other hand, the number of items in class C is relatively large but the annual usage value is relatively small. The items between classes A and C constitute to class B.

A-items
Class A items account for the highest total annual usage value (approximately 80%) but include the lowest number of units (approximately 20%). Therefore, A-items are the most important items. These items have to be controlled tightly and monitored closely.

B-items
Class B items account for the second highest total annual usage value (approximately 15%) and are therefore secondary important. Approximately 30% of all SKUs fall into this category. The inventory management of these SKUs is mostly done computer-based.

C-items
Class C items account for a minor part of the total annual usage value (approximately 5%). Overall, most items are in class C (approximately 50%). The main interest of the low-value items (C items) is to avoid stock-outs and to reduce costs like procurement, material handling, and order inspection costs. The inventory management for these SKUs must be kept as simple as possible like a computer-based reorder point (ROP).

3.1.2 XYZ-analysis

The XYZ-analysis is a method to classify items based on the demand uncertainty (Dhoka and Choudary, 2013). In other words, the items are classified based on the fluctuation in demand (Scholz-Reiter et al., 2012). The demand uncertainty is determined with help of the coefficient of variation (CV). The CV is calculated with Equation 2, where σ is the demand standard deviation and $\overline{X}$ the demand average.

$$CV = \frac{\sigma}{\overline{X}} \tag{2}$$

The SKUs will be ranked according to their CV. The SKUs with the lowest CV (<0,5) are classified under X. These items are easy to forecast because they have the lowest demand uncertainty. SKUs with the highest CV (>1), and thus high demand uncertainty, are classified under Z. The demand for Z-items fluctuates strongly or occurs sporadically. There are barely predictable causal factors, making it hard to get a reliable demand forecast. The raw materials with a CV between these two bounds are Y-items and have medium demand uncertainty. The demand for Y-items is not steady, but the demand fluctuations are usually caused by known factors such as seasonality. Therefore, variability in demand can be predicted to a certain extend. The demand patterns of the different classes can be seen in Figure 3.1.

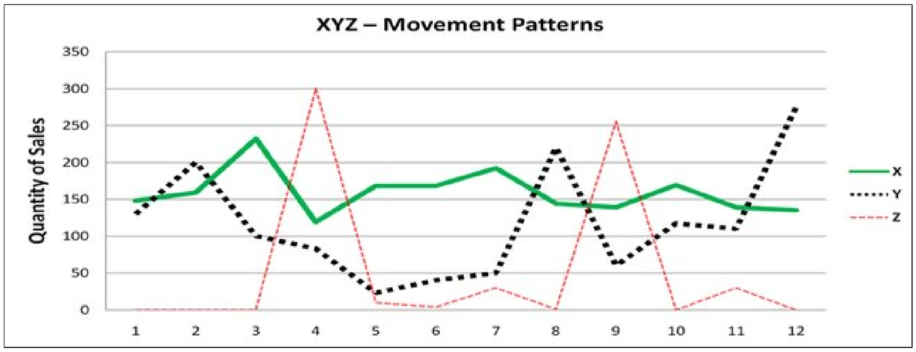


Figure 3.1: Demand patterns (Dhoka and Choudary, 2013)

3.1.3 ABC-XYZ analysis

The classification methods mentioned in Sections 3.1.1 and 3.1.2 can also be combined into one method. Then both the annual usage value and demand uncertainty are taken into account in the classification. This method has a total of 9 classes, as can be seen in Table 3.1. The AX category needs the most attention in inventory management since the value of these items is relatively high. The items in this category account for the most revenue and are good to forecast. The CZ category is the least important one, the items account for the least revenue and are hard to forecast.

Table 3.1: Classification categories according to the ABC-XYZ analysis

	X	Y	Z
A	AX	AY	AZ
B	BX	BY	BZ
C	CX	CY	CZ

3.2 Inventory control

The purpose of inventory control systems is to determine when and how much to order (Axsäter, 2015; van der Heijden, 2020c). This decision should be based on the inventory position, (forecasted) demand, and different cost factors (e.g., holding cost). The decision should be based on the inventory position instead of the inventory level. The difference between the two of them is that the inventory level is only the physical on-hand stock. The inventory position also takes the outstanding orders and backorders into account. Outstanding orders are purchase orders that have not yet arrived. Backorders are customer orders that have been demanded but are not yet delivered. So the inventory position can be calculated with Equation 3.

$$Inventory\ position = on\ hand\ stock + outstanding\ orders - backorders \quad (3)$$

The four most common inventory control policies are presented in Table 3.2. The policies can be categorized in continuous or periodic review. In continuous review, the inventory is continuously tracked. When the inventory position drops to the reorder point, an order is placed. An alternative to continuous review is periodic review. In periodic review, the inventory position is only considered at certain points in time. The interval between the points is in general constant, the review period. In periodic review, an order is placed when the inventory position is equal to or lower than the reorder point at the beginning of the review period. Another possibility is that in every review period an order is placed (except when demand was 0) (Chopra et al., 2013).

The advantage of continuous review over periodic review is that less safety stock is required in the continuous review policies (van der Heijden, 2020d), because the safety stock only needs to cover the variation in lead time demand. In contrast, the safety stock in a periodic review policy needs to cover the variation in demand over the lead time plus review period (Axsäter, 2015). The advantage of periodic review is that it is capable of multi-item coordination. Multi-order coordination is that it is possible to order multiple items from the same supplier at the same time (Silver et al., 1998). In continuous review policies, an order is placed directly when the inventory position drops to or below the reorder point, therefore it is hard to combine multiple purchase orders in the continuous review policies.

Besides the continuous and periodic review categorization, the policies can be categorized in fixed or variable lot size. In a fixed lot size, the order quantity is always the same (or a multiplicity of the order quantity). When the policy applies a variable lot size, the quantity purchased is variable and the goal is to reach a certain inventory position. The advantage of a fixed lot size is that the supplier is less prone to make mistakes in the quantity and a fixed lot size can reduce the service level (Axsäter, 2015; van der Heijden, 2020d). A (practical) drawback of a variable lot size is material handling, because a lot of items are purchased in boxes or pallets with a fixed number of units. However, the total cost of a variable lot size policy will be smaller or equal to the fixed lot size policy.

Table 3.2: Inventory control policies (van der Heijden, 2020c)

	Continuous review	Periodic review
Fixed lot size	(s,Q) or (s,nQ)	(R,s,Q) or (R,s,nQ)
Variable lot size	(s,S)	(R,S) or (R,s,S)

3.2.1 Inventory control policies

Below, the four inventory control policies, given in Table 3.2, will be described in more detail.

(s,Q)- or (s,nQ)-policy
The (s,Q)-policy is a policy with continuous review and fixed lot size. Continuous review means that the inventory position is reviewed continuously to determine whether a purchase order needs to be placed or not. When the inventory position drops below the reorder point (s), a purchase order is made. The reorder point is equal to the expected lead time during demand plus the safety stock. Safety stock is explained in Section 3.2.3. The fixed lot size means that when a purchase order is made, always the same quantity (Q) is purchased. Sometimes it is possible to purchase a multitude of Q, then the policy is (s,nQ).

(s,S)-policy
The (s,S)-policy is a policy with continuous review and variable lot size. Just like the (s,Q)-policy, when the inventory position drops below the reorder point, a purchase order is made. The lot size in the (s,S)-policy is the difference between the order-up-to-level and the inventory position (Bartmann and Bach, 2012). The inventory position will never drop below the reorder point when the order size is always 1, because an purchase order is placed when the invenotry position is exactly the reorder point. So when the order size is always 1, the (s,S)-policy is the same as the (s,Q)-policy. The order-up-to-level (S) is equal to the reorder point (s) plus the fixed lot size (Q) (Silver et al., 2016).

(R,s,Q)- or (R,s,nQ)-policy
The (R,s,Q)-policy is a policy with a periodic review and fixed lot size. A periodic review means that the inventory position is checked periodically (every R periods) whether a purchase order needs to be made or not. Same as with continuous review, when the inventory position is lower or equal to the reorder point (s), a purchase order needs to be made. In this policy, the lot size is fixed. Every time an order is created, the quantity Q needs to be purchased. Also here, it is possible to purchase a multiple of Q, then the policy is (R,s,nQ).

(R,S)- or (R,s,S)-policy
The (R,S)- and (R,s,S)-policies are policies with a periodic review and variable lot size. Every R periods, the inventory position is reviewed. In the (R,S)-policy, the inventory position is raised to the order-up-to-level in every review period. In the (R,s,S)-policy, an order is placed when the inventory position drops to or below the reorder point. The order quantity is the difference between the order-up-to-level and the inventory position.

3.2.2 Policy selection

A standard procedure for selecting the most appropriate policy for each SKU does not exist. However, there are some rules of thumb one can use. In Table 3.3 a rule of thumb can be found for items classified in class A and class B (see Section 3.1.1). A items are the most important and most of the time expensive parts. Therefore, it is understandable that you do not want to order a fixed quantity to prevent purchasing unnecessary items. Furthermore, when there are enough parts, it is not needed to order every review period. So the (R,s,S)- and (s,S)-policy are the most appropriate inventory control policies for A-items. B items are less important than A items but still need to be monitored from time to time.

Table 3.3: Rule of thumb for selecting the inventory policy (Silver et al., 1998)

	Continuous review	Periodic review
A items	(s,S)	(R,s,S)
B items	(s,Q)	(R,S)

C items are not included in Table 3.3, because a more simple approach is sufficient. A simple approach can be an (s,Q)- or (R,S)-policy with parameters that need little attention.

Besides using the above mentioned rule of thumb, it is possible to simulate the different policies and rank them according to how they perform on different criteria. Examples of criteria could be fill rate and holding costs. This is especially a good method to consider when the customer demand is uncertain (Petrovic and Petrovic, 2001).

3.2.3 Parameter selection

In this section, the parameters of the policies described in Section 3.2.1 will be explained and how to select the proper values will be described.

Order quantity

The order quantity (Q) should be the maximum of the EOQ and the MOQ. An optimal order quantity is where the ordering costs are equal to the holding costs (Axsäter, 2015).

With the EOQ model, the optimal order quantity can be calculated. The aim of the model is minimizing the overall cost (total relevant costs TRC), including holding and ordering cost, such that demand is met (Rezaei, 2014). The total relevant cost can be calculated with Equation 4, where A is the fixed ordering cost, D the demand rate, Q the order quantity, v the variable unit cost, and r the carrying charge (Silver et al., 1998).

$$TRC(Q) = \frac{AD}{Q} + \frac{Qvr}{2} \tag{4}$$

$$Q* = \sqrt{\frac{2 \cdot A \cdot D}{v \cdot r}} = \sqrt{\frac{2 \cdot A \cdot D}{h}} \tag{5}$$

Equation 5 is the formula to calculate the EOQ. Where A is the cost per order, D the demand per year, v the price of the part and r the holding cost rate (van der Heijden, 2020c).

Unfortunately, Equation 5 does not work when there is a quantity discount. Quantity discount means that when the order quantity is sufficiently large, one gets an all-unit discount on the purchase price (Axsäter, 2015).

$$Q' = \sqrt{\frac{2 \cdot A \cdot D}{v' \cdot r}} \tag{6}$$

For example, let Q_0 be the coupling point. Meaning a quantity below Q_0 will cost the normal price, v. When the order quantity is equal to or greater than Q_0, all units will have a discounted price of v'. The optimal solution can be found using two steps:

1. Find the optimal order quantity for Q larger than Q_0 with Equation 6, which results in Q'. The corresponding TRC is calculated with Equation 4, where instead of using v, v' is used.

2. When Q' is smaller than Q_0, the optimal order quantity for the normal price v needs to be determined. This can be done with Equation 5. When TRC(EOQ) is lower than TRC(Q_0), the best order quantity is the EOQ. Otherwise, the best order quantity is Q_0.

When needed, the above procedure can be expanded to multiple coupling points. The best order quantity is always at a coupling point or at a feasible EOQ.

Review period

According to Sezen (2006), the length of the review period (R) is affected by two dimensions:

1. Demand variability: the higher the demand variability, the shorter the review period should be.

2. Average demand: the higher the average demand, the shorter the review period should be.

According to Van der Heijden (2020d), the review period should approximately be the order quantity divided by the annual demand. This corresponds to the second dimension of Sezen (2006). Demand between reviews must be large enough to place a replenishment order every review cycle (Babiloni et al., 2010).

The cycle time can be calculated with Equation 7. The optimal cycle time, which can be seen as the review period, can be calculated by using Equation 8, where $T*$ is the review period, $Q*$ the optimal order quantity, and d the annual demand (Axsäter, 2015).

$$T = \frac{Q}{d} \tag{7}$$

$$T* = \frac{Q*}{d} \tag{8}$$

Undershoot
The undershoot is the amount below the reorder point to which the inventory position has fallen when the order is placed (De Kok et al., 1996). In order words, the undershoot is the difference between the reorder point and the inventory position when an order is placed. An order cannot always exactly be placed on the reorder point, but the formulas are based on the assumption that the order is placed on exactly the reorder point. This is compensated by adding the undershoot to the formulas.

The undershoot can be caused by two factors, the review period or the order size. Figure 3.2 shows how the inventory position and the on-hand inventory behave in a periodic review period. The inventory position is equal to the reorder point between the second and third reorder point. However, an order can only be placed on the second or the third reorder point. In this case, the order is placed on the third reorder point, because that is the first reorder point when the inventory position is equal to or below the reorder point. The undershoot is the difference between the reorder point and the inventory position when the order is placed.
Figure 3.3 shows how the inventory position and the on-hand inventory behave in a continuous review period, with order sizes that can exceed 1 unit. Imagine that the reorder point is 40 units and the current inventory position is 42 units. When an order of 5 units is placed, the inventory position drops to 37 units, which is below the reorder point and thus the undershoot is 3.

In Figure 3.4, an undershoot caused by both the order size and the review period is shown. In the figure, R is the reorder point, y is the undershoot due to the order size, and w is the undershoot caused by the reorder point.

In case of a continuous demand distribution, the expectation and variance of the undershoot can be calculated with Equations (9) and (10) respectively, where Z is the undershoot and Y is the order size (Hill, 1988).

$$E[Z] = \frac{E[Y^2]}{2E[Y]} \tag{9}$$

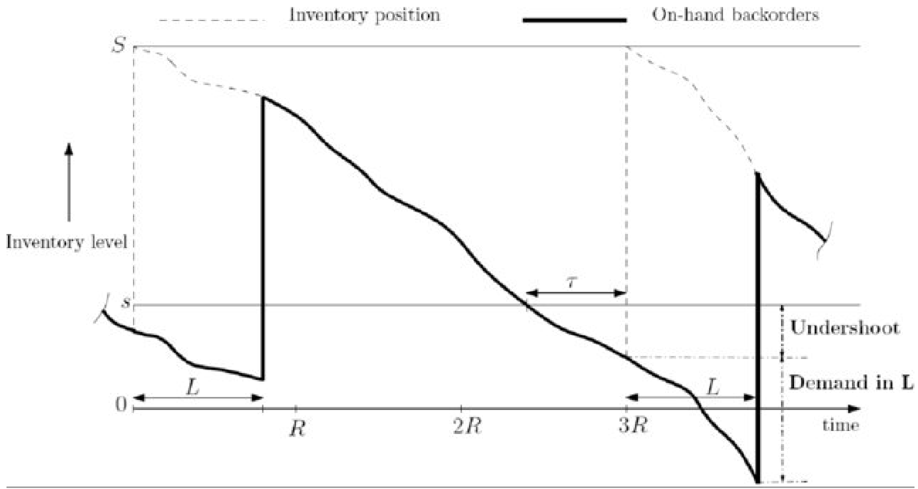


Figure 3.2: Undershoot due to review period (Silver et al., 2009)

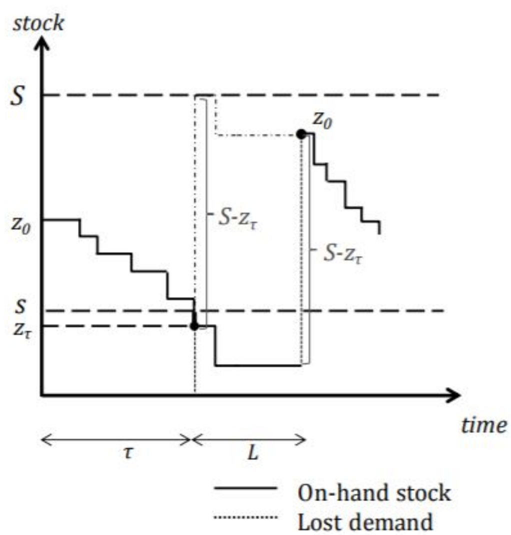


Figure 3.3: Undershoot due to order size (Guijarro et al., 2020)

$$Var[Z] = \frac{E[Y^3]}{3E[Y]} - \left(\frac{E[Y^2]}{2E[Y]}\right)^2 \tag{10}$$

In case the demand distribution is discrete, the expectation and variance of the undershoot can be calculated with Equations (11) and (12) respectively (Hill,

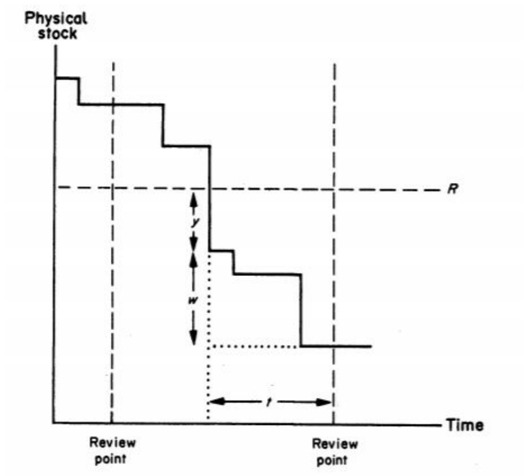


Figure 3.4: Undershoot due to order size and review period (Hill, 1988)

1988).

$$E[Z] = \frac{E[Y^2]}{2E[Y]} - \frac{1}{2} \tag{11}$$

$$Var[Z] = \frac{E[Y^3]}{3E[Y]} - \frac{(E[Y^2])^2}{(2E[Y])^2} - \frac{1}{12} \tag{12}$$

The first, second, and third moment of the demand need to be determined to calculate the expectation and variance of the undershoot. The first moment ($E[Y]$) is the expected value for the demand. The second moment ($E[Y^2]$) can be calculated by rewriting Equation (13) to Equation (14) (Larsen and Marx, 2005).

$$Var(Y) = E[Y^2] - E[Y]^2 \tag{13}$$

$$E[Y^2] = Var(Y) + E[Y]^2 \tag{14}$$

The third moment can be calculated by using moment generating functions (MGF). To get the third moment, the MGF needs to be differentiated three times (see Equation (15)). For example, the third moment of the Normal distribution is given in Equation (16) and the third moment of the Poisson distribution is given in Equation (17). The elaboration of these equations can be found in Appendices A.11 and A.12.

$$E[Y^3] = M_Y^{(3)}(0) \tag{15}$$

$$E[Y^3] = \mu + 3\mu\sigma^2 \tag{16}$$

$$E[Y^3] = \lambda^3 + 3\lambda^2 + \lambda \tag{17}$$

Reorder point
The reorder point (s) should cover the lead time demand (for periodic review this is lead time demand + review period demand). Therefore the reorder point should be equal to the expected lead time demand plus the safety stock (Moon and Choi, 1998). The safety stock is inventory carried to satisfy demand when there is a product shortage, because the demand exceeds the amount forecasted for a given period (Chopra et al., 2013). The safety stock is a safety factor multiplied by the standard deviation of the lead time demand (Ouyang et al., 1996). The calculation of the reorder point for continuous review is given in Equation (18) (Pan et al., 2004) and for the periodic review in Equation (19). Where $\hat{x}$ is the expected demand, k the safety factor and $\sqrt{Var(x)}$ the demand variation (van der Heijden, 2020c). When the undershoot is taken into account, Equations (20) and (21) are used for the continuous and periodic policies respectively. Where $E[Z]$ is the expected undershoot and $Var(Z)$ is the variance of the undershoot.

$$s = \hat{x}_L + k \cdot \sigma_L \tag{18}$$

$$s = \hat{x}_{R+L} + k \cdot \sigma_{R+L} \tag{19}$$

$$s = \hat{x}_L + E[Z] + k \cdot \sqrt{Var(x_L) + Var(Z)} \tag{20}$$

$$s = \hat{x}_{L+R} + E[Z] + k \cdot \sqrt{Var(x_{L+R}) + Var(Z)} \tag{21}$$

The expected demand during lead time (or lead time plus review period for periodic review) is given in Equation 22 (Equation 23). Furthermore, the demand variation during lead time (lead time plus review period) is given in Equation 24 (Equation 25). Where μ is the expected demand, σ the standard deviation of the demand, L the lead time and R the interval between the review periods (Moon and Choi, 1998).

$$\hat{x}_L = \mu \cdot L \tag{22}$$

$$\hat{x}_{L+R} = \mu \cdot (L + R) \tag{23}$$

$$\sigma_L = \sqrt{Var(x_L)} = \sigma \cdot \sqrt{L} \tag{24}$$

$$\sigma_{L+R} = \sqrt{Var(x_{R+L})} = \sigma \cdot \sqrt{L + R} \tag{25}$$

The safety factor (k) can be calculated with Equation 26. Where CSL stands for cycle service level, the probability of not having a stock-out during the replenishment cycle. The higher the cycle service level, the higher the safety factor (van der Heijden, 2020c). For the (R,s,S)-policy, a more complicated formula is needed to calculate the safety factor. Equation (27) is used for the (R,s,S)-policy to calculate the safety factor.

$$k = \phi^{-1}(CLS) \tag{26}$$

$$J_u(k) = \frac{2(1-P_2)\bar{x}_R(S-s+E[Z])}{\sigma^2_{R+L}} \tag{27}$$

Order-up-to-level
The order-up-to-level is the maximum inventory position. If the inventory position drops to or below the order point, it will be replenished to this level. The order-up-to-level minus the reorder point is the order quantity. So when the policy has a reorder point, the order-up-to-level can be calculated with Equation (28). When the undershoot needs to be taken into account, the order-up-to-level can be calculated with Equation (29). Figure 3.5 shows an order cycle when a reorder point is used.

$$S = s + (S - s) = s + EOQ \tag{28}$$

$$S = s + EOQ - E[Z] \tag{29}$$

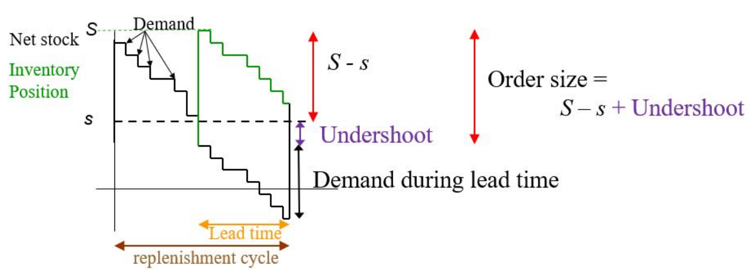


Figure 3.5: Order-up-to-level continuous review (van der Heijden, 2020d)

When no reorder point is used in the policy, the order-up-to level should be calculated differently. This is only the case in a periodic review policy. The order-up-to-level for a periodic review should be sufficient to cover all demand until the arrival of the next replenishment order (see Figure 3.6). In other words, it should cover demand during the lead time plus review period. When no undershoot needs to be taken into account, the order-up-to-level can be calculated with Equation (30). When the undershoot is taken into account, the order-up-to-level is calculated using Equation (31).

$$S = \hat{x}_{L+R} + k \cdot \sqrt{Var(x_{L+R})} \tag{30}$$

$$S = \hat{x}_{L+R} + E[Z] + k \cdot \sqrt{Var(x_{L+R}) + Var(Z)} \tag{31}$$

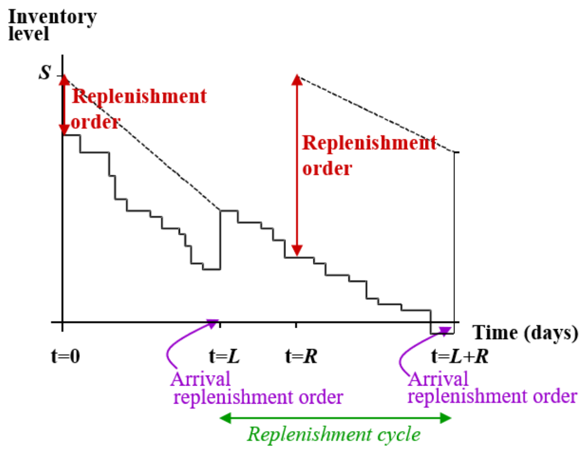


Figure 3.6: Order-up-to-level periodic review (van der Heijden, 2020d)

3.3 Can-order system

Besides the policies described in Section 3.2, there exists another policy, the can-order system. A can-order system is specifically designed to save setup costs like ordering costs. The system is a continuous review system for controlling coordinated items (Silver et al., 1998). The can-order policy is a variation on the continuous review, variable quantity policy

Whenever the inventory position of item i drops to or below the must-order point (s_i), a replenishment order is triggered that will raise the inventory position of item i to its order-up-to-point S_i. When the inventory position of an item in the same family (from the same supplier) drops below its can-order point (c), the replenishment of this item is included. In Figure 3.7, the behavior of an item under the can-order system can be found.

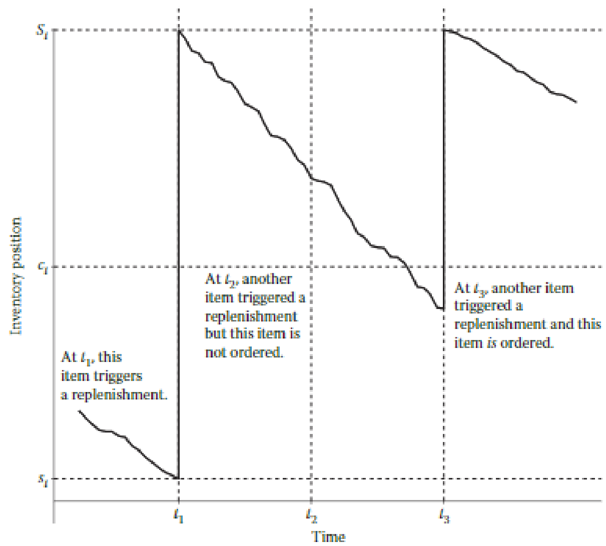


Figure 3.7: Behaviour of an item in a can-order system (Silver et al., 1998)

3.4 Non-stationary demand

The customer demand for Hortec is highly variable. The static policies given in Sections 3.2 and 3.3 may not be suitable considering non-stationary demand. Although most of the models investigated in the literature assume stationary demand, some work considers non-stationary demand. Most of this literature is based on the work of Scarf (1959) and Karlin (1960), who showed that the optimal policy for non-stationary demand is a dynamic (s,S)-policy.

Graves (1999) proposed an adaptive base-stock policy for inventory in a single-item inventory system with a deterministic lead-time and non-stationary demand. He observed that the safety stock required for non-stationary demand is much greater than for stationary demand.

Babaï and Dallery (2006) proposed two forecast-based (dynamic) inventory control policies for a single-stage and single-item system with non-stationary demand. The (s_k,Q)-policy and the (s_k,Q_k)-policy. To compute the parameters of the policies, a sequential approach is used. In this approach, the order quantity is computed first, ignoring the impact of the reorder point. The cycle service level is used to calculate the safety factor.

3.4.1 (s_k,Q)-policy

The (s_k,Q)-policy works almost the same as the static (s,Q)-policy. If the inventory position at the beginning of period k is below the reorder point s_k, a quantity Q is ordered. In the dynamic policy, the reorder point is different for each period. How the inventory of this policy evolves over time is visualized in Figure 3.8. The safety stock is equal to the sum of the replenishment lead time and a single forecast period, because the policy uses a discrete time review. This means that the reorder point (s_k) should be equal to the cumulative forecast and the maximum cumulative forecast uncertainty over this period (L+1). The reorder point is calculated with Equation 34. The first part of the equation ($\sum_{j=1}^{L+1} F_{k+j-1}$) is the cumulative demand forecast over period L+1. The second part is the maximum cumulative forecast uncertainty over period L+1. The standard deviation of the cumulative forecast uncertainty over inverval L+1 ($\sigma_{CFU_{L+1}}$) is assumed to be fixed over all periods. The forecast uncertainty is the difference between the forecast and actual demand (see Equation (32)). With the standard deviation of these forecast errors (σ_{FU}), the standard deviation of the cumulative forecast errors can be calculated with Equation (33) (Babaï and Dallery, 2006). The order quantity Q can be calculated with Equation 35, which is in principle equivalent to the EOQ formula.

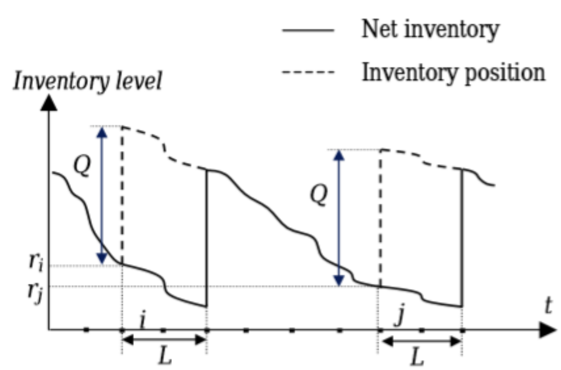


Figure 3.8: The (s_k,Q)-policy (Babaï and Dallery, 2006)

$$e_t = D_t - \hat{x}_t \tag{32}$$

$$\sigma_{CFU_{L+1}} = \sigma_{FU} \cdot \sqrt{L+1} \tag{33}$$

$$s_k = \sum_{j=1}^{L+1} F_{k+j-1} + \phi^{-1}(CSL)\sigma_{CFU_{L+1}} \tag{34}$$

$$Q = \sqrt{\frac{2A\sum_{i=1}^{H} F_i}{hH}} \tag{35}$$

The (s_k,Q_k)-policy is an extension of the (s_k,Q)-policy. In this extension, not only the reorder point is variable, but also the order quantity. How the inventory of the (s_k,Q_k)-policy evolves is visualized in Figure 3.9. Again, the reorder point is calculated with Equation 34. The order quantity for period k (Q_k) is calculated by using a heuristic based on the Silver-Meal heuristic, which is not further discussed into detail.

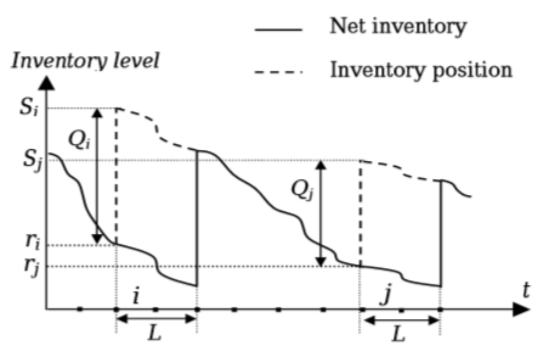


Figure 3.9: The (s_k,Q_k)-policy (Babaï and Dallery, 2006)

The study of Babaï and Dallery (2006) showed that when the forecasts are reliable, it is beneficial to use forecast based inventory control policies. Unfortunately, when the forecast uncertainty is high, the standard deviation of the cumulative forecast uncertainty is also high. Because of this, it is better to use the static (s,Q)-policy when the forecasts uncertainty is high.

3.4.2 Yield and lead time uncertainty

In Babai and Dallery (2006), these dynamic inventory control systems are extended by including yield and lead time uncertainties. Yield uncertainty is the uncertainty that when a quantity is ordered, the received quantity is random. The yield uncertainty only impacts the order quantity. The order quantity increases with the expected yield uncertainty, under the assumption that the yield uncertainty is normally distributed with mean m_{EQ} and standard deviation σ_{EQ} (see Equation 36).

$$Q = \sqrt{\frac{2A\sum_{i=1}^{H} F_i}{hH}} - m_{\text{EQ}} \tag{36}$$

On the other hand, lead time uncertainty only impacts the reorder point. The higher the uncertainty of the lead time, the reorder point will become higher (Song et al., 2010). The reorder point can be calculated with Equation 37. FD_{L_i+1} is the cumulative forecasted demand over period L_i+1 and $\phi_{FD_{L_i+1}}(.)$ the cumulative distribution function. The proof of this equation can be found in the paper of Babai and Dallery (2006).

$$\sum_i P_i \phi_{FD_{L_i+1}}(r_k) = CSL \tag{37}$$

3.4.3 (R,$\mathbf{S_k}$)-policy

Babai and Dallery (2009) introduced dynamic inventory control systems based on the corresponding static inventory control system (R,S), the (R,$\mathrm{S_k}$)-policy. Where R is the review period and S_k the dynamic order-up-to-level. The order-up-to-level at period k is equal to the cumulative forecasts plus the maximal cumulative forecast uncertainty over L+R periods that satisfies the target cycle service level. The order-up-to-level for this policy calculated with Equation 38.

$$S_k = \sum_{j=1}^{L+R} F_{k,k+j-1} + \phi^{-1}(CSL)\sigma_{CFU_{L+R}} \tag{38}$$

Just like for the ($\mathrm{s_k}$,Q)-policy, the (R,$\mathrm{S_k}$)-policy is advantageous to use if the forecasts are reliable. If the forecast uncertainty is high, it is more beneficial to use the static inventory control policy.

3.5 Demand forecasting

A demand forecast is needed to calculate the control parameters of the inventory control policies. The better the forecast, the lower the forecast error and the less safety stock is required.

There are two forecasting approaches (Axsäter, 2015):

- Extrapolation of historical data
  In this approach, the forecast is based on previous demand data which is the most common approach to obtain forecasts. This approach will be explained further in this section in more detail.

- Forecasts based on other factors
  Besides historical data, forecasts can be based on other factors such as promotions or the demand for other items.

Forecasting can be done over a short, medium, or long time horizon. In a short time horizon, only a couple of months of demand is forecasted. In a medium time horizon, demand for a couple of months to 1 or 2 years is forecasted. A couple of years of demand are forecasted in a long time horizon.

The forecast depends on four components. The level, trend, seasonality, and random fluctuations. The latter is random and therefore not predictable. The other three are predictable (van der Heijden, 2020a).

Demand model
The first step in demand forecasting is to choose the demand model. There are three general demand models:

- *Constant model*
  This is the simplest model since it only consists of a level component and random fluctuations. The average of this random fluctuation is assumed to be stable (i.e., mean is zero). The demand in period t can be calculated with the following equation:

  $$x_t = a + \epsilon_t \tag{39}$$

  Where x_t is the demand in period t, a is the average demand per period (i.e., level), and ϵ_t the random fluctuation.

- *Trend model*
  The trend model consists of a level, trend, and random fluctuations. The demand in the trend model can be calculated with the following equation:

  $$x_t = a + b_t + \epsilon_t \tag{40}$$

  Where b_t is the trend in period t.

- *Trend-seasonal model*
  In this model, all the components are included. The demand can be calculated with the following equation:

  $$x_t = (a + bt)F_t + \epsilon_t \tag{41}$$

  Where F_t is the seasonal index in period t.

Forecasting methods
Depending on the demand model, different forecasting methods can be appropriate. Below, some forecasting methods are explained.

Moving average
Moving average is a good method to estimate the parameters of a constant model in a short time horizon. The idea of the moving average method is to focus on the N most recent values of x_t. Since the random fluctuation cannot be predicted, only the level needs to be predicted. The level is calculated as follows:

$$\hat{a}_t = \frac{x_t + x_{t-1} + x_{t-2} + ... + x_{t-N+1}}{N} \tag{42}$$

Single exponential smoothing
The simple exponential smoothing (SES) method is a time series forecasting method for data without a trend or seasonality. In the SES method, the level needs to be estimated with Equation 43.

$$\hat{a}_t = (1 - \alpha)\hat{a}_{t-1} + \alpha x_t \tag{43}$$

Where $\hat{a}_t$ is the estimated level at period t, α is the smoothing factor and x_t is the observed demand data in period t. The forecast of h periods ahead is calculated with Equation 44.

$$\hat{x}_{t+h,t} = \hat{a}_t \tag{44}$$

The smoothing factor α is a value between 0 and 1. The smoothing factor linearly smooths the differences between the predicted and actual demand (Ferbar et al., 2009). A smoothing factor close to 1 means that the most recent observations have a greater influence on the forecast than older observations. A smoothing factor close to 0 means that past observations have a large influence on the forecast.

The SES method is simple to use since it only requires the last demand forecast and the actual demand of the last period. Moreover, the smoothing factor can be easily changed. For this reason, the SES method is a good method for forecasting intermittent demand (Sani and Kingsman, 1997).

Double exponential smoothing
The double exponential smoothing method is an extension of the SES method. The double exponential smoothing method is for time series that include a trend. First the level needs to be predicted with Equation 45.

$$\hat{a}_t = (1 - \alpha)(\hat{a}_{t-1} + \hat{b}_{t-1}) + \alpha x_t \tag{45}$$

The level is used to predict the trend:

$$\hat{b}_t = (1 - \beta)\hat{b}_{t-1} + \beta(\hat{a}_t - \hat{a}_{t-1}) \tag{46}$$

Where $\hat{b}_t$ is the estimated trend at period t and β is the smoothing factor to control the change in trend. When the level and the trend are estimated, the forecast of h periods ahead is calculated with Equation 47.

$$\hat{x}_{t+h,t} = \hat{a}_t + h \cdot \hat{b}_t \tag{47}$$

Holt-Winters' method
This is another variant of the SES method. The Holt-Winters' method can model trend and seasonality. This method generally works well in practice, and

is particularly suitable for producing short-term forecasts (Chatfield and Yar, 1988).

This method can be applied either in an automatic or non-automatic way. In the automatic way, no subjectivity is used during the forecast. In the non-automatic way, the forecaster can use its subjective judgement to improve the forecast (Chatfield and Yar, 1988).

First the level needs to be estimated for period t with Equation 48. Where $\hat{F}_t$ is the seasonal index for period t and P is the number of periods in a season (e.g., P is twelve for monthly seasonality).

$$\hat{a}_t = (1-\alpha)(\hat{a}_{t-1} + \hat{b}_{t-1}) + \alpha(\frac{x_t}{\hat{F}_{t-P}}) \tag{48}$$

The level estimation is used to estimate the trend and seasonal index for period t, with Equations 49 and 50 respectively. Where γ is the smoothing factor for the seasonality. The seasonal index should be normalized such that the sum of all seasonal indexes is equal to P.

$$\hat{b}_t = (1-\beta)\hat{b}_{t-1} + \beta(\hat{a}_t - \hat{a}_{t-1}) \tag{49}$$

$$\hat{F}_t = \gamma(\frac{x_t}{\hat{a}_t}) + (1-\gamma)\hat{F}_{t-P} \tag{50}$$

The demand forecast made at time t of the demand h periods ahead is calculated with Equation 51.

$$\hat{x}_{t+h|t} = (\hat{a}_t + h \cdot \hat{b}_t) \cdot \hat{F}_{t-P+h} \tag{51}$$

3.6 Conclusion

In this chapter, a literature study was performed to answer the second research question. In this section, the second research question is answered by answering the corresponding sub-questions.

What classification methods are available in the literature?
In this literature study, only ABC-classification, XYZ-classification, and a combination of the two are considered. ABC classifies items on their annual usage value and XYZ classified items on their demand uncertainty. The combination of the two takes both aspects into account. Using a combination of the two classification methods would be the best option for Hortec, because there is uncertainty involved in the demand and the current inventory control system already takes the annual usage value into account. This means that the items will be classified in one of the nine categories. The inventory of the items in each category will be controlled differently, which will be discussed in Chapter 4.

What inventory control policies are available in the literature?
There are four common inventory control policies, that can be distinguished in two ways. A distinction can be made between continuous review policies and periodic review policies. Another distinction can be made between the quantities purchased. Each time a purchase order is placed, a fixed quantity or a variable quantity can be purchased. The most suitable control policy depends on the item characteristics and different items can have different control policies. Another policy is the can-order policy, which is designed to safe ordering costs. The can-order policy is a variation on the continuous review, variable quantity policy.

How do the control parameters of the inventory control policies need to be determined?
The control parameters can be calculated with the equations in Section 3.2.3. To be able to use these equations, characteristics of the item are needed. These characteristics include demand per unit of time, lead time and item price.

What methods are described in the literature that deal with non-stationary demand?
Little literature is devoted on non-stationary demand. However, some papers do take non-stationary demand into account. It is possible to adjust the static inventory control policies to make them dynamic. Up till now, the benefits of the dynamic inventory control policies are only investigated for small variations in demand. For this reason, it is interesting to investigate how the static inventory control policies can be adjusted to be able to use them when high variations in demand are experienced.

How can the demand be modeled from using forecasts?
Demand data can be forecasted using historical data. First, the demand model needs to be determined. The demand model is input for choosing an appropriate forecasting method. Simple forecasting methods are available for the constant model. More elaborated methods are available for the trend and trend-seasonal model.

4 Solution design

In this chapter, a proposed inventory control policy for raw materials of annual orders is described. These items account for approximately €250,000, which is almost a quarter of the total inventory value. This chapter answers the third research question: *"What is the most suitable inventory control policy for Hortec and how can it be designed?"*. The goal of the proposed inventory control policy is to make decisions based on the same principle as the current policy, thus on the demand and price of an item. As mentioned in Section 2.2.1, the current inventory control policy is made by experience, the proposed policy will be based on calculations. The demand Hortec faces includes uncertainty, therefore the XYZ-analysis is also added to the proposed inventory control policy.

This chapter is designed according to the flowchart in Figure 4.1. First, the demand of the end products is forecasted in Section 4.1. The historical demand data of end products is used to forecast the demand of these items. In Section 4.2, this forecast is converted to an estimated demand for the raw materials using the bill of materials (BOM). For some end products it is impossible to forecast demand, because these products show low demand (or no demand). For this reason, these products are excluded. The corresponding raw materials are also excluded, because it is also impossible to forecast the demand of the corresponding raw materials. An ABC-XYZ classification is performed in Section 4.3 on the remaining raw materials. This classification will be input for the corresponding inventory control policies, which will be selected in Section 4.4. Section 4.5 explains how the control parameters will be calculated.

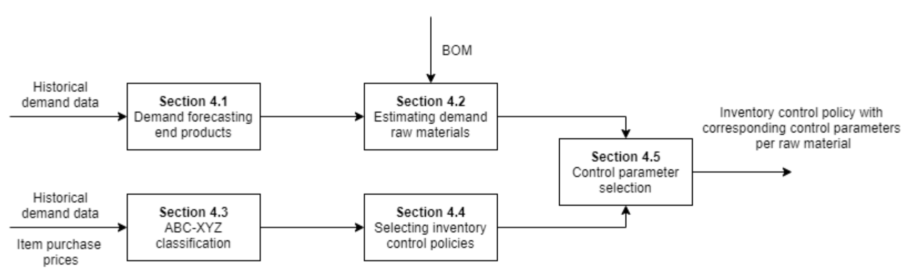


Figure 4.1: Flow diagram of Chapter 4

4.1 Demand forecasting end products

To train the forecasting model, the historical demand data of the years 2014 to 2018 are used. The demand data of 2019 is used to test the model in Chapter 5. First, the demand model needs to be determined for each end product. When the demand model is determined, an appropriate forecasting method can be selected. R software is used for the demand forecasting.

4.1.1 Demand model

The different demand models were explained in Section 3.5. To identify the appropriate demand model for each end product, the trend and seasonality need to be determined. This can be done in multiple ways. One method is using ACF plots (Eni et al., 2015). ACF plots can easily be generated in the R software. In Figure 4.2, an example of a time series plot of a constant line with trend (left) and the correlogram, an autocorrelation plot, of its ACF (right) is shown. As can be seen, the correlogram of a constant line is a linearly decreasing function over time. In Figure 4.3, a time series plot of a discrete sine wave with clear seasonality (left) and the correlogram of its ACF (right) is shown. The correlogram is also a sine wave whose amplitude decreases linearly over time. In Figure 4.4, a time series plot with both trend and seasonality and its ACF plot are shown. A correlogram with a sine wave whose amplitude and center decreases over time signals a trend with seasonality. Unfortunately, it takes a lot of work to analyze the plot for each product separately.

Next to the ACF plots, it is possible to fit the different demand models using the built-in HoltWinters function in R. This function determines the unknown parameters by minimizing the squared prediction error (Kleiber and Zeileis (2008)). The HoltWinters function returns among others the sum of squared errors (SSE). Among the three models, the model with the lowest SSE is selected for each product. Since this method can be automatized, it is more efficient to use then the ACF plots.

According to Eni et al. (2015), the ACF plots are a good method to identify trend and seasonality. However, the use of ACF plots is not preferred, because it is very time consuming to analyse all plots. The ACF plots are compared with the outcome of the HoltWinters function to see if there was a difference. The two methods resulted in the same conclusion. In the remainder of this section, only the results of the HoltWinters function are presented for the sake of simplicity.

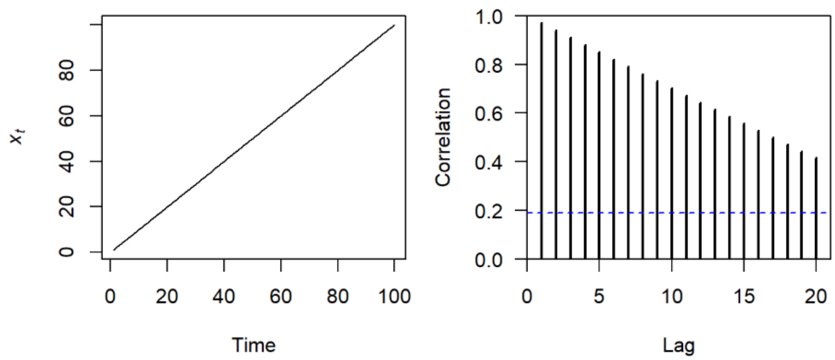


Figure 4.2: Time series and ACF plot with trend (Holmes and Ward (2020))

Trend

A trend in time-series is a systematic increase or decrease per period (Axsäter (2015)). With the HoltWinters function in R, a β-value is determined. The beta is the parameter used to determine the trend component. The HoltWinters function applies some kind of significance, which makes a zero-value for the beta possible. When this beta is a non-zero value, it is assumed that the product has a trend. The number of products with and and the number of products without a trend can be found in Table 4.1.

Table 4.1: Number of products with trend

	Number of products
Trend	64
No trend	113

Seasonality

Seasonality is a predictable pattern in the demand data which recurs every calendar year. Just like for the trend, the HoltWinters function in R is used to identify the seasonality. This function determines a γ-value, which is the parameter used for the seasonal component. The HoltWinters function applies some kind of significance, which makes a zero-value for the gamma possible. When gamma is a non-zero value, the product has seasonality. The number of products with and the number of products without seasonality can be found in Table 4.2.

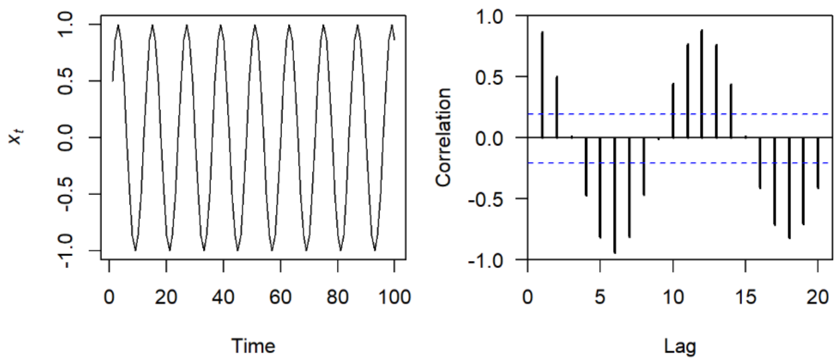


Figure 4.3: Time series and ACF plot with seasonality (Holmes and Ward (2020))

Table 4.2: Number of products with seasonality

	Number of products
Seasonality	58
No seasonality	119

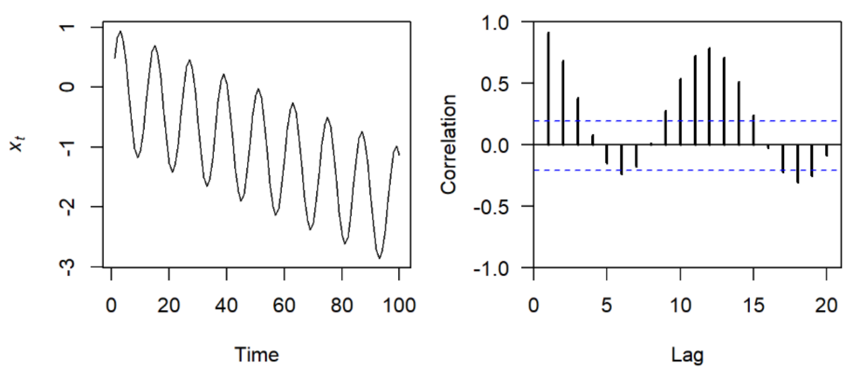


Figure 4.4: Time series and ACF plot with trend and seasonality (Holmes and Ward (2020))

Demand model

The demand model can be determined with help of the trend and seasonality. The number of products with a constant model, trend model, and trend-seasonal model can be found in Table 4.3.

Table 4.3: Number of products with constant, trend, and trend-seasonal model

	Number of products
Constant model	71
Trend model	48
Trend-seasonal model	58

4.1.2 Forecasting method

For the constant model, the simple exponential smoothing method will be used to forecast the demand. This is the most simple method and a constant model is easy to forecast. For the trend model, double exponential smoothing (i.e., exponential smoothing with trend) will be used to forecast the demand. The Holt-Winters' method will be used to forecast the trend-seasonal models.

4.1.3 Forecasting parameters

When the forecasting methods are clear, the forecasting parameters need to be defined. First, the initial parameters for the level and the trend (if the product has a trend) need to be estimated. The initial parameters for the level and trend can be calculated with Equation (52) and Equation (53) respectively (Silver et al. (2016)), where x_t is the deseasonalized demand, n the number of observations and P the number of periods in a cycle. In our case, the periods are months and therefore P is equal to twelve with a cycle of one year. The equations are based on linear regression.

$$\hat{a}_0 = \sum_{t=1}^{n} \frac{x_t}{n} - \frac{\hat{b}(n+1)}{2} \tag{52}$$

$$\hat{b}_0 = \frac{\sum_{i=1}^{n} t x_t - (\frac{n+1}{2}) \sum_{i=1}^{n} x_t}{n(n^2-1)/P} \tag{53}$$

The x_t in Equations 52 and 53 is the deseasonalized demand, so before we can calculate the initial parameters, we need to determine the deseasonalized demand. This is done with the centered moving average (CMA). When P is an even number, as in our case, the CMA is calculated as the average of the two adjacent uncentered moving averages. The CMA can be calculated with

Equation 54, where $\bar{y}_t$ is the centered moving average at period t, y_t is the demand at period t, and P is the number of periods in a cycle.

$$\bar{y}_t = \frac{y_{t-(P/2)} + 2y_{t-(P/2)+1} + ... + 2y_t + ... + 2y_{t+(P/2)-1} + y_{t+(P/2)}}{2p} \tag{54}$$

When the $\bar{y}_t$ for each time period is calculated, the ratio per time unit needs to be calculated. The ratio is calculated by dividing the actual demand of that period by the CMA (ratio = $y_t/\bar{y}_t$). The average of the ratios of the same period (e.g., month July) gives the unadjusted seasonal factor per period. In the end, the seasonal factors should sum up to the number of periods (in this case twelve), so the factors need to be adjusted. The demand can be deseasonalized by dividing the actual demand with the adjusted seasonal factors (van der Heijden (2020b)).

4.1.4 Forecasting

The initial parameters and the forecasting method are used to obtain a forecast of twelve months (in this case March 2019 till March 2020) in the R software. Examples of the forecasting plots for each forecasting method can be found in Figures 4.5-4.7. The blue line is the forecast and the gray area indicates a 95% confidence interval. When a product does not have a trend or seasonality, the forecast is a flat line. This is shown in Figure 4.5. When a product has a trend, the forecast is a linear increasing or decreasing line. This can be seen in Figure 4.6. The forecast of a product with seasonality is fluctuating, see Figure 4.7.

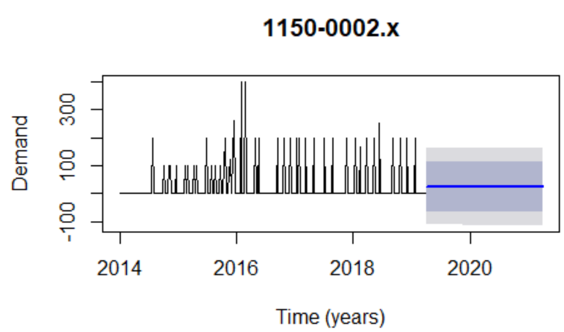


Figure 4.5: Forecast simple exponential smoothing

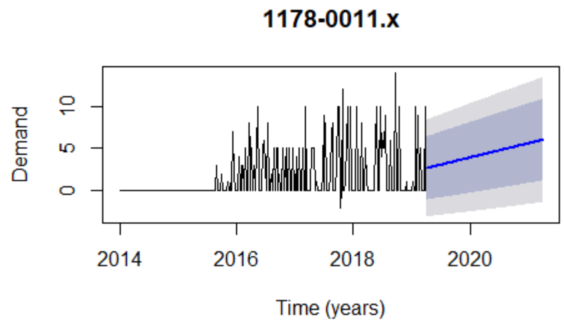


Figure 4.6: Forecast double exponential smoothing

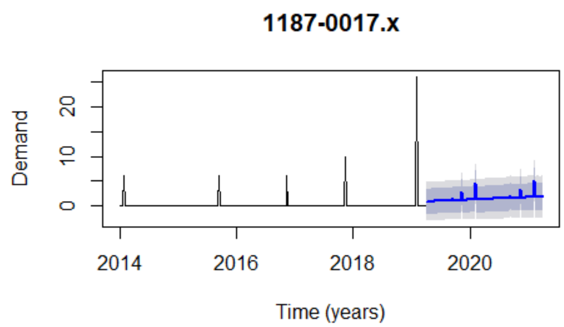


Figure 4.7: Forecast Holt-Winters

4.2 Estimating demand raw materials

The demand forecast of the end products can be used to determine the demand forecast of the raw materials. The quantity of the raw materials needed to produce and end product is known, this quantity is multiplied with the demand forecast of the end product. This gives the demand forecast for the raw materials per product. If a raw material is needed for multiple products, these demand forecasts are added. In total, there are 675 raw materials needed to produce the 177 end products. For those 675 raw materials, an inventory control policy will be developed further in this research. In the remainder of this thesis, the raw materials will be called items.

4.3 Item classification

In this section, the items are classified according to the ABC-XYZ analysis described in Section 3.1.3. The ABC-analysis is solely based on the annual usage value and the XYZ-analysis is based on the demand uncertainty. So the ABC-XYZ analysis is based on both the annual usage value as well as the demand uncertainty.

First, the ABC-analysis is performed for the raw materials of annual orders. After that, the items are classified according to the XYZ-analysis. Table 4.4 shows the number of items in each category.

Table 4.4: Number of items classified by ABC-XYZ analysis

	X	Y	Z	Total
A	25	25	11	61
B	15	54	27	96
C	64	180	274	518
Total	104	259	312	675

4.3.1 Applying ABC-analysis

The annual demand and price of an item are needed for the ABC-analysis. Historical data of the last year is used to calculate the annual demand. The purchase price is used as item price since the raw materials do not have a selling price.

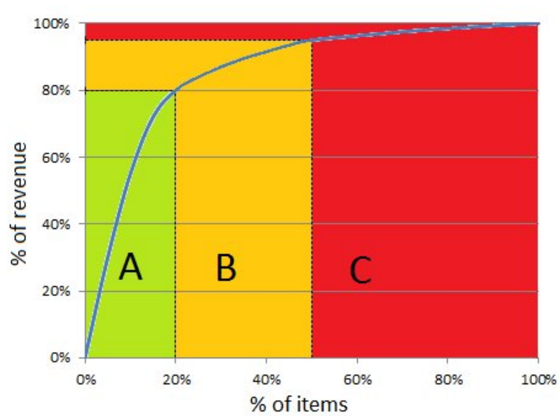


Figure 4.8: Pareto curve ABC-analysis

The annual demand is multiplied with the price, which results in the annual usage value. The values are sorted from largest to smallest and the cumulative annual usage value is calculated. The items are classified according to the Pareto curve (see Figure 4.8). A-items are items of which the annual usage value is the highest. The A-items are approximately 20% of the total items and account for 80% of the total annual usage value. B-items are the items with moderate demand and the next 30% of the items which account for 15% of the total annual usage value. The last 50% of the items are C-items and have low demand. C-items account for the last 5% of the total annual usage value (Pandya[1] and Thakkar (2016)).

As can be seen from Table 4.4, A small part (less than 10%) of the raw materials are classified as A-items. These items overall have a high demand rate, which is clear from Appendix A.7. Most of them have a demand rate higher than 2000 units. The items with a lower demand rate are relatively expensive. Fourteen percent of the raw materials are classified as B-items. These items have an average demand and price. The remaining raw materials (almost 80%) are classified as C-items. Those items have low to zero demand and/or are relatively cheap.

4.3.2 Applying XYZ-analysis

For the XYZ-analysis, the demand per period is needed to calculate the standard deviation and the average of the demand. With these two, the coefficient of the variance can be calculated. A month is taken as period, because the annual orders are placed at most once a month. Historical demand data of the last five years is used to calculate the demand per period. The average demand per month for each year is calculated. An example is given in Appendix A.8.

As mentioned in Section 3.1.2, the raw materials with a CV lower than 0.5 are classified as X-items. Raw materials with a CV between 0.5 and 1 are Y-items and raw materials with a CV higher than one are Z-items. X-items are items that have relatively constant demand. The ability to schedule or obtain a correct predication is very high. Y-items are items that show substantial fluctuations in demand because of trend and/or seasonality factors. The ability to schedule or obtain a correct prediction is medium. Z-items are items with very irregular demand. The ability to schedule or correctly predict is very low (Pandya[1] and Thakkar (2016)).

Table 4.4 shows that most of the C-items are classified as Z-items. This makes sense because these items mostly show intermittent demand, which is low and unpredictable. What also can be seen is that least of the A-items are classified as Z-items. Most A-items have a high demand rate, which makes it better to predict their demand. When the item is expensive, A-items also can have a low demand rate.

4.4 Selecting inventory control policies

In this section, inventory control policies are chosen for each classification category based on the characteristics of the category. The policies linked to each category can be found in Table 4.5. Below, the reasoning will be given.

The A-items are, as mentioned in Section 4.3, the most important items and the inventory of these products should be closely monitored. Therefore, the inventory of the A-items should be monitored with the most sophisticated policies, like (s,S) and (R,s,S). The C-items on the other hand, are the least important items. The demand and price of C-items are relatively low. One does not want to invest a lot of time in monitoring the inventory of these items, but stock-outs needs to be avoided for these items. So, for C-items a simple policy is good enough, like (s,Q).

X-items are easy to forecast. Therefore, the forecast-errors should be small resulting in small safety stocks. Because these items are easy to forecast and have relatively small demand variability, a static inventory control policy is appropriate for these items. Furthermore, a periodic review policy has more advantages than a continuous review policy because of the low demand variability. The demand variability of Y-items is somewhat larger than of X-items. However, as mentioned in Section 3.1.2, the variability can be predicted to a certain extend. Therefore, dynamic policies will work best for Y-items. The Z-items have high demand variability. To find out whether the static or dynamic policy works best for high demand variability, both policies are simulated. Because of the high demand variability, a continuous review policy is used.

Table 4.5: Chosen policies for each category

	X	Y	Z
A	(R,s,S)	(s_k,S)	(s,S) & (s_k,S)
B	(R,S)	(s_k,Q)	(s,Q) & (s_k,Q)
C	(s,Q)	(s,Q)	(s,Q) & (s_k,Q)

4.5 Calculation of the control parameters

In Chapter 3, the formulas needed to calculate the control parameters were provided. Section 4.5.1 explains how the control parameters for each classification can be calculated. In Section 4.5.2 the demand distribution is determined to be able to calculate the expectation and variance of the undershoot. The calculations and input values for the order quantity are explained in Section 4.5.3.

4.5.1 Calculations control parameters

For the (R,s,S)-policy, the review period, reorder point, and the order-up-to-level need to be calculated. When we look at Table 4.5, the (R,s,S)-policy is selected for the AX-items only. The AX-items are the most important items and need to be monitored carefully. Therefore, a small review period is chosen. The items are delivered at most once a week, so we take a review period of one week for the (R,s,S)-policy. The undershoot can be ignored since demand arrives maximum once a week and thus the probability of two orders arriving in the same week is negligible. The reorder point (s) is calculated with Equation (19). The safety factor (k) in this Equation is calculated with Equation (27). The order-up-to-level (S) is calculated with Equation (28).

The (s_k,S)-policy is the dynamic variant of the (s,S)-policy. The reorder point (s_k) is calculated with Equation (34), the standard deviation of the cumulative forecast errors can be calculated with Equation (33). The order-up-to-level is calculated with Equation (28).

For the (s,S)-policy, the reorder point (s) and the order-up-to-level (S) needs to be calculated. The reorder point is calculated with Equation (20) and order-up-to-level is calculated with Equation (29).

The (R,S)-policy is only selected for the BX-items. The review period (R) can be calculated with Equation (8) and the order-up-to-level with Equation (30).

For the (s_k,Q)-policy, the reorder point and order quantity need to be calculated. This is done with Equations (34) and (5) respectively.

For the (s,Q)-policy, the reorder point (s) is calculated with Equation (18). The order quantity (Q) is the economic order quantity, which can be calculated with Equation (5).

Table 4.6: Control parameter formulas per policy

Policy	Reorder point	Order-up-to-level	Review period	Order quantity
(R,s,S)	$s = \hat{x}_{R+L} + k \cdot \sigma_{R+L}$	$S = s + (S - s) = s + EOQ$	1 week	$Q* = \sqrt{\frac{2 \cdot A \cdot D}{v \cdot r}}$
(s_k,S)	$s_k = \sum_{j=1}^{L+1} F_{k+j-1} + \phi^{-1}(CSL)\sigma_{CFU_{L+1}}$	$S = s + (S - s) = s + EOQ$	N/A	$Q* = \sqrt{\frac{2 \cdot A \cdot D}{v \cdot r}}$
(s,S)	$s = \hat{x}_L + E[Z] + k \cdot \sqrt{Var(x_L) + Var(Z)}$	$S = s + EOQ - E[Z]$	N/A	$Q* = \sqrt{\frac{2 \cdot A \cdot D}{v \cdot r}}$
(R,S)	N/A	$S = \hat{x}_{L+R} + k \cdot \sqrt{Var(x_{L+R})}$	$T* = \frac{Q*}{d}$	N/A
(s_k,Q)	$s_k = \sum_{j=1}^{L+1} F_{k+j-1} + \phi^{-1}(CSL)\sigma_{CFU_{L+1}}$	N/A	N/A	$Q* = \sqrt{\frac{2 \cdot A \cdot D}{v \cdot r}}$
(s,Q)	$s = \hat{x}_L + k \cdot \sigma_L$	N/A	N/A	$Q* = \sqrt{\frac{2 \cdot A \cdot D}{v \cdot r}}$

4.5.2 Demand distribution

The expectation and variance of the undershoot need to be determined to be able to calculate the control parameters of each policy. To do this, the demand distribution of each item needs to be clear. The demand distribution represents the demand of the random fluctuations. As mentioned in Section 3.2.3, the undershoot is the amount below the reorder point to which the inventory position has fallen when the order is placed. The undershoot is caused by the review period and/or the order size.

According to Ramaekers et al. (2008), the Normal distribution is frequently used for fast moving items and the Poisson distribution is a good fit for low demand. As a rule of thumb, Silver and Peterson (1985) recommend the Normal distribution for items when the average lead-time demand is higher than ten units. However, according to Silver et al. (2016), the Normal distribution is only appropriate when the coefficient of variation of demand is lower or equal to 0.5. Otherwise, the Gamma distribution is a better fit.

To conclude, when the average lead-time demand is lower than 10, the item is slow moving and the Poisson distribution will be used to simulate the random fluctuations. When the average lead-time demand is higher than 10 and the coefficient of variation of demand is higher than 0.5, the Gamma distribution is used. Otherwise, the Normal distribution will be applied. The average lead-time demand and coefficient of variation of demand over R+L are calculated with Equations (55) and (56) respectively.

$$\hat{x}_{R+L} = \hat{x} * (R + L) \tag{55}$$

$$CV_{R+L} = \frac{\sigma_{R+L}}{\hat{x}_{R+L}} \tag{56}$$

As mentioned in Section 3.2.3, to calculate the variance of the undershoot, the third moment needs to be calculated. The third moment of the Poisson, Normal, and Gamma distributions can be calculated with Equations (16), (17), and (57) respectively.

$$E[Y^3] = -\frac{\alpha(\alpha + 1)(\alpha + 2)}{(-\beta)^3} \tag{57}$$

4.5.3 Economic order quantity

The economic order quantity (EOQ) is used to determine the optimal order quantity. The EOQ is the optimal order amount that minimizes the holding and ordering cost and is calculated with Equation (5). To calculate the EOQ, we need to know the annual demand, the cost per order, the item price, and the holding cost.

The historical demand is known and the most recent annual demand is used to determine the annual demand. In Section 5.4, a simulation study is performed for the year 2019. The EOQ for 2019 is calculated with demand data of 2018. To calculate the EOQ, the cost per order needs to be determined. Unfortunately, this is not known for each item. The total annual order cost per supplier and the total annual orders per supplier are known. The total annual order costs are divided by the total annual orders to obtain the order cost per supplier. The price of each item is known and can be found in the ERP system used by Hortec. Different kinds of prices are known per item, of which the purchase price is used to calculate the EOQ. The average carrying cost (r) is unknown. The average carrying cost lies between 20 and 30 percent. To calculate the EOQ, a carrying cost of 22% is used. This approach is used to calculate the EOQ for all items.

As explained in Section 2.2.2, Hortec has to deal with MOQs for certain items. When the EOQ is lower than the MOQ, the MOQ is used as order quantity instead of the EOQ.

4.6 Conclusion

In this chapter, a solution model was designed. To answer the second research question, in this section the corresponding sub-questions are answered.

How are the raw materials of annual orders classified with the new classification method?
The items are classified according to the ABC-XYZ analysis. The ABC-analysis is based on the annual usage value and the XYZ-analysis is based on the demand uncertainty. The number of items per category can be found in Table 4.7.

Table 4.7: Number of items classified by ABC-XYZ method

	X	Y	Z	Total
A	25	25	11	61
B	15	54	27	96
C	64	180	274	518
Total	104	259	312	675

What policy is suitable for each classification?
In Table 4.8, the policies chosen for each category are shown. For the Z-items, both the static and dynamic policies are simulated. In Chapter 5, the results of these policies will be discussed.

Table 4.8: Policy of each category

	X	Y	Z
A	(R,s,S)	(s_k,S)	(s,S) & (s_k,S)
B	(R,S)	(s_k,Q)	(s,Q) & (s_k,Q)
C	(s,Q)	(s,Q)	(s,Q) & (s_k,Q)

How can the existing data be used to determine the control parameters of the inventory control policy?
The historical demand data of the end products of approximately four years is used to forecast the demand of the corresponding raw materials. The price and demand of the raw materials is used to classify each item, this classification is used to determine the most appropriate inventory control policy.

How can demand forecasting be used to determine the control parameters of the inventory control policy?
To calculate the control parameters, the expectation and variance of the demand during lead time (for periodic review lead time plus review period) is needed. The demand forecast and BOM are used to determine these values. The demand is forecasted per week because items can be delivered at most once a week. The lead times and review periods are also determined in weeks.

5 Solution test

In this chapter, the results of the proposed policy are analyzed and the model is tested. This chapter answers the fourth research question: "*What is the effect and improvement of the proposed inventory control policy after implementation?*". First, the values for the control parameters are calculated in Section 5.1. In Section 5.2, the simulation model used to get results is explained. The results of the model are presented and analyzed in Section 5.4. The model is in Section 5.5 tested to see if the results are realistic and the model is resistant to changes. A small description of how the proposed model can be implemented is given in Section 5.6. The conclusion can be found in Section 5.7.

5.1 Values of the control parameters

In this section, the control parameters for each item are calculated. The inventory control policies were determined in Section 4.4 and the formulas needed per policy are described in Section 4.5. The decision is made to use cycle service levels between 80% and 99%. The service levels can be found in Table 5.1. The more important (according to the ABC-classification) and the easier to forecast (according to the XYZ-classification) an item is, the higher the cycle service level. In Section 5.5.2, an analysis is performed to test how the results are affected when the service levels are changed.

Table 5.1: Target service level per category

	X	Y	Z
A	0.99	0.97	0.95
B	0.97	0.95	0.9
C	0.95	0.9	0.8

The values for the control parameters for each item can be found in Appendix A.14. Below, the parameters of the A-items are shortly analyzed. In Section 5.4, the control parameters and corresponding results of some items are explained in more detail. The higher the annual demand, the higher the control parameters of the AX-items. This can be explained by the fact that the expected demand is higher when the annual demand is higher. The control parameters of the AX-items depend on the expected demand. The AY-items have dynamic reorder points. For most items, the start and end reorder points differ a lot, which means that there is a significant trend and/or seasonality. Both a static and a dynamic policy are used for the AZ-items. The two policies show for a lot of items a big difference in the reorder points. The reorder point of the static policy depends partly on the undershoot. The expectation and variance of the undershoot are for some items very high, which results in a high reorder point. The reorder point of the dynamic policy depends partly on the standard deviation of the forecast error. When this value is high, the reorder point is also high. For the dynamic policy, the start reorder point is for most items (almost) the same as the end reorder point. So the trend and/or seasonality do not have a large influence on the control parameters.

5.2 Simulation model

The model designed in Chapter 4 will be tested in this chapter. To test the model, a simulation model is created which is explained in this section. The simulation is performed in Excel and is deterministic, so it contains no randomness. The goal of the simulation is to determine the average inventory level with the proposed policy. The simulation is performed over the period April 2019 till March 2020, each week representing one period. The simulation model is discreet, since each period a decision needs to be made. The decision is how much to order that period. The decision is dependent on the control parameters and the inventory position. The control parameters are calculated in Section 5.1. The inventory position is dependent on the inventory level (i.e., net stock), the order release, the demand, and the number of items in the pipeline. The simulation needs the inventory level of the first period and the demand of all periods as input. The inventory level of the first of April 2019 is used as inventory level of the first period. The weekly demand during the period April 2019 till March 2020 is used as demand of all periods. In the end, the average inventory levels can be calculated. The average inventory level is multiplied with the unit price to calculate the average inventory value of the proposed policy. This value is compared to the current inventory value, which is obtained from the ERP system.

5.2.1 Input parameters

To be able to perform the simulation, the starting inventory levels need to be known. The actual inventory levels are used to obtain a realistic simulation. The inventory levels of the first of April 2019 is used because that is the first week of the simulation. Besides the actual inventory levels, the realized demand of the period April 2019 till March 2020 is used in the simulation. The realized demand is also known in the ERP system. To determine whether or not to order and the order size, the control parameters calculated in Section 5.1 are used. To know when the purchase orders arrive, the lead time is also an input value for the simulation model.

5.2.2 Output parameters

The most important outputs of the simulation model are the average inventory levels. The average inventory level per item is the summation of the inventory levels over all periods divided by 53 (the number of periods). The average inventory level is multiplied with the unit price to get the average inventory value. The average inventory value of the proposed policy can be compared to the current average inventory value. The other outputs of the proposed policy are:

- Which period to order and how much
- Number of weeks with stockout
- Number of orders placed
- Inventory value improvement

5.2.3 Simulation visualization

An example of the simulation for one item is visualized in Figure 5.1. The first twelve weeks of the simulation model of item 399.002455 are performed. This item has a reorder point of 143 units. In the second period, the inventory position drops below the reorder point and an order is placed. The order size is the order-up-to-level minus the inventory position. The order-up-to-level of item 399.002455 is 286 units. The purchase lead time of this item is one period, so the order is delivered in the third period. The next order is placed in period ten.

	Time (weeks)	1	2	3	4	5	6	7	8	9	10	11	12
Start day	Net Stock	200	200	50	285,931	285,931	285,931	235,931	235,931	185,931	185,931	85,9308	285,931
	Order Release	0	0	235,931	0	0	0	0	0	0	0	200	0
	Demand	0	150	0	0	0	50	0	50	0	100	0	0
End day	Pipeline	0	0	0	0	0	0	0	0	0	0	0	0
	Order Release	0	235,931	0	0	0	0	0	0	0	200	0	0
	Inventory position	200	50	285,931	285,931	285,931	235,931	235,931	185,931	185,931	85,9308	285,931	285,931

Figure 5.1: Simulation item 399.002455 first 12 weeks

5.3 Forecast accuracy

During this research, demand forecasting was performed in Section 4.1. Demand forecasting was needed to calculate the control parameters which is done in Section 5.1. The more accurate the forecast, the better the control parameters. Therefore, we need to test the forecast accuracy. In Table 5.2, the average value of four forecast accuracy measures per classification group are shown. In Appendix A.15, the variance is shown. The forecast accuracy measures per item can be found in Appendix A.16.

To analyze the forecast, we used four forecast accuracy measures. The Mean Absolute Percentage Error (MAPE) is calculated per item by Equation 58, where A_i is the actual demand of period i, F_i the demand forecast of period i, and n the total number of periods. MAPE is one of the most common measures. Unfortunately, our demand contains a lot of zeros. The MAPE does not perform well with a lot of extremes, so also not with zeros. When the actual demand is zero, the error will be divided by zero which is not possible. So when the actual demand is zero, we used an APE ($\left|\frac{A_i-Fi}{Ai}\right|$) of zero. So the MAPE is way lower because of all the zeros.

$$MAPE = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{A_i - Fi}{Ai}\right| \tag{58}$$

Table 5.2: Average forecasting accuracy measures

	MAPE(%)	MAD	MSE	Bias
AX-items	16	278	3837581	-161
AY-items	11	53	156650	-23
AZ-items	9	43	11298	-8
BX-items	18	177	324146	-31
BY-items	8	213	60168764	-163
BZ-items	7	32	20151	-4
CX-items	18	99	381380	-31
CY-items	9	37	173546	-22
CZ-items	21	24	2424450	-10

Another measure we used is the Mean Absolute Deviation (MAD). The MAD is calculated with Equation 59 and is a good measure to analyze the forecast error of a single item since it does not make a distinction between high- and low-volume products. So the high-volume products probably have a higher MAD.

$$MAD = \frac{1}{n}\sum_{i=1}^{n}|(A_i - Fi)| \tag{59}$$

The third measure we used is the Mean Squared Error (MSE). The MSE is almost the same as the MAD, but instead of the absolute value, the squared value is used (see Equation 60). The MSE is sensitive to large errors. All errors are squared, so the large errors become even larger. So the MSE puts more weight on the larger errors.

$$MSE = \frac{1}{n}\sum_{i=1}^{n}(A_i - Fi)^2 \tag{60}$$

The last measure we used is the bias. The bias can be used to identify over-forecasting or under-forecasting. In over-forecast, the forecast is higher than the actual demand. In under-forecast, the forecast is lower than the actual demand.

$$Bias = \frac{1}{n}\sum_{i=1}^{n}(F_i - A_i) \tag{61}$$

Table 5.2 shows that the AX- and BY-items have relatively high values for the MAD and MSE. The bias for these items is very low, which means that the forecast of the items is (way) lower than the actual demand. The forecast of the BZ-items is good in comparison with the other items when we look at the accuracy measures. The bias is for all categories negative, which means that there is under-forecast.

5.4 Results

To test the policy proposed in Chapter 4, the simulation study explained in Section 5.2 is performed. The current and the proposed policies can be compared using different performance measures. The first performance measure we used is the inventory value since this is the measurement Hortec currently uses. The average inventory levels over the 53 weeks for both policies are determined. The total inventory value is calculated with Equation (62), where c_n is the cost of item n and I_n is the average inventory level of item n. The inventory value per item or per classification group can be calculated by changing the summation index so only the corresponding items are used.

$$Total\ inventory\ value = \sum_{n=1}^{675} c_n * I_n \tag{62}$$

The results of this measurement can be found in Table 5.3. Three policies show negative performance, meaning the current policy performs better in this simulation than the proposed policy. The classification categories with X-items all show a negative performance. The inventory value of the AX-items for the proposed policy is a little bit higher than the inventory value with the current policy. The main reason for this increase is the demand forecast. The BX-items show an increase in the inventory value of €4276 with the proposed policy. The main reason for this increase is that the order-up-to-level for some items is too high. The reason CX-items show an increase in inventory value is that some items have a realized demand of 0 in 2019, while they did have demand in 2018. Although some classes show negative performance, the total inventory value shows a reduction of € 32,591 with the proposed policy. The current inventory value of raw materials for annual orders is approximately €250,000 (see Section 2.4). A reduction of € 32,591 is thus a reduction of approximately 13%.

A paired t-test is performed to determine whether the differences in Table 5.3 are statistically significant. The rightmost column of Table 5.3 shows the p-value of the t-test. The T-test says whether or not two inventory values are statistically significantly different, so the test is two-tailed. There is a statistically significant difference if the p-value is lower than 0.025. A p-value larger than 0.025 means no statistically significant difference between the inventory values.

Most classification categories have a p-value higher than 0.05. This means that there is no statistically significant difference and the increase or decrease in inventory value is due to coincidence. All B-items, the CY-items, and CZ-items have a p-value lower than 0.025. These difference between the proposed and current policy for those items is statistically significant.

Table 5.3: Total change in inventory value

Category	Difference	P-value
AX-items	-€319	0.491
AY-items	€6043	0.108
AZ-items	€2799 (static) €6640 (dynamic)	0.268 (static) 0.171 (dynamic)
BX-items	-€4276	**0.014**
BY-items	€6031	**0.000**
BZ-items	€5829 (static) €4768 (dynamic)	**0.000 (static)** **0.000 (dynamic)**
CX-items	-€1014	0.180
CY-items	€3966	**0.001**
CZ-items	€9691 (static) €9484 (dynamic)	**0.000 (static)** **0.000 (dynamic)**
Total	€32591	

The second performance measure is the total annual cycle-inventory and ordering cost, consisting of the holding and ordering cost. This can be calculated with Equation (63). Where C is the total annual cycle-inventory and ordering cost, Q the lot size, H the holding cost per unit per year, D the annual demand, and S the ordering cost per order. The results of the second measurement are visualized in Table 5.4. The proposed policy can reduce the total annual cycle-inventory and ordering cost with €6108.

$$C = \frac{Q}{2} * H + \frac{D}{Q} * S \tag{63}$$

In the following sections, the results per classification category are explained.

Table 5.4: Improvement in total annual cycle-inventory and ordering cost

Category	Total annual cycle-inventory and ordering cost improvement	P-value
AX-items	1710	0.295
AY-items	1660	0.072
AZ-items	€196 (static) €1323 (dynamic)	0.428 (static) 0.191 (dynamic)
BX-items	-€1019	0.029
BY-items	-€1579	**0.002**
BZ-items	-€2854 (static) -€3257 (dynamic)	**0.006 (static)** **0.002 (dynamic)**
CX-items	951	**0.004**
CY-items	2933	**0.000**
CZ-items	€3386 (static) €2621 (dynamic)	0.388 (static) 0.413 (dynamic)
Total	€6108	

5.4.1 AX-items

All AX-items are categorized under the (R,s,S)-policy. The results of this policy can be found in Appendix A.17.1. The proposed policy increases the total inventory value of the AX-items with €319 (see Table 5.3). The goal of this research is to decrease the inventory value, so this policy does not performs worse compared to the current policy. The corresponding p-value (see Table 5.3) is lower than 0.05, so the difference in inventory value between the current and proposed policy is due to coincidence.

In Table 5.5, the items with the highest increase in inventory value are presented. In total, these items cause the inventory value to increase with more than €17000. All three items have a high reorder point in comparison to the annual demand. The reorder point of item 399.002382 is even higher than the annual demand. A high reorder point is closely related to a high average inventory level, which leads to high inventory value. The high reorder points are caused by a high expected demand. For example, item 399.002383 has an expected demand during lead time of 104 units, while the annual demand in 2018 was 'only' 98 units. This would mean that a positive trend is forecasted. The reorder point should be equal to the expected demand plus a safety stock. This means the average inventory of the proposed policy is much higher than the current policy. The expected demand is derived from the demand forecast, so a more accurate forecast would lead to a more realistic and hopefully better result.

Table 5.5: AX-items with highest increase in inventory value

Item number	335.000761	365.000334	399.002383
Inventory control policy	(R,s,S)	(R,s,S)	(R,s,S)
Review period (weeks)	1	1	1
Reorder point	76	59	119
Order-up-to-level	88	89	144
Average inventory level proposed policy	68	64	109
Average inventory level current policy	48	44	64
Difference in inventory value	-€ 3843	-€ 1821	-€ 11499
Number of stockouts	0	0	0
Number of orders placed	4	2	3
Realized annual demand (2019)	68	68	68
Annual demand (2018)	98	98	98
Lead time (weeks)	6	5	10
Expected demand (R+L)	63	51	104
Variance demand (R+L)	13	5	21
Expected undershoot	10	10	10
Variance undershoot	2	1	2

Table 5.6 shows the forecast accuracy measures of item 399.002383. The most important accuracy measure for this item is the bias since this measure gives an insight into whether the item is over- or under-forecasted. The bias of item 399.002383 is 9.15 which is positive. A positive bias means over-forecast and thus the forecast is higher than the actual demand.

Table 5.6: Forecast accuracy measures 399.002383

Item	MAPE (%)	MAD	MSE	Bias
399.002383	2	9	98	9.15

In Appendix A.18.1, the results of the total annual cycle-inventory and ordering cost for the AX-items can be found. The holding and ordering costs of the proposed policy are compared to the current policy, see Table 5.7. For three items, the ones in Table 5.5, the annual cycle-inventory and ordering cost increased. For the other AX-items, these costs decreased with the proposed policy. This resulted in a total decrease of € 1710 for the AX-items with the proposed policy compared to the current policy. The ordering costs are the reason for this decrease. Overall, the holding costs increased a bit (€ 70), which was already concluded based on the inventory value. The ordering cost decreased a lot. The ordering cost of the current policy were € 3190, the ordering cost of the proposed policy would be € 1410.

Table 5.7: Cycle inventory cost AX-items

Holding cost proposed policy	€14370
Ordering cost proposed policy	€1410
Total inventory cost proposed policy	€15780
Holding cost current policy	€14300
Ordering cost current policy	€3190
Total inventory cost current policy	€17490

5.4.2 AY-items

The results of the AY-items under the proposed policy, (s_k,S), can be found in Appendix A.17.2. A negative performance can be seen for 11 of the 25 items. For these items, the inventory value increases. In Table 5.8, the two items with the worst performance are shown. Item 399.002428 has a high reorder point compared to the expected demand during lead time. Furthermore, the order-up-to-level is higher than the annual demand, so the demand for a whole year is bought at once, resulting in high inventories. The average inventory of the proposed policy is almost the same as the annual demand. Item 399.001521 has a high lead time resulting in a high reorder point. However, the (start) reorder point is 150 units more than the expected demand. This means that the safety stock is 150 units, which is very large. The high safety stock is due to the high standard deviation of the forecast error. The safety stock is calculated by multiplying the safety factor and the standard deviation of the forecast error (see Equation 34). The safety factor is approximately 4 because of the service level of 97%. The realized demand in the simulation is smaller (802 units) than the demand a year before (1102 units). But the demand forecast showed a positive trend, because the end parameters are higher than the start parameters. Although eleven items have a negative performance with the proposed policy, the policy can decrease the total inventory value with €6043.

The results of the holding and ordering cost for the AY-items can be found in Appendix A.18.2. For 8 items, these costs have increased. For most items, this is due to the high(er) holding cost. As can be seen in Table 5.4, with the proposed policy, the total cycle inventory cost for the AY-items can be decreased with €1660. Overall, both the holding and the ordering cost decrease with the proposed policy, as can be seen in Table 5.9.

5.4.3 AZ-items

For the AZ-items, a dynamic and static policy of the (s,Q)-policy are performed and the results are in Appendix A.17.3. Both policies have four items with negative performance. When we use the inventory value as measure, the dynamic policy is better. However, this policy has more stockouts. Remarkable is that in the static policy, 41 orders are placed for item 350.002469. This means that it is

Table 5.8: AY-items with highest increase in inventory value

Item number	399.001521	399.002428
Inventory control policy	(s_k,S)	(s_k,S)
Start reorder point	507	100
Start order-up-to-level	531	208
End reorder point	755	125
End order-up-to-level	779	234
Average inventory level proposed policy	259	160
Average inventory level current policy	199	83
Difference in inventory value	-€1762	-€2013
Number of stockouts	3	0
Number of orders placed	12	2
Realized annual demand	802	180
Annual demand (2018)	1102	165
Lead time (weeks)	18	5
Expected demand (L)	346	37
Stdev forecast error	40	16

Table 5.9: Cycle inventory cost AY-items

Holding cost proposed policy	€9556
Ordering cost proposed policy	€1330
Total inventory cost proposed policy	€10886
Holding cost current policy	€10885
Ordering cost current policy	€1660
Total inventory cost current policy	€12545

purchased almost every week (only 12 weeks without an order). The proposed policy works best for item 399.002741. It shows a big improvement in inventory value and zero stockouts, in both the static and dynamic policy. The proposed policy improves the total inventory value with €6651 for the dynamic policy and €2799 for the static policy. The item with the best performance and the item with the worst performance can be found in Tables 5.10 and 5.11 for the static and dynamic policy respectively. Item 399.000063 has the worst performance, with an increase in inventory value of €2427 and €2204 for the static and dynamic policies respectively. The reorder points of this item are high relatively high compared to the expected demand. The difference in inventory level for the proposed and current policy is small, only seven units for both policies. This means that the item is very expensive, approximately €350.

The results for the total annual cycle-inventory and ordering cost for the AZ-items can be found in Appendix A.18.3. For the static policy, 5 out of 11 items

Table 5.10: Important results AZ-items static

Item number	399.000063	399.002741
Inventory control policy	(s,S)	(s,S)
Reorder point	11	37
Order-up-to-level	25	31
Average inventory level proposed policy	14	27
Average inventory level current policy	7	40
Difference in inventory value (euro)	-2427	3135
Number of stockouts	2	0
Number of orders placed	1	3
Realized annual demand	12	20
Annual demand (2018)	12	10
Lead time (weeks)	8	4
Expected demand (L)	3	14
Variance demand (L)	0	1
Expected undershoot	1	7
Variance undershoot	3	17

Table 5.11: Important results AZ-items dynamic

Item number	399.000063	399.002741
Inventory control policy	(s_k,S)	(s_k,S)
Start reorder point	9	14
Start order-up-to-level	24	15
End reorder point	9	22
End order-up-to-level	24	23
Average inventory level proposed policy	14	15
Average inventory level current policy	7	40
Difference in inventory value	-€2204	€6073
# out of stock	2	0
# orders	1	9
Realized annual demand	12	20
Annual demand (2018)	12	10
Lead time	8	4
Expected demand (L)	3	14
Stdev forecast error	2	0

have an increase in holding and ordering costs. The static policy can reduce these costs with €196. The ordering costs are doubled with the proposed policy. The holding costs decreased with €616. For the dynamic policy, 4 out of 11 items show an increase in holding and ordering costs. This policy can reduce the costs with € 1323. In Table 5.12, the total holding and ordering costs of the AZ-items can be found. For both proposed policies, the ordering costs increased a bit. However, the holding cost showed a larger decrease causing the annual cycle-inventory and ordering cost to decrease.

Table 5.12: Cycle inventory cost AZ-items

	AZ-static	AZ-dynamic
Holding cost proposed policy	€ 4196	€ 3349
Ordering cost proposed policy	€ 770	€ 490
Total inventory cost proposed policy	€ 4966	€ 3839
Holding cost current policy	€ 4812	€ 4812
Ordering cost current policy	€ 350	€ 350
Total inventory cost current policy	€ 5162	€ 5162

5.4.4 BX-items

As discussed in Section 4.4, the BX-items have the (R,S)-policy. The results of this policy can be found in Appendix A.17.4. From the 15 BX-items, the inventory value of 8 items increased. The proposed policy increases the total inventory value of the BX-items with € 4276. The results of the four most interesting items can be found in Table 5.13. The first two items, item 350.000176 and item 350.001374, show a lot of stockouts. So, either the review period should be lower or the order-up-to-level should be higher. The review period depends on the order quantity, so when the order quantity is lower, the review period will also be lower. The order-up-to-level depends on the forecast. The order-up-to-level is already high because of the high variance of demand. The proposed policy increased the inventory value of the items in the two righmost columns of Table 5.13. To inventory level of the proposed policy is for both items approximately four times the inventory level of the current policy. For item 399.001968, the realized annual demand for 2019 is 68 units, which is way lower than the 3120 units in 2018. For item 399.002483, only one order is placed during the simulation, but this order is placed in the first week. The order-up-to-level of this item is very high because the expectation and variance of the demand forecast are very high.

The results of the total annual cycle-inventory and ordering cost for the BX-items can be found in Appendix A.18.4. The proposed policy will increase the holding and ordering cost with € 1019 because 9 out of 15 items have an increase. As can be seen from Table 5.14, the highest increase is due to the holding cost. The holding cost of the current policy is € 1369, the holding cost with the proposed policy is € 2738. The increase in holding costs was expected due to the increase in inventory value. The ordering cost decreased with € 350 when using the proposed policy. Unfortunately, this does not compensate for

Table 5.13: Results interesting BX-items

Item number	350.000176	350.001374	399.001968	399.002483
Inventory control	(R,S)	(R,S)	(R,S)	(R,S)
Review period (weeks)	21	12	8	77
Order-up-to-level	1266	930	123	63325
Average inventory level proposed policy	876	770	110	45860
Average inventory level current policy	3122	1146	26	10283
Difference in inventory value	€281	€132	-€1341	-€889
Number of stockouts	25	18	0	0
Number of orders placed	3	2	6	1
Realized annual demand (2019)	5590	2720	68	32100
Annual demand (2018)	5650	3120	3120	28800
Lead time (weeks)	0	7	7	1
Expected demand (R+L)	1099	930	105	56864
Variance demand (R+L)	1724	0	21	2593016

Table 5.14: Cycle inventory cost BX-items

Holding cost proposed policy	€2738
Ordering cost proposed policy	€330
Total inventory cost proposed policy	€3068
Holding cost current policy	€1369
Ordering cost current policy	€680
Total inventory cost current policy	€2049

the high holding cost.

5.4.5 BY-items

The results of the proposed policy can be found in Appendix A.17.5. From the 54 BY-items, 9 have a negative performance. Furthermore, 18 items have some stockouts. Most of the items have a couple of stockouts. Of them, 6 items show stockouts in more than 10 weeks. The item with the worst performance and the item with the best performance can be found in Table 5.15. When the proposed policy is implemented, the total inventory value of the BY-items can be reduced by €6031.

In Appendix A.18.5, the total annual cycle-inventory and ordering cost for each BY-item can be found. The holding and ordering cost of 18 out of 54 items are higher with the proposed policy. For 4 items, this is due to higher holding costs. 8 items have higher ordering costs as reason. 6 items have higher holding and ordering costs. From Table 5.16 shows that the holding costs are reduced with €1279 and the ordering costs with €300. So in total, the proposed policy can

Table 5.15: Results interesting BY-items

Item number	315.000563	350.000735
Inventory control policy	(s_k,Q)	(s_k,Q)
Start reorder point	0	276
Order quantity	32	255
End reorder point	0	261
Average inventory level proposed policy	159	492
Average inventory level current policy	64	1030
Difference in inventory value	-€ 445	€ 592
Number of stockouts	12	0
Number of orders placed	1	2
Realized annual demand (2019)	260	1023
Annual demand (2018)	260	934
Lead time (weeks)	12	0
Forecast lead time	0	15
Stdev forecast error	0	76

reduce the total annual cycle-inventory and ordering cost with € 1579 for the BY-items.

Table 5.16: Cycle inventory cost BY-items

Holding cost proposed policy	€ 4315
Ordering cost proposed policy	€ 1830
Total inventory cost proposed policy	€ 6145
Holding cost current policy	€ 5594
Ordering cost current policy	€ 2130
Total inventory cost current policy	€ 7724

5.4.6 BZ-items

For the BZ-items, the static and dynamic policies are simulated to see which one performs better. In Appendix A.17.6, the results of both policies can be found. Both policies perform well when the inventory value is the measurement. For the dynamic policy, 2 out of 27 have a negative improvement. For the static policy, this is 0 out of 27 items. For both policies, seven items have a lot of stockouts (more than 40 weeks). So the reorder point for these items is way to low. In Table 5.17, the two items with the highest improvement with the static policy are shown. In Table 5.18, the items with a negative performance and the item with the best performance with the dynamic policy are shown. The total inventory value can be reduced by € 5829 for the static policy and € 4768 for the dynamic policy.

Table 5.17: Results interesting BZ-items static

Item number	335.000409	365.000008
Inventory control policy	(s,Q)	(s,Q)
Reorder point	1049	2
Economic order quantity	1044	10
Average inventory level proposed policy	1584	10
Average inventory level current policy	7283	53
Difference in inventory value	€1140	€887
Number of stockouts	0	0
Number of orders placed	2	1
Realized annual demand (2019)	5200	20
Annual demand (2018)	4000	19
Lead time (weeks)	6	3
Expected demand (L)	951	2
Variance demand (L)	670	0

Table 5.18: Results interesting BZ-items dynamic

Item number	315.001444	365.000008	399.002423
Inventory control policy	(s_k,Q)	(s_k,Q)	(s_k,Q)
Start reorder point	628	2	200
Economic order quantity	1154	10	422
End reorder point	714	3	229
Average inventory level proposed policy	1111	10	424
Average inventory level current policy	936	53	209
Difference in inventory value	-€28	€887	-€86
Number of stockouts	0	0	0
Number of orders placed	3	1	3
Realized annual demand (2019)	3748	20	1253
Annual demand (2018)	3748	19	1253
Lead time (weeks)	0	3	0
Expected demand (L)	111	2	37
Stdev forecast error	150	0	47

The results for the total annual cycle-inventory and ordering cost of the BZ-items can be found in Appendix A.18.6. 15 of the 27 items have higher holding and ordering costs with the proposed policy. In total, the static policy increases these costs with €2854 for the BZ-items. The ordering cost of the current policy is €820, the proposed policy has an ordering cost of €4930. This is a significant increase. The holding costs, however, are decreased with €1256. The dynamic policy also has 15 items with higher holding and ordering costs. The total holding and ordering costs are even higher than the static policy, namely an increase of €3257. The ordering costs are €5100. The corresponding holding costs are €1987, which is a decrease of €1023. After analyzing why the ordering costs are this high, we found out that the EOQ is for some items 0 because the demand for those items was 0 in 2018. The order quantity became 1 or larger because the MOQ is at least 1. So for these items, every time the inventory position drops to or below the reorder point, only one unit was ordered.

Table 5.19: Cycle inventory cost BZ-items

	BZ-static	BZ-dynamic
Holding cost proposed policy	€1754	€1987
Ordering cost proposed policy	€4930	€5100
Total inventory cost proposed policy	€6684	€7087
Holding cost current policy	€3010	€3010
Ordering cost current policy	€820	€820
Total inventory cost current policy	€3830	€3830

5.4.7 CX-items

All CX-items are simulated with the (s,Q)-policy. 22 out of 64 items have an increase in inventory value and the total inventory value increases with €1014 with the proposed policy. This is mainly due to the items 399.001221 and 365.000357. The results of these items can be found in Table 5.20. The items have an increase in inventory value of €466 and €1111 respectively. Both items have no demand during the simulation, but an order is placed for both. With the current policy, no order is placed. All other items have a small positive or negative improvement between €0 and €100.

In Appendix A.18.7, the results for the annual cycle-inventory and ordering cost of the CX-items can be found. 12 out of 64 items have higher annual cycle-inventory and ordering cost with the proposed policy. Only two of them have a higher increase than €20. From Table 5.21 we see that the holding cost are increased but the ordering has decreased. In total, the policy can reduce the total annual cycle-inventory and ordering cost of the CX-items with €951.

5.4.8 CY-items

The results of the proposed policy for the CY-items can be found in Appendix A.17.8. The inventory value of 65 items (out of 180) increased. With the proposed policy, the total inventory value can be reduced with €3966. Most items have (almost) no stockout, but item 399.000266 has in 23 weeks a stockout. The

Table 5.20: Results interesting CX-items

Item number	365.000357	399.001221
Inventory control policy	(s,Q)	(s,Q)
Reorder point	22	18
Order quantity	58	10
Average inventory level proposed policy	63	21
Average inventory level current policy	12	12
Difference in inventory value	-€1111	-€466
Number of stockouts	0	0
Number of orders placed	1	1
Realized annual demand (2019)	0	0
Annual demand (2018)	114	114
Lead Time	5	4
Expected demand (L)	17	11
Variance demand (L)	1	3

Table 5.21: Cycle inventory cost CX-items

Holding cost proposed policy	€1109
Ordering cost proposed policy	€400
Total inventory cost proposed policy	€1509
Holding cost current policy	€860
Ordering cost current policy	€1600
Total inventory cost current policy	€2460

reason for the stockouts is that the order sizes are larger than the order quantity (Q). Item 340.000137 has the highest reduction in inventory value (€445) because the item has no demand and therefore the proposed average demand is zero.

The results of the holding and ordering cost can be found in Appendix A.18.8 for each CY-item. From the 180 CY-items, 44 items have higher holding and ordering costs. Table 5.23 shows that the holding and ordering costs are lower with the proposed policy. The total cost can be reduced by €2933.

5.4.9 CZ-items

The proposed policies for the CZ-items work well, which can be seen in Appendix A.17.9. The inventory value of 41 out of 274 items for the dynamic policy and 42 out of 274 items for the static policy have a higher inventory value. Most items have a small difference in inventory value. The total inventory value can be reduced with €9489 and €9691 for the dynamic and static policy respectively.

Table 5.22: Results interesting CY-items

Item number	340.000137	375.000295	399.002150
Inventory control policy	(s,Q)	(s,Q)	(s,Q)
Reorder point	0	20	69
Order quantity	59	2634	1828
Average inventory level proposed policy	0	2520	1142
Average inventory level current policy	156	14816	430
Difference in inventory value	€ 445	€ 235	-€ 70
Number of stockouts	0	0	0
Number of orders placed	0	1	1
Realized annual demand (2019)	0	12349	660
Annual demand (2018)	0	14316	660
Lead Time (weeks)	1	0	0
Expected demand (L)	0	1	26
Variance demand (L)	0	26	134

Table 5.23: Cycle inventory cost CY-items

Holding cost proposed policy	€ 2398
Ordering cost proposed policy	€ 1540
Total inventory cost proposed policy	€ 3938
Holding cost current policy	€ 3111
Ordering cost current policy	€ 3760
Total inventory cost current policy	€ 6871

There are, however, items with high stockout rates (more than 30 weeks).
In Table 5.25, the item with the worst improvement and two items with very good performance with the dynamic policy are shown. Item 335.000411 has the worst improvement, i.e. highest increase in inventory value. However, this increase is € 155, which is relatively low. Item 345.000327 has an inventory value decrease of € 597. No order is placed because the item has no demand in 2019. However, with the current policy, two orders are placed resulting in a higher inventory level. Item 350.001279 has a lot of stockouts, namely in 36 weeks. The results of the same items with the static policy can be found in Table 5.24.

With both proposed policies, the total annual cycle-inventory and ordering costs are increased by approximately € 10,000. This is due to the high ordering cost. As mentioned in Section 5.4.6, some items have an EOQ of 0. For these items, the order size is always 1 which is way to low for the items, especially C-items.

Table 5.24: Results interesting CZ-items static

Item number	335.000411	345.000327	350.001279
Inventory control policy	(s,Q)	(s,Q)	(s,Q)
Reorder point	1671	1	4
Order quantity	2113	24	1
Average inventory level proposed policy	2219	11	7
Average inventory level current policy	800	27	31
Difference in inventory value	-€155	€597	€44
Number of stockouts	0	0	36
Number of orders placed	1	0	38
Realized annual demand (2019)	0	0	47
Annual demand (2018)	1750	0	134
Lead time (weeks)	6	1	3
Expected demand (L)	1176	1	3
Variance demand (L)	20524	0	0

Table 5.25: Results interesting CZ-items dynamic

Item number	335.000411	345.000327	350.001279
Inventory control policy	(s_k,Q)	(s_k,Q)	(s_k,Q)
Start reorder point	873	1	3
Order quantity	2113	24	1
End reorder point	2159	1	5
Average inventory level proposed policy	2219	11	7
Average inventory level current policy	800	27	31
Difference in inventory value	-€155	€597	€45
Number of stockouts	0	0	36
Number of orders placed	1	0	38
Realized annual demand (2019)	0	0	47
Annual demand (2018)	1750	0	134
Lead time (weeks)	6	1	3
Expected demand (L)	845	1	3
Stdev forecast error	8	0	0

5.5 Model test

The proposed model should be tested to see if the results are realistic and if the model is robust to changes. In Section 5.5.1, the proposed model is verified and validated. A sensitivity analysis is performed in Section 5.5.2.

Table 5.26: Cycle inventory cost CZ-items

	CZ-static	CZ-dynamic
Holding cost proposed policy	€ 6475	€ 6520
Ordering cost proposed policy	€ 12630	€ 13350
Total inventory cost proposed policy	€ 19105	€ 19870
Holding cost current policy	€ 7484	€ 7485
Ordering cost current policy	€ 1930	€ 1930
Total inventory cost current policy	€ 9414	€ 9414

5.5.1 Verification & validation

In this section, the simulation study is verified and validated to check whether it is realistic and representative for the current situation. Verification is used to ensure that the proposed model is correctly implemented with respect to the conceptual model. Validation is used to ensure that the model represents the reality accurately (Law et al. (2000)).

Verification
To verify the proposed model, the model needs to be checked if it meets all requirements. To do so, we will check if the MOQ is used correctly, the forecast is non-negative, and whether the orders are placed in the right period.

To determine the order quantity, the MOQ needs to be taken into account. The MOQ is the minimum quantity which can be ordered. The EOQ is used as the order quantity for most items. However, when the EOQ is smaller than the MOQ, the order quantity is equal to the MOQ. So, the MOQ is taken into account in the proposed model.

To determine the control parameters, the demand forecast was used. To get non-negative control parameters, the forecast also needs to be non-negative. This was not the case at first. For this reason, the negative demand forecast was set to zero. After this transformation, all control parameters were non-negative (See Appendix A.14).

To check whether the simulation works correctly, we need to check if the orders are placed on the correct moment and if the order size is of the right size. A small part of the simulation of item 399.002455 can be found in Figure 5.1. The item has an (R,s,S)-policy with a one week review period, the reorder point is equal to 143 units and the order-up-to-level is 286 units (both rounded to integers). When we look at Figure 5.1, we see that the inventory position is lower than the reorder point in the second week and an order is placed this week. The size of the order is the difference between the order-up-to-level and the inventory position. So, the simulation works properly.

Validation
To validate the proposed model, the control parameters should be validated. Unfortunately, no control parameters are used in the current situation. So we can not compare these. To validate the control parameters, the average inventory levels of the current and proposed policy are compared.

The goal of this research was to decrease the inventory values. Most of the time, the inventory values of the proposed policy are smaller than the inventory levels of the current policy. Unfortunately, the dimensions of the items are unknown. So we cannot say with certainty that the items fit in the warehouse. However, when we look at Table 5.27, we see that with the proposed model fewer items are in stock. We assume that the A-items need the most space per item because those are the most expensive items. All A categories have lower total inventories with the proposed model. The BX-, CX- and CX-items have more items in stock with the proposed model than with the current model. However, overall the proposed model has lower inventories, so we assume that it fits in the warehouse. Furthermore, as mentioned in Section 1.4, this research is initiated because of the high inventory value and not because the inventories do not fit in the warehouse.

The simulation is made realistic by using real data from the previous year instead of probability distributions. The starting inventory value of 31 March 2019 is used, since the first data point of the simulation is 1 April 2019. Furthermore, the demand data of April 2019 till March 2020 is used.

Table 5.27: Total units in inventory

Category	Proposed policy	Current policy
AX	40098	107329
AY	8107	18145
AZ	4754	6638
BX	135640	55616
BY	129721	145647
BZ	9454	17320
CX	200967	183563
CY	281649	232452
CZ	248476	423177
Total	929145	1189887

5.5.2 Sensitivity analysis

The proposed model should be robust enough to withstand changes. To check if the model is indeed robust, changes are made to check whether the results changes a lot. Below, the results of these changes are outlined.

Change start value for inventory

The results in Section 5.4 are obtained by performing a simulation. For this simulation, a starting value for the inventory was needed. Real data was used as starting value. However, the inventory is probably higher than required. Another simulation is performed with other starting values for the inventory, to see what the impact on the results is. In Table 5.28, the results are given with a starting inventory of zero.

Table 5.28: Total change in inventory value start inventory 0

Category	Inventory value improvement	Mean stockout in days
AX-items	€1104	9.12
AY-items	€10205	5.08
AZ-items	€12265 (static) €8713 (dynamic)	6.81 (static) 5.72 (dynamic)
BX-items	-€1909	11.33
BY-items	€10296	5.30
BZ-items	€11094 (static) €10074 dynamic	19.70 (static) 19.37 (dynamic)
CX-items	-€850	0.65
CY-items	€5661	1.33
CZ-items	€16550 (static) €16457 (dynamic)	5.58 (static) 5.54 (dynamic)
Total	€64416	

The proposed policy works even better when the starting inventory is equal to zero. However, this is not completely fair because the starting value of the current policy still has a high value.

Change cycle service level

For the different classification categories, different service levels are used. However, the service levels of the current policy are unknown. So the simulation is performed again, but with a service level of 99% and another simulation with a service level of 80% for all items. In Tables 5.29 and 5.30, results are shown if all service levels were 99% and 80% respectively.

As expected, the inventory values increase in comparison with the results in Section 5.4.1. The inventory value will increase with approximately €20,000 in comparison with the current situation. A service level of 99% does not work well for the CY-items, because the inventory value will increase with more than €60000. The service level has a high impact on the CY-items.

An 80% service level performs well. The inventory value can be reduced with almost €50,000, while the inventory value can be reduced with approximately €25,000 when using the service levels from Table 5.1. A lower service level means a lower safety stock. A lower safety stock results in fewer inventories so it is no surprise that an 80% service level has a lower total inventory value. However, a lower safety stock means more stockouts, which is a disadvantage.

Table 5.29: Total change in inventory value CSL 99%

Category	Inventory value improvement (CSL 99%)	Mean stockout in days (CSL 99%)
AX-items	-€638	5.08
AY-items	€5838	2.28
AZ-items	€9303 (static) €6588 (dynamic)	4.18 (static) 3.81 (dynamic)
BX-items	-€4294	4
BY-items	€5201	2.67
BZ-items	€5809 (static) €4726 dynamic	16.78 (static) 16.22 (dynamic)
CX-items	-€1014	0.28
CY-items	-€61713	7.62
CZ-items	€10051 (static) €9824 (dynamic)	3.69 (static 3.66 (dynamic)
Total	-€19867	

Table 5.30: Total change in inventory value CSL 80%

Category	Inventory value improvement (CSL 80%)	Mean stockout in days (CSL 80%)
AX-items	€4227	5.4
AY-items	€7893	3.24
AZ-items	€9500 (static) €7041 (dynamic)	4.18 (static) 4 (dynamic)
BX-items	-€4151	4.07
BY-items	€6031	2.70
BZ-items	€5839 (static) €4768 dynamic	16.78 (static) 16.22 (dynamic)
CX-items	-€1014	0.29
CY-items	€4012	0.91
CZ-items	€15846 (static) €15640 (dynamic)	4 (static) 4 (dynamic)
Total	€48183	

Static policy for Y-items
From Table 5.3, we see that the static policy works in most cases better for the Z-items than the dynamic policy. Therefore, it would be good to investigate how static policies perform for the Y-items. As the CY-items already have a static policy, only the AY-items and BY-items need to be tested. The results can be found in Table 5.31.

When we compare the improvement in inventory value with the results of the dynamic policy, we can conclude that the static policy performs better. When

Table 5.31: Static policy Y-items

Category	Policy	Improvement inventory value	Mean stockout
AY	(s,S)	€17796	5.56
BY	(s,Q)	€9952	5.94

the dynamic policy is only used for the AZ-items and the static policy is used for all other items, the proposed policy can reduce the inventory value with almost €50,000. This is 20% of the total inventory value.

Policy selection per item

In Section 3.1 was decided that the items are classified to choose an inventory control policy for each class. However, it may be better to determine the optimal policy per item by doing trial-and-error. For the AX-, BX-, CX-, and BZ-items, the simulation is performed with trial-and-error. All policies are simulated for each item and the policy with the best performance (i.e., lowest inventory value) is selected per item.

In Table 5.32, the improvement in inventory value and the best performing inventory control policy are shown. Remarkable is that for only 2 of the 25 items th chosen inventory control policy was equal to the selected policy in Section 4.4. Selecting the best performing policy can reduce the total inventory value of the AX-items with €4313. When the (R,s,S)-policy is selected for all AX-items, the inventory value will increase with €319 (see Table 5.3). The average number of weeks of stockout is somewhat higher when the best policy is selected (according to the inventory value). The average number of weeks of stockout for the (R,s,S)-policy is 5.08 weeks, for the best selected policy this is 7,76 weeks. The results for the BY-items can be found in Appendix A.19. The total improvement in inventory value is €18120 compared with the current situation with an average stockout of 6,91 weeks. The (s_k,Q)-policy selected in Section 4.4 has a inventory value improvement of €6031 compared to the current situation and 3 weeks stockout.

Selecting an inventory control policy per item is also tested for the BX- and CX-items, since those are the categories with a negative performance. For the BX-items, the (R,S)-policy selected in Section 3.2.2 is for 2 of the 15 items the best policy. For two other items, the (s,S)-policy performs the best. For 8 items, the (s,Q)-policy is the best fit. For the other three items, all policies perform the same, so there is no preference there. Choosing a policy per item can reduce the inventory value with €1205, instead of an increase of €4276 when selecting a policy per category. For the CX-items, the selected (s,Q)-policy is for 25 of the 64 items the best policy. The (R,S)-policy is for 11 items the best performing policy. 2 items perform best with the (R,s,S)-policy. The remaining 26 items perform equal for all policies. Choosing a policy per item increases the inventory value with €859, instead of an increase of €1014 when selecting a

Table 5.32: Results AX-items best policy selection

Item number	Improvement (euro)	Best inventory control policy
395.000226	293	(R,s,S)
365.000029	412	(R,s,S)
345.000163	270	(R,S)
399.001703	423	(R,S)
399.001705	160	(R,S)
395.000384	3974	(R,S)
335.000692	385	(s,Q)
370.000206	703	(s,Q)
365.000334	-1739	(R,S)
335.000761	-3312	(s,Q)
399.001967	564	(s,Q)
399.002383	-11226	(s,Q)
315.000062	849	(R,S)
399.002455	1286	(s,Q)
399.002456	2441	(s,Q)
399.002457	832	(R,S)
399.002461	2175	(s,Q)
399.002462	2704	(s,Q)
399.002463	259	(R,S)
399.002464	76	(s,Q)
399.002465	231	(s,Q)
399.002467	401	(R,S)
399.002468	547	(R,S)
399.002470	1521	(R,S)
399.002471	86	(R,S)

policy per category.

For comparison, the BZ-items are also tested to see whether the selected (s,Q) policy performs best for most items. For 17 of the 27 items, the (s,Q)-policy performs best. For 3 items, the (R,S)-policy works better than the other policies. For the remaining 7 items, all policies perform equally. Selecting a policy per item can reduce the inventory value with €6065. Selecting a policy per category reduces the inventory value with €5829.

Selecting the policy per item works for all tested categories better than selecting the policy per category. For the AX-, BX, and CX-items, it often occurred that a policy other than the selected one performed best. For the BZ-items, the selected policy almost always performed best. For all items, it is better to try all policies and select the best performing policy. However, selecting the best policy is time-consuming because four policies needs to be simulated and the best policy need to be selected. A trade-off needs to be made to determine whether it is beneficial to select the best policy or use a pre-selected policy.

5.6 Implementation

The proposed model is designed in Excel. The model determines the control parameters for a given inventory control policy. Besides the control parameters, the model can determine what policy is most applicable in terms of inventory value. Purchasing is done in the ERP-system Hortec uses. In this system, the characteristics of all items are stored. The inventory control policy and corresponding control parameters can be added to this list.

5.7 Conclusion

Which raw material inventory control policy is most suitable for each classification category?
A simulation is performed in Section 5.4 with dynamic policies for the Y-items. For the Z-items, both the static and dynamic policies were simulated. The AZ-items have lower inventory values when using the dynamic policy. The static policy performed better for the BZ- and CZ-items. This was the reason that in Section 5.5.2 a simulation for the Y-items was performed using a static policy. The static policies showed better results than the dynamic policies. The best policies are shown in Table 5.33.

Table 5.33: Best policy for each category

	X	Y	Z
A	(R,s,S)	(s,S)	(s_k,S)
B	(R,S)	(s,Q)	(s,Q)
C	(s,Q)	(s,Q)	(s,Q)

In the sensitivity analysis in Section 5.5.2, a trial-and-error simulation was performed to see if the best policies were selected. The simulation showed better performances according to the inventory value than the policies in Table 5.33. This means that, when using the inventory value as accuracy measure, it is probably better to select the policy per item instead of per classification category. However, this is more time-consuming so a trade-off needs to be made.

How is the performance of the proposed policy in comparison with the current policy?
The raw materials inventory value for the annual orders of the current policy is approximately €250,000. The proposed policy performs well in comparison with the current policy. The inventory value can be reduced with approximately €42,000, which is a reduction of 15%. The total annual cycle-inventory and ordering cost can be reduced by approximately €6000. However, it is hard to compare the proposed policy with the current, because assumptions needed to be made. For example, we approximated the service levels, while in the current policy no service levels are used (and known). In addition, data of the current situation was used, such as the start value for the inventory. This can give a somewhat unrealistic performance.

How can the designed simulation study be verified and validated?
The designed simulation study needs to be verified and validated to check whether it is realistic and representative of the current situation. A model can be verified if it meets all requirements. The simulation study designed during this research is verified by checking whether the MOQ is used correctly, the forecast is non-negative, and the orders are placed in the right period. A model can be validated when it is an accurate representation of the real world. The simulation study is validated by comparing the inventory levels of the current policy with the inventory levels of the proposed policy.

Is the proposed policy close to reality and does it take all restrictions into account?
To make the simulation as realistic as possible, actual data such as demand and inventory data are used. The items can be stocked in the warehouse because most inventory levels are lower with the proposed policy than with the current policy. The MOQ is taken into account during the simulation because ordering a lower quantity is not possible.

How robust is the proposed policy?
To check how the proposed policy reacts to changes, multiple modifications are done. The start value for the inventory level is changed to zero, which resulted in an improvement of inventory value of almost €65,000. The cycle service levels are changed. First, all service levels are set to 99%. A cycle service level of 99% increased the inventory value. After that, a cycle service level of 80% for all items was used. This resulted in a decrease in inventory value since the safety stock is lower with a lower CSL.

How can the inventory control policy be implemented within Hortec so that it can be used efficiently?
Hortec uses the ERP system Isah where the characteristics of all items can be found. The inventory control policy and corresponding parameters can be added to these characteristics. The purchaser can use this information to make more thoughtful decisions.

6 Conclusions & recommendations

This final chapter concludes the research. The main research question will be answered in Section 6.1. The research questions per chapter will also be elaborated. In Section 6.3, some recommendations are provided.

6.1 Conclusion

The assignment of this thesis was initiated because the management of Hortec experienced a high inventory value and they were curious whether they can reduce this and how. The main research question attempted to answer during this study was:

How to control the raw materials inventory within Hortec to reduce the inventory value while satisfying the service level?

To control the inventory of the raw materials, inventory control policies can be used. With the use of these policies, clear decisions about when and how much to order can be made instead of decisions from experience. In this thesis, items are classified according to the ABC-XYZ classification and inventory control policies are chosen per classification category. The proposed policy shows promising results considering the inventory value. It is also possible to choose an inventory control policy per item, which may result in a better performance but it is time-consuming. Therefore, a trade-off needs to be made. Below, the research questions per chapter are answered.

What is the current production-inventory strategy and the corresponding performance of Hortec?
Within Hortec, both the MTS- and MTO-strategies are used. The MTO-strategy is used for first production runs and general orders. For the annual orders, the MTS-strategy is applied. Currently, Hortec does not use a specific classification method or inventory control policy. They take some characteristics per item into account. The most important characteristics are the demand and value of the items. The purchase and planning departments have some built-in buffers of a couple of weeks, which results in higher inventories for raw materials and/or work-in-progress. In total, Hortec has an inventory value of more than €1,000,000. Most of the inventory are raw materials (approximately €723,000). The inventory values can be found in Table 6.1. The inventory value of the WIP is also distributed over the raw materials, semi-finished products, and end products.

Table 6.1: Inventory values

Total	€ 1,075,000
Raw materials	€ 723,000
Semi-finished products	€ 216,000
End products	€ 135,000
(work-in-progess)	€ 200,000

What methods are suggested in the literature to reduce the inventory value?
Four (static) inventory control policies are suggested in the literature to reduce inventories. These policies make sure that purchasing is done according to a clear procedure were no experience is required. Besides static policies, dynamic policies are described in the literature. When demand is non-stationary, it can happen that static policies do not work as expected. The control parameters of dynamic policies can differ between the periods of a cycle, whereas the control parameters of static policies are the same in each period.

What is the most suitable inventory control policy for Hortec and how can it be designed?
In total, 675 raw materials are investigated. The items are classified according to a ABC-XYZ classification. An inventory control policy was chosen for each classification class. For some items, multiple policies were simulated to see which one performed better. The policies selected per class can be found in Table 6.2.

Table 6.2: Policy of each category

	X	Y	Z
A	(R,s,S)	(s_k,S)	(s,S) & (s_k,S)
B	(R,S)	(s_k,Q)	(s,Q) & (s_k,Q)
C	(s,Q)	(s,Q)	(s,Q) & (s_k,Q)

What is the effect and improvement of the proposed inventory control policy after implementation?
According to our simulation study, the inventory control policies in Table 6.3 are most suitable. Remarkable is that for only the AZ-items, the dynamic policy better performs. This means that the non-stationary aspects such as trend and seasonality do not have a great impact on the inventories.

With the inventory control policies from Table 6.3, the proposed policy can reduce the inventory with approximately € 42,000. The proposed policy does not perform well for all items. A possible cause for negative performance of these items is the demand forecast. The expected demand, and thus the safety stock, is for some items higher than the annual demand. Another possible cause can

Table 6.3: Best policy for each category

	X	Y	Z
A	(R,s,S)	(s,S)	(s_k,S)
B	(R,S)	(s,Q)	(s,Q)
C	(s,Q)	(s,Q)	(s,Q)

be the reduction in demand. The control parameters are calculated with help of the data of 2018. During the simulation, these parameters were not updated. For some items, the demand in 2019 is way less than the demand in 2018. The changes in demand are not incorporated in the proposed policy. In the current policy these changes in demand are incorporated.

6.2 Discussion

Although the proposed policy shows a better performance considering the inventory value than the current policy, this research still contains some flaws. Below, this will be elaborated.

The demand forecast is an input for the control parameters. When the demand forecast is inaccurate, the control parameters are also inaccurate. Forecast accuracy measures are used to check the accuracy of the demand forecast. The results show some evidence that the demand forecast is not optimal. When the demand forecast is optimized, the control parameters will be more accurate and the policies will give a more realistic view.

Besides the demand forecast, the cycle service level is also an input for the control parameters. Unfortunately, the current cycle service levels are unknown, so it is unknown whether the used cycle service levels are close to reality. Because the used cycle service levels can differ from the current, the performances of the proposed policy and the current policy are hard to compare.

To run the simulation. The inventory level needs a start value in the first period. For this, the realized inventory level of April the first in 2019 is used. This start value is probably larger than needed, because it is obtained by using the current policy. Therefore, an analysis is done to see how the proposed policy works when the start inventory level is zero. This analysis shows better results in comparison when the realized inventory level is used. Because of this, the proposed policy will show improving results when time proceeds.

In this research, inventory control policies are chosen per classification category. However, although it can be time consuming, it may be better to choose an inventory control policy per item. The results in this thesis are based on the chosen inventory control policies per classification category. When one chooses the best policy per item, it may result in a better performance.

6.3 Recommendations

The goal of this research was to reduce the inventory value. Besides, the management of Hortec wanted a clear decision-making process for the purchasing strategy. With the help of inventory control policies, both would be feasible. In this section, recommendations formed during this research are explained.

Improve the demand forecast
During this research, the demand is forecasted to calculate the control parameters. However, forecasting the demand was hard because of the intermittent demand. Because of the time-frame, the demand forecast is not optimal. This can also be concluded from the results. The results showed that the proposed policy did not always work well due to the demand forecast. Therefore, when implementing inventory control policies, it would be helpful to improve the demand forecast and take intermittent demand into account during the forecast.

Automize purchasing
As made clear in this thesis, purchasing is done manually and is very time-consuming. Unfortunately, this research will not directly result in an automatized purchasing strategy. However, it can help in the decision-making process. Since purchasing will still take a lot of time, it can help to investigate whether the current ERP-system can automatize purchasing. This can save a lot of time. However, before the purchasing can be automated, a check must be done to see whether the proposed policy performs better in practice than the current policy.

Investigate the can-order policy
A small part of the literature study is dedicated to the can-order policy. This policy takes "family-grouping" into account. When items are purchased at the same supplier, it can be more beneficial to order more items although the reorder point of some items is not yet reached. Due to the time-frame of this research, the can-order policy was not investigated further. Since Hortec already tries to purchase multiple items at the same time, this is interesting to consider.

Improve the production planning
Hortec currently makes decisions based on experience and gut feelings. Not only the purchasing strategy but also the planning strategy is based on experience. In fact, no operational planning is used within Hortec. A recommendation resulting from this research is to realize an operational planning and improve the tactical planning.

Invest in more reliable data
A lot of data is stored in the ERP system. Unfortunately, most of the data is not reliable enough to use in research. For example, each employee needs to clock themselves in and out when they are working on a production order. In this way, the working hours are known. However, clocking is not always done correctly which results in unreliable data that can not be used. A way to make clocking more likeable is to purchase scanners.

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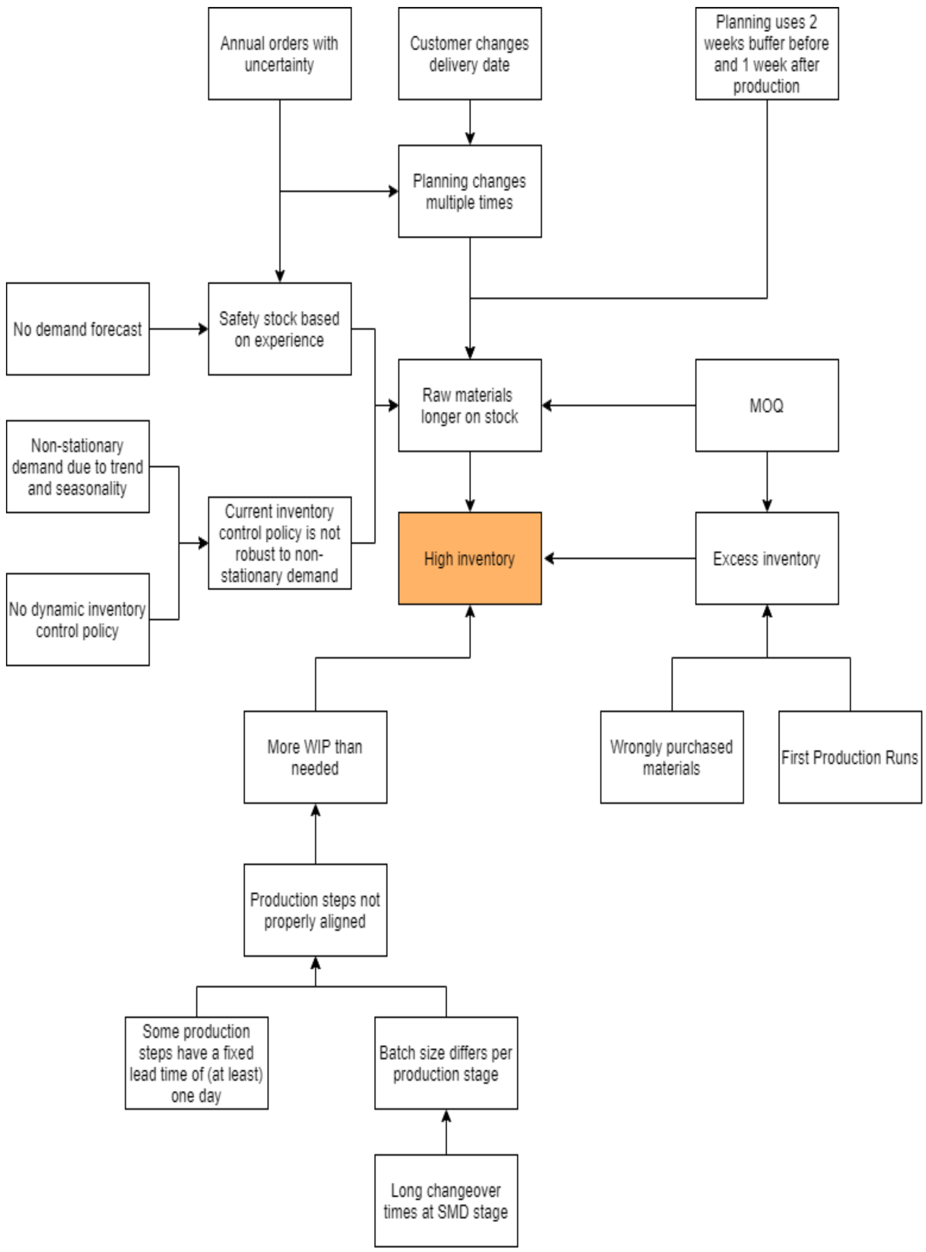
Appendices

A.1 Problem bundle



A.2 Status descriptions

Status	Status Description
10	New production file
11	Work preparation - new product check
13	Work preparation - work description
20	Warehouse - to pick conventional
21	Warehouse - to pick SMD
24	In pick
25	Warehouse - picked conv. incomplete
27	Warehouse - pick external production complete
29	Warehouse - picked conv. complete
30	RMA
31	IMA
38	Production - SMD incomplete
40	Production - conv. incomplete
41	Production - SMD complete
42	Production - conv. complete
43	Production - AOI
44	Production - External
45	Production - final test
47	Quality - visual test
50	Development
60	Warehouse - finalize and clean up
80	Work preparation - recalculation
90	Recalculation
95	History

A.3 Orders ready on time SMT-production

2016 SMD

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
59%	33%	39%	10%	43%	62%	35%	15%	27%	31%	29%	37%

2017 SMD

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
32%	48%	26%	28%	50%	20%	38%	50%	40%	15%	41%	69%

2018 SMD

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
53%	50%	48%	23%	68%	30%	38%	27%	68%	82%	27%	53%

2019 SMD

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
30%	48%	17%	47%	5%	25%	11%	11%	44%	14%	28%	62%

2020 SMD

Jan	Feb
25%	33%

A.4 Orders ready on time TH-production

2016 conv.

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
58%	32%	9%	16%	18%	27%	6%	5%	13%	16%	29%	33%

2017 conv.

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
17%	31%	18%	36%	27%	27%	52%	30%	46%	40%	49%	63%

2018 conv.

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
59%	68%	64%	80%	63%	88%	95%	96%	82%	100%	100%	97%

2019 conv.

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
73%	92%	92%	94%	81%	50%	26%	77%	78%	69%	54%	6%

2020 conv.	
Jan	Feb
35%	51%

A.5 Additional literature

Inventory-production models: make-to-stock vs make-to-order
As stated in Section 1.2, Hortec uses an MTO-policy. To know if this is indeed applied within Hortec, the different between an MTS- and MTO-policy need to be clear. In Figure A.1, a comparison is made between the characteristics of MTS and MTO companies.

Make-to-stock (MTS)
A make-to-stock (MTS) product is produced and stored in the warehouse based on its market demand forecast (Ghalehkhondabi and Suer (2018)), therefore it's most suitable in markets with predictable demand (Stevenson* et al. (2005)). Within an MTS-policy, low customization is possible. This is because up to the point the products are stocked, no customer preferences are taken into account (Mihiotis (2014)). For MTS products, finished goods inventory (FGI) is held (Arreola-Risa and DeCROIX (1998)). This FGI ensures that the products are delivered fast, because (most of the time) they can be delivered from stock. However, because of the FGI, the MTS-policy may lead to obsolete stock (Mihiotis (2014)).

Make-to-order (MTO)
In a make-to-order (MTO) production, the trigger for creating a manufacturing order is a customer's order (Hopp and Spearman (2011) Lödding (2012) Suri (1998)). Production begins when a customer's order is received and confirmed (Mihiotis (2014)). The advantage of an MTO system is that no inventory is needed (Rajagopalan (2002)). However, this is at the same time also a disadvantage. Because there is no FGI (Arreola-Risa and DeCROIX (1998)), the lead times are long(er) (Stevenson* et al. (2005)). Most of the time, MTO items are items with lower demand and high product variation, and forecasting the demand is not/hardly possible (Stevenson* et al. (2005)).

Costs considered in inventory management
Decisions in inventory management influence the corresponding cost. The goal of inventory management is to reduce these costs as much as possible, but at the same time have a good service level. Below, the considered costs are explained (Axsäter (2015)).

Holding costs
The holding costs are all the variable costs that are affected by the inventory level. The largest part of the holding costs are opportunity costs for capital tied

Table 1
A comparison of make-to-order and make-to-stock companies

Characteristic	Make-to-stock companies	Make-to-order companies
Product mix	Many standard products	Few standard products
Resources	Specialist machinery and workforce	Multi-task machinery and flexible workforce
Product demand	Demand for standard products can be forecast	Demand is volatile and can rarely be predicted
Capacity planning	Based on forecast demand. Planned well in advance. Adjusted later if necessary	Based on receipt of customer orders. Cannot be planned far in advance
Product lead times	Unimportant to customer. Can be set internally	Vital for customer satisfaction. Agreed with customer
Prices	Fixed by the producer	Agreed with customer before production commences

Figure A.1: MTO vs MTS (Hendry and Kingsman (1989))

up in inventory. Other parts of the holding costs are material handling, storage, damage and obsolescence, insurance and taxes. The holding cost per unit and time unit is often determined as a percentage of the unit value. This percentage can vary per product.

Ordering costs
When items are purchased, most of the time various fixed costs are associated with the replenishment. Think about transportation, material handling, costs for order forms, and handling of invoices from the supplier. When combining purchase orders, the ordering cost can be reduced.

Shortage costs
If an item is demanded and cannot be delivered due to a shortage, various costs can occur. The customer may agree to wait, so the order is backlogged. When this happens, often price discounts are incurred for late deliveries. Besides, there are often extra costs for administration, material handling, and transportation. Next to that, it is also possible that the customer goes to another supplier and the sale is lost.

A.6 Demand 1178-0011.x

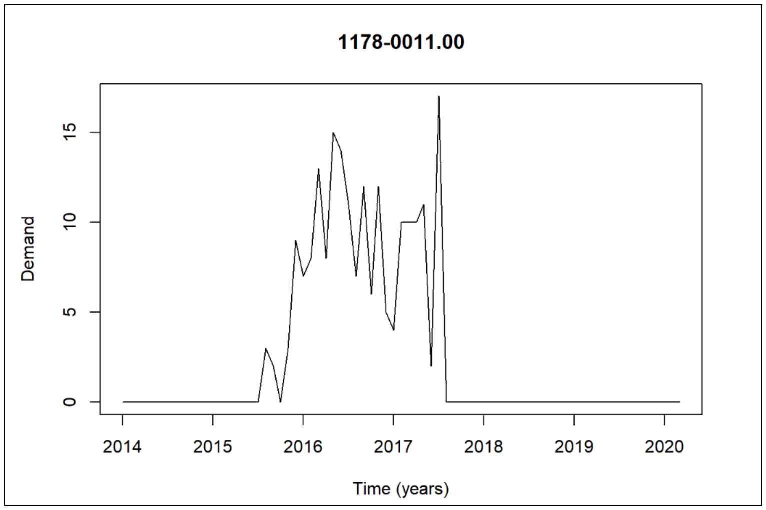


Figure A.2: Demand 1178-0011.00

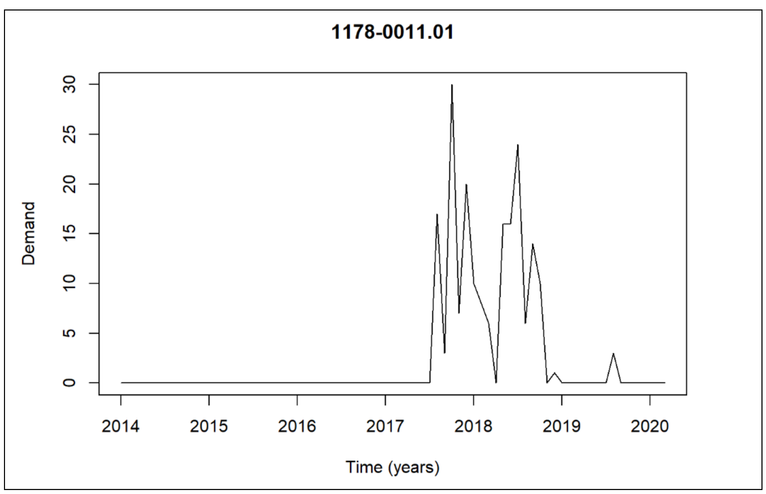


Figure A.3: Demand 1178-0011.01

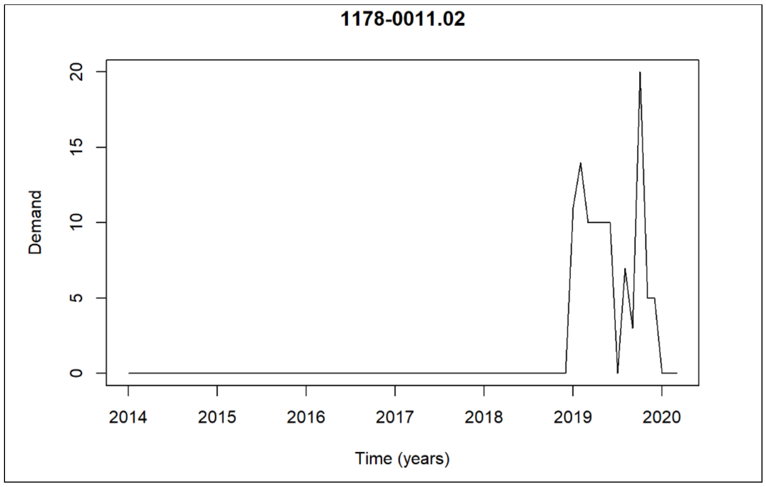


Figure A.4: Demand 1178-0011.02

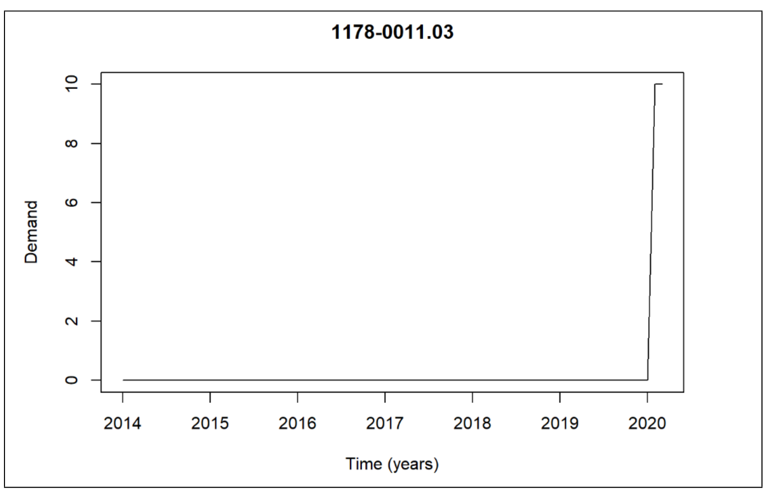


Figure A.5: Demand 1178-0011.03

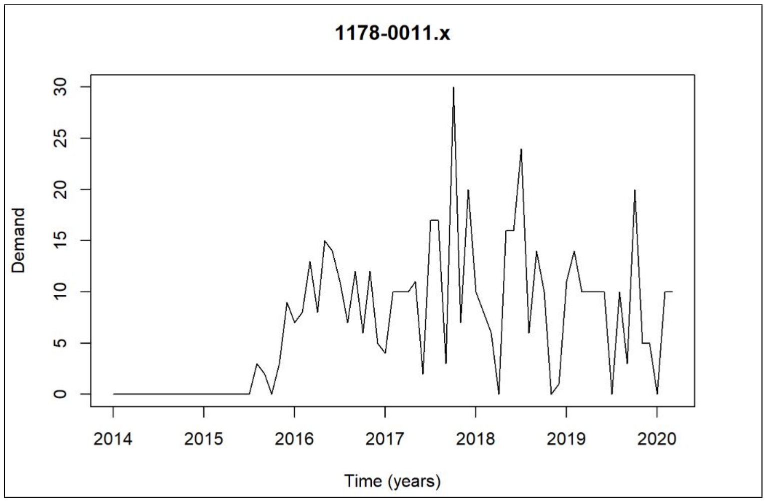


Figure A.6: Demand 1178-0011.x

A.7 Results ABC-analysis

ABC-analyse					
SKU	Unit price	Annual demand (2019)	Annual value	Cumulative	ABC-code
399.001521	29,45	1102	32453,90	0,071276623	A
399.002383	258	98	25284,00	0,12680641	A
399.002462	4,1535	4803	19949,26	0,170619817	A
335.000761	187	98	18326,00	0,21086815	A
350.002075	6,45	2428	15660,60	0,24526262	A
399.002461	6,383	2400	15319,20	0,278907293	A
399.002456	6,02	2400	14448,00	0,3106386	A
350.002078	5,25	2445	12836,25	0,338830113	A
350.002076	5,04	2404	12116,16	0,365440134	A
395.000384	46,1	238,47	10993,47	0,38958445	A
350.002077	4,45	2463	10960,35	0,413656033	A
399.002470	4,29	2408	10330,32	0,436343917	A
399.002455	3,72	2406	8950,32	0,456000987	A
365.000334	90,89	98	8907,22	0,475563399	A
350.002089	1,95	3758	7328,10	0,491657681	A
399.002628	71,15	102	7257,30	0,507596469	A
315.001070	0,2863	20439	5851,69	0,520448188	A
399.002457	1,15	4800	5520,00	0,532571445	A
399.002524	19,54	245	4787,30	0,543085515	A
399.001703	3,0687	1560	4787,17	0,553599304	A
345.000317	5,48	799	4378,52	0,563215594	A
399.002428	26,3	165	4339,50	0,572746187	A
399.002670	34,25	125	4281,25	0,582148848	A
350.002088	1,11	3754	4166,94	0,591300458	A
399.000063	345,16	12	4141,92	0,600397117	A
399.001848	9,9	407	4029,30	0,609246435	A
399.002467	0,27	14400	3888,00	0,617785425	A
315.000062	0,0127	304643,9	3868,98	0,626282637	A
350.001298	1,4	2515	3521,00	0,634015605	A
365.000342	13,55	252	3414,60	0,641514894	A
320.000069	0,58	5600	3248,00	0,648648288	A
399.002465	0,674	4801	3235,87	0,655755051	A
350.001485	1,99	1497	2979,03	0,662297722	A
399.002529	17,9	165	2953,50	0,668784323	A

Figure A.7: Results ABC-analysis

A.8 Coefficient of variation

Demand per month											
Standard deviation	11,90150551	25,47100067	9,42930936	13,83197533	7,99271804	3,093227369	3,093227369	2,343593513	0,276385399	16,74877276	8,65307829
Average	17,95	40,575	4,775	13,475	6,025	1,383333333	1,383333333	1,991666667	0,083333333	31,78333333	9,341666667
Months	350.000779	350.000780	350.000781	350.000783	350.000794	350.000795	350.000796	350.000798	350.000814	350.000815	350.000817
1	28,6	35,7	5,7	21,4	0	0	0	0	0	28,6	0
2	41,4	28,6	0	0	2,1	0	0	7	0	2,9	0
3	18,6	75	0	6,3	14,3	0	0	2,1	0	0	24,9
4	33,3	45,8	8,3	25	16,7	8,3	8,3	2,3	0	50	0
5	14,3	17,7	0	9,7	0	0	0	0	1	34,3	1,7
6	5	99,7	8,3	16,7	20,8	8,3	8,3	0	0	16,7	8,5
7	16,7	25	0	0	0	0	0	1,7	0	34	17
8	8,3	16,7	0,8	6,7	1,7	0	0	4,2	0	33,3	16,7
9	5	50,3	34,2	0	0	0	0	0	0	50	0
10	0	59	0	48,3	0	0	0	0,8	0	50	18,3
11	21,7	16,7	0	3,3	16,7	0	0	0	0	33,3	16,7
12	22,5	16,7	0	24,3	0	0	0	5,8	0	48,3	8,3
Coefficient of variation	0,663036518	0,627751095	1,974724473	1,026491676	1,326592206	2,236067977	2,236067977	1,176699672	3,31662479	0,526967155	0,926288488

Figure A.8: Example of CV calculation

A.9 Results XYZ-analysis

XYZ-code monthly		
SKU	COV	XYZ-code
315.000084	0,84341	Y
315.000088	1,93204	Z
320.000095	0,888	Y
330.000006	0,48937	X
345.001719	1,73926	Z
350.000174	0,43207	X
399.000010	0,85996	Y
399.000014	0,90132	Y
399.000316	0,88681	Y
315.000080	1,13559	Z
395.000226	0,41077	X
310.000347	2,31719	Z
365.000008	1,06026	Z
365.000040	1,06026	Z
370.000043	1,80419	Z
375.000030	1,06026	Z
375.000031	1,06026	Z

Figure A.9: Results XYZ-analysis

A.10 Results AX-items without undershoot

Item	Number out of stock	Proposed inventory	Current inventory	Improvement (euro)
395.000226	0	250	292	293
365.000029	0	1030	1379	412
345.000163	41	27	40	98
399.001703	3	233	284	157
399.001705	13	524	549	16
395.000384	20	19	100	3734
335.000692	0	49	56	172
370.000206	0	22	62	665
365.000334	0	69	44	-2222
335.000761	0	76	48	-5356
399.001967	0	46	58	304
399.002383	0	112	64	-12376
315.000062	3	23268	86997	809
399.002455	0	324	508	683
399.002456	0	293	547	1531
399.002457	0	1283	1940	756
399.002461	0	289	515	1444
399.002462	0	590	990	1662
399.002463	0	394	479	97
399.002464	8	507	444	-57
399.002465	6	925	957	22
399.002467	0	2748	3789	281
399.002468	0	783	1278	296
399.002470	0	314	540	969
399.002471	8	5897	5367	-34

Figure A.10: Results AX-items

A.11 Third moment Normal distribution

$$M_Y(t) = e^{\mu t + (\sigma^2 t^2)/2}$$

$$M_Y^{(1)}(t) = (\sigma^2 t + \mu) e^{\frac{\sigma^2 t^2}{2} + \mu t}$$

$$M_Y^{(2)}(t) = (\sigma^4 t^2 + 2\mu\sigma^2 t + \sigma^2 + \mu^2) e^{\frac{\sigma^2 t^2}{2} + \mu t}$$

$$M_Y^{(3)}(t) = (\sigma^2 t + \mu)(\sigma^4 t^2 + 2\mu\sigma^2 t + 3\sigma^2 + \mu^2) e^{\frac{\sigma^2 t^2}{2} + \mu t}$$

$$E[Y^3] = M_Y^{(3)}(0) = \mu(3\sigma^2 + \mu^2) = \mu + 3\mu\sigma^2$$

A.12 Third moment Poisson distribution

$$M_Y(t) = \mathrm{e}^{\lambda \mathrm{e}^t - \lambda}$$

$$M_Y^{(1)}(t) = \lambda \mathrm{e}^{\lambda \mathrm{e}^t + t - \lambda}$$

$$M_Y^{(2)}(t) = \lambda \left(\lambda \mathrm{e}^t + 1\right) \mathrm{e}^{\lambda \mathrm{e}^t + t - \lambda}$$

$$M_Y^{(3)}(t) = \lambda \left(\lambda^2 \mathrm{e}^{2t} + 3\lambda \mathrm{e}^t + 1\right) \mathrm{e}^{\lambda \mathrm{e}^t + t - \lambda}$$

$$E[Y^3] = M_Y^{(3)}(0) = \lambda \left(\lambda^2 + 3\lambda + 1\right) = \lambda^3 + 3\lambda^2 + \lambda$$

A.13 Third moment Gamma distribution

$$M_Y(t) = \left(\frac{\beta}{\beta - t}\right)^\alpha$$

$$M_Y^{(1)}(t) = \frac{\alpha \left(\frac{\beta}{\beta - t}\right)^\alpha}{\beta - t}$$

$$M_Y^{(2)}(t) = \frac{\alpha \left(\alpha + 1\right) \left(\frac{\beta}{\beta - t}\right)^\alpha}{\left(t - \beta\right)^2}$$

$$M_Y^{(3)}(t) = -\frac{\alpha \left(\alpha + 1\right) \left(\alpha + 2\right) \left(\frac{\beta}{\beta - t}\right)^\alpha}{\left(t - \beta\right)^3}$$

$$E[Y^3] = M_Y^{(3)}(0) = -\frac{\alpha(\alpha + 1)(\alpha + 2)}{(-\beta)^3}$$

A.14 Proposed policies including parameters

A.14.1 Proposed policy AX-items

Table A.4: Control parameters AX-items (R,s,S)-policy

Item	Reorder point	OUTL	EOQ	Annual demand (2018)	Lead time	Expected demand (R+L)	Variance demand (R+L)
315.000062	22	28927	28905	304644	1	14	3
335.000692	36	52	16	98	3	29	3
335.000761	76	88	12	98	6	63	13
345.000163	4	20	15	210	12	2	1
365.000029	82	299	217	1800	4	67	35
365.000334	59	89	31	98	5	51	5
370.000206	16	35	19	98	0	10	1
395.000226	3	63	60	276	5	3	0
395.000384	1	16	15	238	5	1	0
399.001703	49	199	150	1560	1	24	0
399.001705	343	842	500	3120	6	294	0
399.001967	30	46	16	98	2	21	4
399.002383	119	144	26	98	10	104	21
399.002455	143	286	143	2406	0	61	231
399.002456	145	262	117	2400	0	61	231
399.002457	585	1084	499	4800	3	365	2770
399.002461	143	297	154	2400	0	61	231
399.002462	300	570	270	4803	0	122	923
399.002463	426	642	217	2400	5	304	1154
399.002464	901	1144	243	2400	12	729	2770
399.002465	1829	2228	399	4801	12	1458	11081
399.002467	4772	6200	1428	14400	10	3645	83109
399.002468	286	998	711	4800	0	122	923
399.002470	138	429	291	2408	0	61	231
399.002471	10260	18017	7757	26400	12	8019	335208

A.14.2 Proposed policy AY-items

Table A.5: Control parameters AY-items (s_k,S)-policy

Item	Start ROP	Start OUTL	End ROP	End OUTL	Annual demand (2018)	Lead time	Expected demand (L)	Stdev forecast error
315.001070	6	1568	8	1570	20439	0	6	0
325.000179	0	336	0	336	2074	5	0	0
345.000317	425	601	549	725	799	14	270	39
350.001298	824	1314	1133	1623	2515	10	428	99
350.001485	232	579	263	610	1497	1	43	47
350.001571	271	335	271	335	527	4	121	37
350.002075	513	595	914	996	2428	9	163	87
350.002076	547	640	1069	1161	2404	12	229	79
350.002077	534	639	934	1039	2463	9	163	93
350.002078	548	785	1070	1306	2445	12	229	80
365.000337	127	187	128	188	368	3	38	22
365.000342	0	18	0	18	252	0	0	0
365.000378	83	120	83	120	180	3	24	15
365.000379	70	104	71	104	235	3	14	14
365.000415	51	76	71	96	90	5	33	5
399.000608	34	44	61	71	1074	1	33	0
399.001521	507	531	755	779	1102	18	346	40
399.001848	134	183	138	187	407	2	47	22
399.001850	549	707	549	707	1095	2	146	100
399.001946	105	150	123	168	243	3	34	18
399.001948	17	102	17	102	105	5	15	0
399.002428	100	208	125	234	165	5	37	16
399.002524	105	132	123	150	245	3	34	18
399.002529	98	121	119	143	165	4	30	17
399.002628	46	50	63	66	102	4	27	5

A.14.3 Proposed policy AZ-items

Table A.6: Control parameters AZ-items static

Item	Policy	Reorder point	Order-up-to-level	Annual demand (2018)	Lead time
320.000069	(s,S)	4	204	5600	1
350.002088	(s,S)	1237	1266	3754	6
350.002089	(s,S)	1237	1202	3758	6
350.002469	(s,S)	903	734	1935	7

Continued on next page

Table A.6 – Control parameters AZ-items static

Item	Policy	Reorder point	Order-up-to-level	Annual demand (2018)	Lead time
365.000380	(s,S)	13	64	381	4
399.000063	(s,S)	11	25	12	8
399.001601	(s,S)	9	32	204	2
399.002328	(s,S)	53	134	211	4
399.002670	(s,S)	3	12	125	3
399.002741	(s,S)	37	31	10	4
399.002748	(s,S)	29	25	1900	0

Table A.7: Control parameters AZ-items dynamic

Item	Policy	Start ROP	Start OUTL	End ROP	End OUTL	Annual demand (2018)	Lead time
320.000069	(sk,S)	372	572	372	573	5600	1
350.002088	(sk,S)	798	1058	1100	1360	3754	6
350.002089	(sk,S)	798	994	1100	1296	3758	6
350.002469	(sk,S)	391	393	391	393	1935	7
365.000380	(sk,S)	4	57	4	57	381	4
399.000063	(sk,S)	9	24	9	24	12	8
399.001601	(sk,S)	2	26	4	28	204	2
399.002328	(sk,S)	21	112	30	121	211	4
399.002670	(sk,S)	0	8	1	9	125	3
399.002741	(sk,S)	14	15	22	23	10	4
399.002748	(sk,S)	482	483	489	490	1900	0

A.14.4 Proposed policy BX-items

Table A.8: Control parameters BX-items

Item	Policy	Review Period	Order-up-to-level	Annual demand (2018)	Lead Time
315.000574	(R,S)	34	754	98	2
330.000006	(R,S)	27	957	55430	0
335.000009	(R,S)	15	270	5650	0
350.000174	(R,S)	23	2784	3123	2

Continued on next page

Table A.8 – Control parameters BX-items

Item	Policy	Reorder point	Order-up-to-level	Annual demand (2018)	Lead Time
350.000176	(R,S)	21	1266	726	2
350.001374	(R,S)	12	930	3120	7
350.001399	(R,S)	19	466	98	0
370.000229	(R,S)	14	182	196	2
370.000249	(R,S)	14	180	3188	3
399.000664	(R,S)	41	780	13258	1
399.001219	(R,S)	26	1297	98	3
399.001968	(R,S)	8	123	392	5
399.002481	(R,S)	120	48129	14400	1
399.002483	(R,S)	77	63325	28800	1
399.002490	(R,S)	24	1824	2400	1

A.14.5 Proposed policy BY-items

Table A.9: Control parameters BY-items

Item	Policy	Start ROP	Order quantity	End ROP	Annual demand (2018)	Lead Time
310.000994	(sk,Q)	947	291260	2347	861131	1
310.001593	(sk,Q)	64	78	64	150	8
315.000034	(sk,Q)	11	171	1	440	0
315.000084	(sk,Q)	768	236	769	1235	1
315.000563	(sk,Q)	0	32	0	260	12
315.001050	(sk,Q)	96	1337	143	2328	0
315.001051	(sk,Q)	197	403	229	775	3
315.001053	(sk,Q)	371	262	372	825	1
315.001416	(sk,Q)	34	185	61	1100	1
320.000186	(sk,Q)	104	106	104	524	14
335.000408	(sk,Q)	2511	1601	2461	5750	4
335.000676	(sk,Q)	205	256	206	450	3
335.000759	(sk,Q)	752	393	955	1422	8
335.000760	(sk,Q)	830	458	1070	1487	8
345.000019	(sk,Q)	67	26	65	160	0
345.000053	(sk,Q)	19	524	1	1584	0
345.000161	(sk,Q)	57	15	48	160	12
345.000162	(sk,Q)	57	15	48	160	12
345.000164	(sk,Q)	78	19	58	142	12
345.000165	(sk,Q)	77	19	59	107	12
345.000166	(sk,Q)	77	19	59	107	12

Continued on next page

Table A.9 – Control parameters BY-items

Item	Policy	Start ROP	Order quantity	End ROP	Annual demand (2018)	Lead Time
345.000315	(sk,Q)	197	466	229	805	3
345.000318	(sk,Q)	198	257	208	1002	20
350.000556	(sk,Q)	0	121	0	504	0
350.000735	(sk,Q)	276	255	261	934	0
350.000780	(sk,Q)	210	594	267	1348	3
350.001185	(sk,Q)	0	208	0	511	3
350.001197	(sk,Q)	32	619	48	1075	1
350.001204	(sk,Q)	64	657	96	1454	1
350.001225	(sk,Q)	64	824	96	1550	1
350.001308	(sk,Q)	457	530	571	1571	6
350.001526	(sk,Q)	125	40	125	250	4
350.001629	(sk,Q)	18	191	27	240	0
355.001113	(sk,Q)	55	63	55	150	3
370.000021	(sk,Q)	20	230	4	232	2
370.000267	(sk,Q)	106	535	158	1020	2
370.000283	(sk,Q)	86	134	104	170	3
399.000010	(sk,Q)	524	95	527	1142	6
399.000014	(sk,Q)	111	55	113	468	5
399.000154	(sk,Q)	99	251	33	232	15
399.000159	(sk,Q)	112	63	112	230	14
399.000160	(sk,Q)	52	67	52	240	6
399.000213	(sk,Q)	27	171	39	415	2
399.000265	(sk,Q)	2	23	0	167	0
399.000691	(sk,Q)	119	83	119	504	35
399.000700	(sk,Q)	0	248	0	1260	4
399.001695	(sk,Q)	132	234	132	300	3
399.001929	(sk,Q)	32	263	58	1101	0
399.001941	(sk,Q)	18	185	27	244	0
399.001942	(sk,Q)	59	328	85	795	0
399.001945	(sk,Q)	95	53	113	240	3
399.002430	(sk,Q)	86	65	104	165	3
399.002431	(sk,Q)	86	58	104	165	3
399.002530	(sk,Q)	86	50	104	165	3

A.14.6 Proposed policy BZ-items

Table A.10: Control parameters BZ-items static (s,Q)-policy

Item	Reorder point	Order quantity	Annual demand (2018)	Lead Time	Expected demand (L)	Variance demand (L)
315.001444	124	1154	3748	0	77	161
335.000409	1049	1044	4000	6	951	670
335.000651	5	162	2735	4	4	0
340.000507	28	15	3800	1	21	4
345.001719	9	1	907	1	8	0
350.001282	3	1	55	0	2	0
350.002372	10	66	115	6	9	0
350.002444	73	1	1933	6	64	6
350.002445	73	1	1903	6	64	6
350.002446	73	1	1900	6	64	6
350.002447	73	1	1903	6	64	6
355.000212	11	16	44	4	10	0
355.001017	1	3	29	3	1	0
355.001043	1	1	22	4	1	0
355.001053	1	1	23	4	1	0
355.001307	1	57	194	3	1	0
365.000008	2	10	19	3	2	0
365.000040	2	44	19	4	2	0
399.000060	2	12	19	4	2	0
399.001770	599	355	2500	10	498	715
399.002219	1	153	391	0	1	0
399.002423	41	422	1253	0	26	18
399.002665	5	11	130	2	4	0
399.002666	5	24	130	2	4	0
399.002667	3	20	130	1	2	0
399.002668	5	23	130	2	4	0
399.002750	237	5	3800	10	213	40

Table A.11: Control parameters BZ-items dynamic (s_k,Q)-policy

Item	Start ROP	Order quantity	End ROP	Annual demand (2018)	Lead Time	Expected demand (L)	Stdev forecast error
315.001444	628	1154	714	3748	0	111	150
335.000409	5562	1044	5813	4000	6	999	1322
335.000651	4	162	7	2735	4	4	0
340.000507	849	15	862	3800	1	35	236
345.001719	699	1	700	907	1	16	198

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Table A.11 – Control parameters BZ-items dynamic (s_k,Q)-policy

Item	Start ROP	Order quantity	End ROP	Annual demand (2018)	Lead Time	Expected demand (L)	Stdev forecast error
350.001282	4	1	5	55	0	4	0
350.002372	8	66	12	115	6	8	0
350.002444	350	1	374	1933	6	64	83
350.002445	350	1	374	1903	6	64	83
350.002446	350	1	374	1900	6	64	83
350.002447	350	1	374	1903	6	64	83
355.000212	11	16	14	44	4	11	0
355.001017	1	3	2	29	3	1	0
355.001043	1	1	2	22	4	1	0
355.001053	1	1	2	23	4	1	0
355.001307	2	57	2	194	3	2	0
365.000008	2	10	3	19	3	2	0
365.000040	2	44	3	19	4	2	0
399.000060	2	12	3	19	4	2	0
399.001770	749	355	1051	2500	10	421	95
399.002219	2	153	2	391	0	2	0
399.002423	200	422	229	1253	0	37	47
399.002665	6	11	8	130	2	6	0
399.002666	6	24	8	130	2	6	0
399.002667	4	20	5	130	1	4	0
399.002668	6	23	8	130	2	6	0
399.002750	1671	5	1746	3800	10	204	425

A.14.7 Proposed policy CX-items

Table A.12: Control parameters CX-items (s,Q)-policy

Item	Reorder point	Order quantity	Annual demand (2018)	Lead Time	Expected demand (L)	Variance demand (L)
310.000060	31	1419	585	6	11	24
310.000249	0	4878	404	1	0	0
310.000545	2	18938	21135	0	2	0
310.000719	19	63560	135448	1	13	3
310.000727	3	27931	32739	0	2	0
310.000978	2	15629	13654	0	2	0
315.000091	3	501	407	0	0	0
315.000134	3	272	471	0	0	0
315.000209	62	1311	1380	3	42	25

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Table A.12 – Control parameters CX-items (s,Q)-policy

Item	Reorder point	Order quantity	Annual demand (2018)	Lead Time	Expected demand (L)	Variance demand (L)
315.000614	2	448	176	1	0	0
320.000061	279	1697	878	10	228	164
330.000020	60	964	1133	1	23	85
340.000251	1	220	303	1	0	0
350.000043	19	722	462	0	9	6
350.000135	27	385	584	2	12	14
350.000534	34	3286	1138	0	27	3
350.000535	55	2163	2348	0	30	40
350.000718	72	3515	2995	0	20	175
350.000724	57	2864	3702	0	33	35
350.000866	20	864	235	0	6	14
350.000964	78	70	98	7	68	6
350.001373	42	1989	1810	0	41	0
365.000335	60	9238	98	5	51	5
365.000357	22	58	0	5	17	1
370.000204	51	1386	392	0	38	12
375.000014	108	2820	854	0	78	57
375.000044	198	14579	4479	0	126	337
375.000046	2	2740	1131	0	1	0
375.000057	11	445	5	1	0	7
375.000063	21	8424	2974	0	1	26
375.000064	171	5387	1637	0	122	155
375.000071	299	14032	7170	0	224	357
375.000081	77	2913	2459	0	56	30
375.000106	406	9724	8993	0	307	622
375.000152	227	2658	2541	0	165	249
375.000200	221	4273	4831	1	150	328
375.000246	27	1654	208	0	20	4
375.000291	159	3140	1281	0	116	122
375.000350	23	2033	765	0	2	27
375.000382	27	1132	208	0	20	4
375.000386	13	286	104	0	10	1
375.000389	190	2069	1484	0	138	178
375.000408	72	3954	2480	0	41	60
395.000518	12	4583	519	5	11	0
399.000022	10	369	330	0	5	1
399.000163	157	7603	3635	1	97	228
399.000299	10	1507	380	1	5	1
399.000300	9	1692	330	1	5	2
399.000331	17	294	80	0	5	10
399.001221	18	10	0	4	11	3
399.001222	13	474	98	0	10	1

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Table A.12 – Control parameters CX-items (s,Q)-policy

Item	Reorder point	Order quantity	Annual demand (2018)	Lead Time	Expected demand (L)	Variance demand (L)
399.001868	11	9239	2086	0	9	0
399.001870	34	4741	6258	0	26	4
399.002459	121	2385	2400	1	61	231
399.002460	121	6614	2400	1	61	231
399.002469	121	7317	2400	0	61	231
399.002473	121	7317	2400	0	61	231
399.002474	121	7317	2400	0	61	231
399.002475	121	8522	2400	1	61	231
399.002476	362	12053	7200	1	182	2078
399.002479	121	6601	2400	1	61	231
399.002480	121	5390	2400	1	61	231
399.002485	121	7010	2400	0	61	231
399.002494	121	7255	2344	0	61	231

A.14.8 Proposed policy CY-items

Table A.13: Control parameters CY-items (s,Q)-policy

Item	Reorder point	Order quantity	Annual demand (2018)	Lead Time	Expected demand (L)	Variance demand (L)
310.000002	5	343	160	8	1	1
310.000003	5	343	160	8	1	1
310.000004	5	210	161	8	1	1
310.000011	37	153	232	5	37	0
310.000113	45	772	253	6	45	0
310.000204	3	2403	875	1	2	0
310.000210	1	6204	712	1	0	0
310.000211	25	2521	788	1	22	1
310.000229	3	1587	106	0	3	0
310.000327	0	471	283	0	0	0
310.000372	1	447	176	0	0	0
310.000717	12	44488	70912	0	8	1
310.000721	5	26270	22667	1	3	0
310.000871	0	25325	60685	0	0	0
310.001008	1	10885	2390	1	1	0
310.001077	25	5725	2090	0	17	4
310.001079	6	22721	25002	1	4	0
310.001393	71	1138	1550	0	41	60
310.001394	106	1733	2325	0	62	134

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Table A.13 – Control parameters CY-items (s,Q)-policy

Item	Reorder point	Order quantity	Annual demand (2018)	Lead Time	Expected demand (L)	Variance demand (L)
310.001395	1	703	850	0	1	0
310.001397	1	216	75	0	1	0
310.001398	1	348	150	0	1	0
310.001399	1	187	75	0	1	0
310.001400	1	501	225	0	1	0
310.001446	1	390	225	0	1	0
310.001594	7	345	309	0	7	0
310.001595	3	703	150	0	3	0
310.001596	7	1312	300	0	7	0
310.001609	0	4	0	0	0	0
315.000030	36	1247	2856	0	22	15
315.000131	1	97	164	1	0	0
315.000132	50	448	240	8	37	12
315.000155	0	1327	71	3	0	0
315.000211	7	335	250	0	7	0
315.000214	1	137	176	0	0	0
315.000285	3	174	352	1	0	0
315.000359	2	853	467	0	0	0
315.000564	0	75	252	0	0	0
315.000581	2	14829	15310	1	2	0
315.000599	24	492	1100	1	24	0
315.000624	2	3963	11569	1	1	0
315.000666	16	198	80	0	5	10
315.000690	0	312	264	4	0	0
315.000693	0	164	257	0	0	0
315.000817	3	12606	24920	0	2	0
315.000821	4	2405	1540	1	2	0
315.000949	10	1192	475	1	8	1
315.000988	2	4364	2101	1	2	0
315.001080	1	215	225	0	1	0
315.001252	52	1397	723	0	32	27
320.000025	101	4716	1143	2	90	10
320.000095	42	179	1217	5	41	0
320.000384	7	257	310	0	7	0
320.000729	0	769	554	0	0	0
325.000180	0	48	279	2	0	0
330.000021	0	204	1	2	0	0
330.000088	0	241	276	0	0	0
330.000100	49	1780	3404	1	49	0
330.000105	1	158	241	0	1	0
330.000109	7	577	330	0	7	0
335.000011	1	541	313	0	0	0

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Table A.13 – Control parameters CY-items (s,Q)-policy

Item	Reorder point	Order quantity	Annual demand (2018)	Lead Time	Expected demand (L)	Variance demand (L)
335.000021	0	676	386	1	0	0
335.000052	10	792	319	0	2	4
335.000071	706	1283	1200	6	669	98
335.000662	9	1805	4350	2	6	0
335.000798	11	6274	990	0	8	0
335.000799	11	6274	990	0	8	0
340.000137	0	59	0	1	0	0
340.000252	1	249	295	1	0	0
345.000024	13	433	960	0	2	8
345.000043	3	45	160	4	1	0
345.000045	3	45	170	4	1	0
345.000052	16	222	242	2	9	3
350.000046	2	1188	1945	0	1	0
350.000131	9	93	339	2	3	3
350.000132	9	83	244	2	4	2
350.000136	9	146	244	2	4	2
350.000213	59	6316	2002	1	8	185
350.000246	0	240	70	2	0	0
350.000251	0	842	753	1	0	0
350.000256	3	412	70	1	2	0
350.000271	1	93	160	1	0	0
350.000288	0	3143	3031	0	0	0
350.000290	9	947	1520	0	1	4
350.000590	16	299	80	0	5	10
350.000604	48	1126	202	1	13	87
350.000611	17	670	80	0	6	10
350.000700	9	294	130	0	7	0
350.000752	0	370	252	3	0	0
350.000779	16	557	80	1	5	10
350.000815	0	448	524	3	0	0
350.000858	103	1274	560	1	30	375
350.000912	21	45	55	9	19	0
350.000934	112	1463	560	1	34	428
350.001115	134	276	80	17	84	176
350.001116	134	251	80	17	84	176
350.001117	300	316	160	17	200	708
350.001186	0	165	252	3	0	0
350.001206	1	248	75	1	1	0
350.001207	1	209	75	1	1	0
350.001227	1	203	150	1	1	0
350.001228	1	176	75	1	1	0
350.001229	1	168	75	1	1	0

Continued on next page

Table A.13 – Control parameters CY-items (s,Q)-policy

Item	Reorder point	Order quantity	Annual demand (2018)	Lead Time	Expected demand (L)	Variance demand (L)
350.001303	96	843	1107	3	69	52
350.001545	6	6120	1043	0	4	0
350.001546	6	6120	1043	0	4	0
350.002136	17	118	240	1	11	3
370.000055	0	30	20	0	0	0
370.000284	34	313	165	3	25	6
375.000007	15	557	200	1	11	1
375.000017	0	1445	176	0	0	0
375.000018	0	1	0	0	0	0
375.000028	0	580	398	0	0	0
375.000039	2	1011	187	0	1	0
375.000050	28	679	327	0	5	38
375.000065	9	1907	1503	0	2	4
375.000107	20	7997	1886	0	1	26
375.000118	42	2277	1704	0	27	15
375.000203	27	1786	286	0	4	38
375.000276	19	4212	500	0	9	6
375.000295	20	2634	14316	0	1	26
375.000353	0	2554	275	0	0	0
375.000422	151	4834	3740	1	91	251
375.000463	19	1394	500	0	9	6
375.000473	11	2156	2096	0	9	0
375.000474	22	3395	4548	0	17	2
375.000475	22	6871	4511	0	17	2
375.000553	8	726	675	0	7	0
375.000554	15	1343	675	2	13	0
375.000555	8	2703	675	0	7	0
395.000233	0	2132	252	0	0	0
395.000480	17	182	240	0	11	3
399.000023	1	268	334	1	0	0
399.000033	1	188	250	1	0	0
399.000074	1	564	23	0	1	0
399.000101	35	393	471	0	22	12
399.000137	29	1283	696	0	6	37
399.000156	15	542	460	0	15	0
399.000157	7	348	230	0	7	0
399.000247	17	284	80	0	6	10
399.000263	9	797	320	8	3	3
399.000266	13	46	139	7	8	2
399.000310	4	1419	185	1	2	0
399.000316	6	115	368	2	5	0
399.000330	16	185	81	1	5	10

Continued on next page

Table A.13 – Control parameters CY-items (s,Q)-policy

Item	Reorder point	Order quantity	Annual demand (2018)	Lead Time	Expected demand (L)	Variance demand (L)
399.000413	77	927	2200	0	46	69
399.000702	0	275	252	0	0	0
399.000703	0	189	518	1	0	0
399.000877	0	293	62	0	0	0
399.001396	46	86	80	4	22	39
399.001464	17	213	80	0	6	10
399.001525	2	875	450	0	2	0
399.001526	6	539	450	1	5	0
399.001527	4	510	450	1	3	0
399.001815	3	127	166	0	3	0
399.001842	0	95	260	1	0	0
399.001849	24	118	250	2	24	0
399.001853	49	4264	500	2	49	0
399.001858	24	3015	250	2	24	0
399.001859	24	3015	250	2	24	0
399.001860	24	3015	250	2	24	0
399.001861	24	3015	250	2	24	0
399.001862	24	3015	250	2	24	0
399.001863	24	3015	250	2	24	0
399.001864	24	2132	250	2	24	0
399.001865	24	3015	250	2	24	0
399.001867	6	6120	1045	0	4	0
399.001871	6	6120	1043	0	4	0
399.001900	6	255	160	1	6	0
399.001901	3	221	178	1	3	0
399.001943	69	688	960	0	43	47
399.001944	44	150	242	3	32	9
399.002021	24	3015	250	2	24	0
399.002022	24	3015	250	2	24	0
399.002023	24	3015	250	2	24	0
399.002041	12	671	300	1	12	0
399.002150	69	1828	660	0	26	134
399.002477	236	9923	4800	1	122	923
399.002484	84	5209	1741	0	44	116
399.002488	33	4597	627	0	17	20

A.14.9 Proposed policy CZ-items

Table A.14: Control parameters CZ-items static

Item	Policy	Reorder point	Order quantity	Annual demand (2018)	Lead time
315.000088	(s,Q)	4,8	1	198	0
399.000067	(s,Q)	29,9	25	0	1
315.000080	(s,Q)	6,2	1	1104	0
310.000347	(s,Q)	0,0	1	0	0
370.000043	(s,Q)	3,9	2	0	1
375.000030	(s,Q)	0,7	656	19	0
375.000031	(s,Q)	0,7	42	19	0
375.000099	(s,Q)	3,0	138	19	5
375.000111	(s,Q)	1,3	365	38	0
375.000112	(s,Q)	2,0	388	58	0
399.000061	(s,Q)	0,0	1	0	10
399.000065	(s,Q)	2,4	27	19	3
399.000066	(s,Q)	0,1	14	3	0
310.000342	(s,Q)	0,0	1	7	0
310.000349	(s,Q)	0,4	28	12	0
310.000346	(s,Q)	0,0	1	0	0
399.000064	(s,Q)	2,3	15	0	10
310.000188	(s,Q)	0,1	730	220	0
310.000206	(s,Q)	0,1	572	0	0
310.000222	(s,Q)	0,2	3529	282	1
310.000234	(s,Q)	5,9	5393	0	1
310.000236	(s,Q)	0,1	500	0	0
310.000238	(s,Q)	0,5	3917	110	0
310.000257	(s,Q)	0,1	3686	0	0
310.000353	(s,Q)	0,1	390	235	1
310.000397	(s,Q)	0,1	144	0	1
310.000398	(s,Q)	0,1	415	0	0
310.000680	(s,Q)	0,1	376	0	0
315.000064	(s,Q)	1,0	1125	27	0
315.000154	(s,Q)	0,5	575	0	0
315.000284	(s,Q)	0,1	3761	0	0
320.000026	(s,Q)	0,2	4845	27	1
320.000043	(s,Q)	0,4	1062	0	0
330.000019	(s,Q)	0,1	400	0	1
330.000023	(s,Q)	0,0	615	0	0
335.000002	(s,Q)	0,8	236	417	3
335.000386	(s,Q)	0,2	331	0	1
340.000130	(s,Q)	0,1	92	30	1
340.000213	(s,Q)	0,1	150	75	1

Continued on next page

Table A.14 – Control parameters CZ-items static

Item	Policy	Reorder point	Order quantity	Annual demand (2018)	Lead time
340.000301	(s,Q)	0,1	190	0	0
340.000304	(s,Q)	0,1	73	0	0
340.000305	(s,Q)	0,1	285	0	0
345.000001	(s,Q)	0,1	139	0	1
350.000206	(s,Q)	0,1	65	0	1
350.000209	(s,Q)	0,1	94	0	1
350.000244	(s,Q)	0,0	202	0	2
355.000100	(s,Q)	0,2	16	0	3
375.000021	(s,Q)	0,1	695	0	0
375.000045	(s,Q)	0,1	1086	0	0
399.000158	(s,Q)	0,0	70	0	16
399.000165	(s,Q)	0,0	44	0	10
399.000167	(s,Q)	0,0	29	0	6
399.000261	(s,Q)	0,1	621	0	0
399.000410	(s,Q)	0,1	70	0	1
375.000145	(s,Q)	0,0	380	0	0
310.000066	(s,Q)	0,0	586	0	0
315.000210	(s,Q)	0,0	139	0	0
350.000004	(s,Q)	0,0	1368	0	0
375.000464	(s,Q)	0,0	600	0	0
310.000082	(s,Q)	7,5	947	240	0
350.001126	(s,Q)	0,0	29	0	1
350.001620	(s,Q)	0,0	1	0	0
350.001621	(s,Q)	0,1	6	0	0
345.000327	(s,Q)	0,7	24	0	0
350.001205	(s,Q)	1,3	99	150	1
350.001222	(s,Q)	1,3	144	0	1
350.001223	(s,Q)	0,7	162	0	1
350.001224	(s,Q)	0,7	192	0	1
350.001230	(s,Q)	0,7	103	0	1
350.001231	(s,Q)	0,7	91	0	1
375.000109	(s,Q)	2,0	1216	0	0
375.000110	(s,Q)	5,9	2114	81	0
375.000187	(s,Q)	3,3	932	81	0
375.000233	(s,Q)	2,0	3941	0	0
375.000411	(s,Q)	2,0	146	0	0
375.000413	(s,Q)	0,7	106	81	0
375.000414	(s,Q)	3,9	780	81	0
399.001522	(s,Q)	0,7	26	80	0
399.001540	(s,Q)	3,3	356	0	1
399.001541	(s,Q)	2,0	301	0	1

Continued on next page

Table A.14 – Control parameters CZ-items static

Item	Policy	Reorder point	Order quantity	Annual demand (2018)	Lead time
350.001956	(s,Q)	36,9	354	296	0
399.000555	(s,Q)	36,9	1	0	0
315.001143	(s,Q)	0,0	1	0	1
350.001044	(s,Q)	0,0	14	0	1
350.001524	(s,Q)	40,2	903	1256	1
310.000259	(s,Q)	4,9	1806	110	0
310.000263	(s,Q)	315,1	1620	998	9
335.000073	(s,Q)	160,0	1081	0	6
310.000224	(s,Q)	0,0	1	0	0
310.000261	(s,Q)	0,0	679	55	0
370.000037	(s,Q)	0,0	2	0	1
320.000178	(s,Q)	0,0	1	1	0
335.000422	(s,Q)	1,1	1	60	1
355.000913	(s,Q)	0,0	1	1	2
370.000050	(s,Q)	0,0	40	0	0
375.000421	(s,Q)	0,0	1	2	0
335.000411	(s,Q)	1670,7	2113	1750	6
350.000865	(s,Q)	3,1	102	100	0
350.001585	(s,Q)	3,1	168	100	1
370.000194	(s,Q)	0,0	3	0	1
350.000601	(s,Q)	0,0	1719	11068	1
350.000605	(s,Q)	0,0	154	17	1
370.000110	(s,Q)	0,0	1	0	0
335.000621	(s,Q)	0,3	1	0	0
370.000205	(s,Q)	0,0	1	0	8
375.000043	(s,Q)	0,0	1	0	0
375.000383	(s,Q)	0,0	1	0	1
375.000384	(s,Q)	0,0	1	0	1
375.000416	(s,Q)	219,8	3466	1584	0
399.001707	(s,Q)	1,7	1	0	1
310.001743	(s,Q)	0,2	34	25	1
310.001744	(s,Q)	0,2	34	25	1
315.001242	(s,Q)	0,6	123	75	0
340.001759	(s,Q)	0,2	12	25	1
340.001760	(s,Q)	0,2	45	40	1
365.000348	(s,Q)	1,1	145	50	3
365.000349	(s,Q)	1,1	456	50	3
315.001341	(s,Q)	27,7	365	550	0
320.000978	(s,Q)	6,2	196	50	0
335.000663	(s,Q)	12,4	287	100	0
375.000530	(s,Q)	24,9	573	260	0

Continued on next page

Table A.14 – Control parameters CZ-items static

Item	Policy	Reorder point	Order quantity	Annual demand (2018)	Lead time
399.002127	(s,Q)	30,6	290	230	3
399.002128	(s,Q)	30,6	849	232	3
340.000253	(s,Q)	0,0	5	15	0
350.002091	(s,Q)	6,4	466	200	0
350.002475	(s,Q)	0,0	1	0	0
350.002476	(s,Q)	0,0	1	0	3
350.002478	(s,Q)	0,0	1	0	3
365.000431	(s,Q)	0,0	25	0	5
365.000432	(s,Q)	0,0	25	0	5
370.000301	(s,Q)	0,0	1	0	3
399.002787	(s,Q)	0,0	1	0	3
399.002788	(s,Q)	0,0	1	0	3
399.002789	(s,Q)	0,0	1	0	3
399.002792	(s,Q)	0,0	1	0	16
350.001164	(s,Q)	0,0	1	0	1
375.000038	(s,Q)	0,0	1121	0	0
350.000033	(s,Q)	0,0	74	0	0
399.001536	(s,Q)	0,0	1	0	0
350.001280	(s,Q)	3,1	1	55	0
350.001323	(s,Q)	3,1	24	55	1
399.001594	(s,Q)	3,1	1	55	0
399.001597	(s,Q)	3,1	1	55	0
310.001082	(s,Q)	5,7	9392	14962	1
310.001421	(s,Q)	4,3	127	173	0
310.001422	(s,Q)	1,4	1	57	0
310.001423	(s,Q)	2,8	5	114	0
315.000943	(s,Q)	18,2	4	439	2
315.001071	(s,Q)	7,1	1	328	0
350.001278	(s,Q)	3,7	1	72	3
310.001454	(s,Q)	4,0	739	407	2
315.000113	(s,Q)	2,1	992	1245	0
350.001277	(s,Q)	2,1	200	77	0
350.000065	(s,Q)	9,5	1	190	0
325.000722	(s,Q)	6,2	544	475	0
350.001279	(s,Q)	4,0	1	134	3
350.001332	(s,Q)	4,0	25	70	2
315.001117	(s,Q)	8,6	2058	732	0
315.001118	(s,Q)	6,2	2281	127	2
315.001119	(s,Q)	3,4	1	121	0
315.001120	(s,Q)	3,4	1	121	0
315.001121	(s,Q)	3,1	2380	301	2

Continued on next page

Table A.14 – Control parameters CZ-items static

Item	Policy	Reorder point	Order quantity	Annual demand (2018)	Lead time
315.001122	(s,Q)	3,4	1132	351	0
315.001123	(s,Q)	1,7	1278	534	0
315.001124	(s,Q)	1,7	1	314	0
315.001125	(s,Q)	1,7	674	404	0
315.001126	(s,Q)	1,7	1	61	0
350.001369	(s,Q)	1,7	1	77	0
399.002710	(s,Q)	6,0	146	105	0
350.001796	(s,Q)	2,0	226	120	1
350.002381	(s,Q)	1,3	205	80	0
350.002382	(s,Q)	0,7	137	40	0
315.001580	(s,Q)	1,3	50	80	1
350.002384	(s,Q)	0,7	59	40	0
355.001822	(s,Q)	5,4	1	40	2
399.002672	(s,Q)	23,3	230	520	0
399.002673	(s,Q)	5,8	234	520	0
399.002675	(s,Q)	5,8	145	260	0
399.002676	(s,Q)	5,8	947	260	1
399.002678	(s,Q)	8,7	619	390	1
399.002679	(s,Q)	14,6	731	650	1
399.002680	(s,Q)	5,8	478	260	1
399.002681	(s,Q)	23,3	925	1040	1
399.002682	(s,Q)	14,6	1023	650	1
399.002740	(s,Q)	5,8	1651	260	1
350.000777	(s,Q)	16,4	2236	80	1
310.000420	(s,Q)	7,0	40	11	0
399.001974	(s,Q)	27,9	143	0	0
350.001999	(s,Q)	4,7	132	0	0
350.002000	(s,Q)	4,7	96	0	0
375.000356	(s,Q)	18,6	175	100	0
350.000031	(s,Q)	0,1	18	0	1
399.002758	(s,Q)	0,4	5	73	1
399.002805	(s,Q)	0,0	5	35	1
350.000121	(s,Q)	0,0	63	10	1
350.000956	(s,Q)	0,0	89	10	0
350.000960	(s,Q)	0,0	184	0	0
310.001608	(s,Q)	0,2	5	0	0
335.000724	(s,Q)	5,9	1	0	0
310.001643	(s,Q)	1,9	1394	1444	0
335.000723	(s,Q)	0,0	1	7260	0
350.001528	(s,Q)	0,0	1	0	10
350.001529	(s,Q)	0,0	1	0	10

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Table A.14 – Control parameters CZ-items static

Item	Policy	Reorder point	Order quantity	Annual demand (2018)	Lead time
350.001547	(s,Q)	0,0	1	5	1
395.000432	(s,Q)	0,3	1	0	0
395.000435	(s,Q)	0,1	1	0	3
395.000436	(s,Q)	0,2	1	0	4
395.000437	(s,Q)	0,1	1	0	0
395.000438	(s,Q)	5,4	1	0	0
350.001958	(s,Q)	10,1	1	0	2
395.000425	(s,Q)	0,3	1	0	0
395.000434	(s,Q)	0,5	5	0	0
395.000439	(s,Q)	0,5	5	0	0
395.000440	(s,Q)	0,1	5	0	0
395.000449	(s,Q)	0,3	1	0	1
395.000484	(s,Q)	0,2	12	0	0
395.000486	(s,Q)	2,5	75	0	3
395.000487	(s,Q)	4,8	15	0	3
395.000488	(s,Q)	5,4	1	0	0
365.000435	(s,Q)	2,7	1	6	0
399.001964	(s,Q)	0,8	1	0	0
399.002106	(s,Q)	0,0	1	0	0
399.002193	(s,Q)	0,7	1	0	0
399.002210	(s,Q)	0,1	1	0	0
399.002205	(s,Q)	0,7	1	0	0
399.002207	(s,Q)	0,2	1	0	0
399.002212	(s,Q)	0,1	1	0	0
399.002213	(s,Q)	0,2	1	0	0
399.002239	(s,Q)	5,2	1	0	0
395.000543	(s,Q)	1,1	12	0	0
399.002267	(s,Q)	0,0	2132	0	0
399.002354	(s,Q)	0,0	2132	0	0
399.002356	(s,Q)	0,0	2132	0	0
399.002358	(s,Q)	0,0	1	0	0
399.002426	(s,Q)	7,3	9511	900	0
335.001823	(s,Q)	526,4	1	15000	0
335.001824	(s,Q)	526,4	1	15000	0
335.001825	(s,Q)	456,2	1	187200	0
399.002427	(s,Q)	13,5	2132	150	0
350.000719	(s,Q)	5,4	527	0	0
350.001666	(s,Q)	5,4	520	0	1
350.001667	(s,Q)	5,4	515	0	1
350.001668	(s,Q)	23,7	101	0	5
399.001374	(s,Q)	5,4	357	0	1

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Table A.14 – Control parameters CZ-items static

Item	Policy	Reorder point	Order quantity	Annual demand (2018)	Lead time
399.002004	(s,Q)	10,1	3729	0	2
350.001961	(s,Q)	2,6	72	0	0
399.002329	(s,Q)	2,6	91	0	0
399.000279	(s,Q)	4,5	230	385	0
399.002536	(s,Q)	4,5	343	364	0
350.002474	(s,Q)	1,2	2	416	3
325.000928	(s,Q)	2,1	143	100	0
345.001653	(s,Q)	2,1	74	105	0
399.000478	(s,Q)	2,1	335	100	1
399.002559	(s,Q)	2,1	174	100	0
399.002560	(s,Q)	2,1	169	104	0
365.000409	(s,Q)	0,8	1	0	1
399.002223	(s,Q)	17,4	14460	3200	0
399.002442	(s,Q)	0,8	1	0	0
350.001262	(s,Q)	2,1	107	100	1
350.002003	(s,Q)	8,3	447	400	0
399.002367	(s,Q)	2,1	47	105	0
399.001391	(s,Q)	1,1	1	0	0
399.002491	(s,Q)	1,1	1	0	0
399.002808	(s,Q)	112,1	1	1400	0
399.002795	(s,Q)	0,1	1	355	1
399.002820	(s,Q)	0,1	1	0	0
345.001624	(s,Q)	3,5	221	0	0
350.000781	(s,Q)	3,5	551	0	1
399.002534	(s,Q)	47,9	985	0	0
315.001596	(s,Q)	14,1	7	1900	0
320.001182	(s,Q)	14,1	5	1970	0
350.002448	(s,Q)	14,1	5	1901	0
399.002747	(s,Q)	6,3	1	700	0
399.002749	(s,Q)	14,1	2	1900	0
399.002534	(s,Q)	32,2	97	0	0
315.001596	(s,Q)	10,7	10	1900	0
320.001182	(s,Q)	10,7	10	1970	0
350.002448	(s,Q)	10,7	10	1901	0
399.002747	(s,Q)	4,8	7	700	0
399.002749	(s,Q)	10,7	10	1900	0

Table A.15: Control parameters CZ-items dynamic

Item	Policy	Start ROP	Order quantity	End ROP	Annual demand (2018)	Lead time
315.000088	(sk,Q)	7	1	9	198	0
399.000067	(sk,Q)	50	25	30	0	1
315.000080	(sk,Q)	764	1	764	1104	0
310.000347	(sk,Q)	0	1	0	0	0
370.000043	(sk,Q)	6	2	7	0	1
375.000030	(sk,Q)	1	656	1	19	0
375.000031	(sk,Q)	1	42	1	19	0
375.000099	(sk,Q)	8	138	8	19	5
375.000111	(sk,Q)	2	365	2	38	0
375.000112	(sk,Q)	3	388	4	58	0
399.000061	(sk,Q)	0	1	0	0	10
399.000065	(sk,Q)	2	27	3	19	3
399.000066	(sk,Q)	0	14	0	3	0
310.000342	(sk,Q)	0	1	0	7	0
310.000349	(sk,Q)	1	28	1	12	0
310.000346	(sk,Q)	0	1	0	0	0
399.000064	(sk,Q)	2	15	3	0	10
310.000188	(sk,Q)	0	730	0	220	0
310.000206	(sk,Q)	0	572	0	0	0
310.000222	(sk,Q)	326	3529	326	282	1
310.000234	(sk,Q)	11	5393	12	0	1
310.000236	(sk,Q)	0	500	0	0	0
310.000238	(sk,Q)	1	3917	1	110	0
310.000257	(sk,Q)	0	3686	0	0	0
310.000353	(sk,Q)	0	390	0	235	1
310.000397	(sk,Q)	0	144	0	0	1
310.000398	(sk,Q)	0	415	0	0	0
310.000680	(sk,Q)	0	376	0	0	0
315.000064	(sk,Q)	1	1125	2	27	0
315.000154	(sk,Q)	1	575	1	0	0
315.000284	(sk,Q)	0	3761	0	0	0
320.000026	(sk,Q)	0	4845	0	27	1
320.000043	(sk,Q)	1	1062	1	0	0
330.000019	(sk,Q)	0	400	0	0	1
330.000023	(sk,Q)	0	615	0	0	0
335.000002	(sk,Q)	161	236	161	417	3
335.000386	(sk,Q)	0	331	0	0	1
340.000130	(sk,Q)	0	92	0	30	1
340.000213	(sk,Q)	0	150	0	75	1

Continued on next page

Table A.15 – Control parameters CZ-items dynamic

Item	Policy	Start ROP	Order quantity	End ROP	Annual demand (2018)	Lead time
340.000301	(sk,Q)	0	190	0	0	0
340.000304	(sk,Q)	0	73	0	0	0
340.000305	(sk,Q)	0	285	0	0	0
345.000001	(sk,Q)	0	139	0	0	1
350.000206	(sk,Q)	0	65	0	0	1
350.000209	(sk,Q)	0	94	0	0	1
350.000244	(sk,Q)	0	202	0	0	2
355.000100	(sk,Q)	0	16	0	0	3
375.000021	(sk,Q)	0	695	0	0	0
375.000045	(sk,Q)	0	1086	0	0	0
399.000158	(sk,Q)	0	70	0	0	16
399.000165	(sk,Q)	0	44	0	0	10
399.000167	(sk,Q)	0	29	0	0	6
399.000261	(sk,Q)	0	621	0	0	0
399.000410	(sk,Q)	0	70	0	0	1
375.000145	(sk,Q)	0	380	0	0	0
310.000066	(sk,Q)	0	586	0	0	0
315.000210	(sk,Q)	0	139	0	0	0
350.000004	(sk,Q)	0	1368	0	0	0
375.000464	(sk,Q)	0	600	0	0	0
310.000082	(sk,Q)	15	947	15	240	0
350.001126	(sk,Q)	0	29	0	0	1
350.001620	(sk,Q)	0	1	0	0	0
350.001621	(sk,Q)	0	6	0	0	0
345.000327	(sk,Q)	1	24	1	0	0
350.001205	(sk,Q)	2	99	2	150	1
350.001222	(sk,Q)	2	144	2	0	1
350.001223	(sk,Q)	1	162	1	0	1
350.001224	(sk,Q)	1	192	1	0	1
350.001230	(sk,Q)	1	103	1	0	1
350.001231	(sk,Q)	1	91	1	0	1
375.000109	(sk,Q)	3	1216	4	0	0
375.000110	(sk,Q)	8	2114	11	81	0
375.000187	(sk,Q)	5	932	6	81	0
375.000233	(sk,Q)	3	3941	4	0	0
375.000411	(sk,Q)	3	146	4	0	0
375.000413	(sk,Q)	1	106	1	81	0
375.000414	(sk,Q)	6	780	7	81	0
399.001522	(sk,Q)	1	26	1	80	0
399.001540	(sk,Q)	5	356	6	0	1
399.001541	(sk,Q)	3	301	4	0	1

Continued on next page

Table A.15 – Control parameters CZ-items dynamic

Item	Policy	Start ROP	Order quantity	End ROP	Annual demand (2018)	Lead time
350.001956	(sk,Q)	34	354	61	296	0
399.000555	(sk,Q)	34	1	61	0	0
315.001143	(sk,Q)	0	1	0	0	1
350.001044	(sk,Q)	0	14	0	0	1
350.001524	(sk,Q)	200	903	229	1256	1
310.000259	(sk,Q)	7	1806	9	110	0
310.000263	(sk,Q)	1249	1620	1320	998	9
335.000073	(sk,Q)	187	1081	187	0	6
310.000224	(sk,Q)	0	1	0	0	0
310.000261	(sk,Q)	0	679	0	55	0
370.000037	(sk,Q)	0	2	0	0	1
320.000178	(sk,Q)	0	1	0	1	0
335.000422	(sk,Q)	2	1	2	60	1
355.000913	(sk,Q)	0	1	0	1	2
370.000050	(sk,Q)	0	40	0	0	0
375.000421	(sk,Q)	0	1	0	2	0
335.000411	(sk,Q)	873	2113	2159	1750	6
350.000865	(sk,Q)	6	102	6	100	0
350.001585	(sk,Q)	6	168	6	100	1
370.000194	(sk,Q)	0	3	0	0	1
350.000601	(sk,Q)	29	1719	29	11068	1
350.000605	(sk,Q)	0	154	0	17	1
370.000110	(sk,Q)	0	1	0	0	0
335.000621	(sk,Q)	0	1	0	0	0
370.000205	(sk,Q)	0	1	0	0	8
375.000043	(sk,Q)	0	1	0	0	0
375.000383	(sk,Q)	0	1	0	0	1
375.000384	(sk,Q)	0	1	0	0	1
375.000416	(sk,Q)	526	3466	612	1584	0
399.001707	(sk,Q)	1	1	0	0	1
310.001743	(sk,Q)	0	34	0	25	1
310.001744	(sk,Q)	0	34	0	25	1
315.001242	(sk,Q)	1	123	1	75	0
340.001759	(sk,Q)	0	12	0	25	1
340.001760	(sk,Q)	0	45	0	40	1
365.000348	(sk,Q)	1	145	1	50	3
365.000349	(sk,Q)	1	456	1	50	3
315.001341	(sk,Q)	140	365	147	550	0
320.000978	(sk,Q)	42	196	42	50	0
335.000663	(sk,Q)	83	287	83	100	0
375.000530	(sk,Q)	167	573	167	260	0

Continued on next page

Table A.15 – Control parameters CZ-items dynamic

Item	Policy	Start ROP	Order quantity	End ROP	Annual demand (2018)	Lead time
399.002127	(sk,Q)	92	290	90	230	3
399.002128	(sk,Q)	92	849	90	232	3
340.000253	(sk,Q)	0	5	0	15	0
350.002091	(sk,Q)	8	466	11	200	0
350.002475	(sk,Q)	0	1	0	0	0
350.002476	(sk,Q)	0	1	0	0	3
350.002478	(sk,Q)	0	1	0	0	3
365.000431	(sk,Q)	0	25	0	0	5
365.000432	(sk,Q)	0	25	0	0	5
370.000301	(sk,Q)	0	1	0	0	3
399.002787	(sk,Q)	0	1	0	0	3
399.002788	(sk,Q)	0	1	0	0	3
399.002789	(sk,Q)	0	1	0	0	3
399.002792	(sk,Q)	0	1	0	0	16
350.001164	(sk,Q)	0	1	0	0	1
375.000038	(sk,Q)	0	1121	0	0	0
350.000033	(sk,Q)	0	74	0	0	0
399.001536	(sk,Q)	0	1	0	0	0
350.001280	(sk,Q)	4	1	5	55	0
350.001323	(sk,Q)	4	24	5	55	1
399.001594	(sk,Q)	4	1	5	55	0
399.001597	(sk,Q)	4	1	5	55	0
310.001082	(sk,Q)	186	9392	189	14962	1
310.001421	(sk,Q)	5	127	7	173	0
310.001422	(sk,Q)	2	1	2	57	0
310.001423	(sk,Q)	3	5	5	114	0
315.000943	(sk,Q)	17	4	26	439	2
315.001071	(sk,Q)	8	1	12	328	0
350.001278	(sk,Q)	3	1	5	72	3
310.001454	(sk,Q)	4	739	6	407	2
315.000113	(sk,Q)	3	992	4	1245	0
350.001277	(sk,Q)	3	200	4	77	0
350.000065	(sk,Q)	6	1	8	190	0
325.000722	(sk,Q)	7	544	11	475	0
350.001279	(sk,Q)	3	1	5	134	3
350.001332	(sk,Q)	3	25	5	70	2
315.001117	(sk,Q)	9	2058	14	732	0
315.001118	(sk,Q)	5	2281	9	127	2
315.001119	(sk,Q)	4	1	6	121	0
315.001120	(sk,Q)	4	1	6	121	0
315.001121	(sk,Q)	3	2380	4	301	2

Continued on next page

Table A.15 – Control parameters CZ-items dynamic

Item	Policy	Start ROP	Order quantity	End ROP	Annual demand (2018)	Lead time
315.001122	(sk,Q)	4	1132	6	351	0
315.001123	(sk,Q)	2	1278	3	534	0
315.001124	(sk,Q)	2	1	3	314	0
315.001125	(sk,Q)	2	674	3	404	0
315.001126	(sk,Q)	2	1	3	61	0
350.001369	(sk,Q)	2	1	3	77	0
399.002710	(sk,Q)	5	146	7	105	0
350.001796	(sk,Q)	2	226	3	120	1
350.002381	(sk,Q)	1	205	2	80	0
350.002382	(sk,Q)	1	137	1	40	0
315.001580	(sk,Q)	1	50	2	80	1
350.002384	(sk,Q)	1	59	1	40	0
355.001822	(sk,Q)	6	1	8	40	2
399.002672	(sk,Q)	30	230	41	520	0
399.002673	(sk,Q)	7	234	10	520	0
399.002675	(sk,Q)	7	145	10	260	0
399.002676	(sk,Q)	7	947	10	260	1
399.002678	(sk,Q)	11	619	15	390	1
399.002679	(sk,Q)	19	731	26	650	1
399.002680	(sk,Q)	7	478	10	260	1
399.002681	(sk,Q)	30	925	41	1040	1
399.002682	(sk,Q)	19	1023	26	650	1
399.002740	(sk,Q)	7	1651	10	260	1
350.000777	(sk,Q)	15	2236	11	80	1
310.000420	(sk,Q)	0	40	0	11	0
399.001974	(sk,Q)	1	143	1	0	0
350.001999	(sk,Q)	0	132	0	0	0
350.002000	(sk,Q)	0	96	0	0	0
375.000356	(sk,Q)	0	175	1	100	0
350.000031	(sk,Q)	0	18	0	0	1
399.002758	(sk,Q)	0	5	1	73	1
399.002805	(sk,Q)	0	5	0	35	1
350.000121	(sk,Q)	0	63	0	10	1
350.000956	(sk,Q)	0	89	0	10	0
350.000960	(sk,Q)	0	184	0	0	0
310.001608	(sk,Q)	0	5	0	0	0
335.000724	(sk,Q)	12	1	9	0	0
310.001643	(sk,Q)	1	1394	3	1444	0
335.000723	(sk,Q)	0	1	0	7260	0
350.001528	(sk,Q)	0	1	0	0	10
350.001529	(sk,Q)	0	1	0	0	10

Continued on next page

Table A.15 – Control parameters CZ-items dynamic

Item	Policy	Start ROP	Order quantity	End ROP	Annual demand (2018)	Lead time
350.001547	(sk,Q)	0	1	0	5	1
395.000432	(sk,Q)	0	1	0	0	0
395.000435	(sk,Q)	0	1	0	0	3
395.000436	(sk,Q)	0	1	0	0	4
395.000437	(sk,Q)	0	1	0	0	0
395.000438	(sk,Q)	7	1	10	0	0
350.001958	(sk,Q)	11	1	15	0	2
395.000425	(sk,Q)	0	1	0	0	0
395.000434	(sk,Q)	1	5	1	0	0
395.000439	(sk,Q)	1	5	1	0	0
395.000440	(sk,Q)	0	5	0	0	0
395.000449	(sk,Q)	0	1	0	0	1
395.000484	(sk,Q)	0	12	0	0	0
395.000486	(sk,Q)	3	75	3	0	3
395.000487	(sk,Q)	5	15	6	0	3
395.000488	(sk,Q)	7	1	10	0	0
365.000435	(sk,Q)	4	1	5	6	0
399.001964	(sk,Q)	2	1	2	0	0
399.002106	(sk,Q)	0	1	0	0	0
399.002193	(sk,Q)	1	1	1	0	0
399.002210	(sk,Q)	0	1	0	0	0
399.002205	(sk,Q)	1	1	1	0	0
399.002207	(sk,Q)	0	1	0	0	0
399.002212	(sk,Q)	0	1	0	0	0
399.002213	(sk,Q)	0	1	0	0	0
399.002239	(sk,Q)	10	1	10	0	0
395.000543	(sk,Q)	1	12	2	0	0
399.002267	(sk,Q)	0	2132	0	0	0
399.002354	(sk,Q)	0	2132	0	0	0
399.002356	(sk,Q)	0	2132	0	0	0
399.002358	(sk,Q)	0	1	0	0	0
399.002426	(sk,Q)	7	9511	12	900	0
335.001823	(sk,Q)	453	1	856	15000	0
335.001824	(sk,Q)	453	1	856	15000	0
335.001825	(sk,Q)	27	1	622	187200	0
399.002427	(sk,Q)	24	2132	26	150	0
350.000719	(sk,Q)	7	527	10	0	0
350.001666	(sk,Q)	7	520	10	0	1
350.001667	(sk,Q)	7	515	10	0	1
350.001668	(sk,Q)	22	101	29	0	5
399.001374	(sk,Q)	7	357	10	0	1

Continued on next page

Table A.15 – Control parameters CZ-items dynamic

Item	Policy	Start ROP	Order quantity	End ROP	Annual demand (2018)	Lead time
399.002004	(sk,Q)	11	3729	15	0	2
350.001961	(sk,Q)	4	72	5	0	0
399.002329	(sk,Q)	4	91	5	0	0
399.000279	(sk,Q)	5	230	8	385	0
399.002536	(sk,Q)	5	343	8	364	0
350.002474	(sk,Q)	0	2	2	416	3
325.000928	(sk,Q)	2	143	4	100	0
345.001653	(sk,Q)	2	74	4	105	0
399.000478	(sk,Q)	2	335	4	100	1
399.002559	(sk,Q)	2	174	4	100	0
399.002560	(sk,Q)	2	169	4	104	0
365.000409	(sk,Q)	2	1	2	0	1
399.002223	(sk,Q)	32	14460	34	3200	0
399.002442	(sk,Q)	2	1	2	0	0
350.001262	(sk,Q)	3	107	4	100	1
350.002003	(sk,Q)	11	447	15	400	0
399.002367	(sk,Q)	3	47	4	105	0
399.001391	(sk,Q)	1	1	2	0	0
399.002491	(sk,Q)	1	1	2	0	0
399.002808	(sk,Q)	72	1	175	1400	0
399.002795	(sk,Q)	0	1	0	355	1
399.002820	(sk,Q)	0	1	0	0	0
345.001624	(sk,Q)	4	221	6	0	0
350.000781	(sk,Q)	4	551	6	0	1
399.002534	(sk,Q)	50	985	81	0	0
315.001596	(sk,Q)	425	7	432	1900	0
320.001182	(sk,Q)	441	5	448	1970	0
350.002448	(sk,Q)	425	5	432	1901	0
399.002747	(sk,Q)	171	1	174	700	0
399.002749	(sk,Q)	425	2	432	1900	0
399.002534	(sk,Q)	50	1115	81	0	0
315.001596	(sk,Q)	425	7	432	1900	0
320.001182	(sk,Q)	441	5	448	1970	0
350.002448	(sk,Q)	425	5	432	1901	0
399.002747	(sk,Q)	171	1	174	700	0
399.002749	(sk,Q)	425	2	432	1900	0

A.15 Variance forecasting accuracy measures

Table A.16: Variance forecasting accuracy measures

	MAPE (%)	MAD	MSE	Bias
AX-items	289	759525	354246447606609	77390
AY-items	67	12469	578753282142	13134
AZ-items	69	2414	219366006	818
BX-items	411	73530	644206554867	26211
BY-items	42	1920756	195469419875227000	1497150
BZ-items	16	2778	3918809542	308
CX-items	546	65629	7324287078753	69443
CY-items	51	12404	1860204808354	12426
CZ-items	93031	50614	1593351722551030	43047

A.16 Forecast accuracy measures

A.16.1 Forecast accuracy measures AX-items

Table A.17: Forecast accuracy measures AX-items

Item	MAPE	MAD	MSE	Bias
395.000226	34	5	123	-4
365.000029	22	32	3907	-13
345.000163	7	3	119	-3
399.001703	12	44	4354	-1
399.001705	12	87	17417	-2
395.000384	29	4	80	-3
335.000692	2	9	84	8
370.000206	2	9	84	8
365.000334	2	9	92	9
335.000761	2	9	98	9
399.001967	2	9	98	9
399.002383	2	9	98	9
315.000062	87	4372	94173127	-4361
399.002455	16	76	9720	10
399.002456	16	76	9720	10
399.002457	16	152	38879	21
399.002461	16	76	9720	10
399.002462	16	152	38887	21
399.002463	16	76	9720	10
399.002464	16	76	9720	10

Continued on next page

Table A.17 – Results inventory ordering cost AX-items

Item	MAPE	MAD	MSE	Bias
399.002465	16	152	38879	21
399.002467	16	457	349911	62
399.002468	16	152	38879	21
399.002470	16	76	9720	10
399.002471	16	837	1176090	113
Average	16	278	3837581	-161
Variance	289	759525	354246447606609	766390

A.16.2 Forecast accuracy measures AY-items

Table A.18: Forecast accuracy measures AY-items

Item	MAPE	MAD	MSE	Bias
399.001521	12	32	1423	8
345.000317	9	26	1017	10
399.000608	43	32	1417	8
325.000179	9	39	16269	-39
365.000342	9	5	240	-5
350.001298	15	80	11674	3
350.001485	16	46	3932	0
365.000415	4	7	46	6
399.002628	5	7	46	6
315.001070	16	573	3808157	-568
399.001946	7	13	211	7
399.001948	3	4	35	2
399.002524	7	13	211	7
399.002428	6	10	173	5
399.002529	6	10	173	5
365.000337	9	11	159	5
365.000378	3	7	56	5
365.000379	10	6	79	0
350.001571	6	28	978	17
399.001848	7	20	693	10
399.001850	6	57	4250	32
350.002075	17	76	16215	-21
350.002076	17	75	15655	-21
350.002077	17	77	16976	-23
350.002078	17	76	16161	-22
Average	11	53	156650	-23
Variance	66,6	12469	5,79E+11	13134

A.16.3 Forecast accuracy measures AZ-items

Table A.19: Forecast accuracy measures AZ-items

Item	MAPE	MAD	MSE	Bias
320.000069	30	92	43512	-91
399.000063	5	1	1	0
350.002469	8	76	13014	12
350.002088	15	120	25997	6
350.002089	15	120	26056	6
399.002741	2	4	13	3
399.001601	4	7	938	-5
399.002670	2	0	0	0
399.002328	2	7	213	3
365.000380	7	10	1193	-9
399.002748	9	38	13343	-19
Average	9	43	11298	-8
Variance	69	2414	219366006	818

A.16.4 Forecast accuracy measures BX-items

Table A.20: Forecast accuracy measures BX-items

Item	MAPE	MAD	MSE	Bias
330.000006	12	65	19162	-13
350.000174	64	204	107564	-58
350.000176	23	94	35240	-42
399.000664	44	50	5927	-37
335.000009	0	11	147	11
350.001374	12	87	17417	-2
370.000229	2	9	84	8
399.001219	2	35	1351	34
350.001399	2	18	367	18
370.000249	2	9	98	9
399.001968	2	9	98	9
315.000574	53	620	2915458	-595
399.002481	16	457	349911	62
399.002483	16	914	1399644	123
399.002490	16	76	9720	10

Continued on next page

Table A.20 – Forecast accuracy measures BX-items

Item	MAPE	MAD	MSE	Bias
Average	18	177	324146	-31
Variance	411	73530	644206554867	26211

A.16.5 Forecast accuracy measures BY-items

Table A.21: Forecast accuracy measures BY-items

Item	MAPE	MAD	MSE	Bias
315.000084	12	24	4713	-10
399.000010	12	23	3961	-9
399.000014	10	10	308	0
370.000021	0	4	18	4
399.000154	0	5	23	5
399.000159	0	7	56	7
399.000160	0	7	56	7
399.001929	12	32	1416	8
315.001050	9	77	9186	30
315.001051	9	26	1017	10
315.001053	6	14	2850	-9
335.000676	6	7	839	-5
345.000315	9	26	1074	10
345.000318	15	15	1288	-12
350.001197	12	31	1621	4
350.001204	7	49	3568	24
350.001225	9	51	4070	20
350.001308	9	51	4076	20
315.001416	12	32	1418	8
345.000019	7	3	119	-3
345.000053	7	31	11661	-28
345.000161	7	3	119	-3
345.000162	7	3	119	-3
350.000735	11	20	4100	-18
399.000265	7	3	119	-3
315.000034	6	15	3495	-10
345.000164	6	5	326	-3
345.000165	6	4	187	-2
345.000166	6	4	187	-2
315.000563	9	5	256	-5
320.000186	9	10	1045	-10
350.000556	9	10	959	-10

Continued on next page

Table A.21 – Forecast accuracy measures BY-items

Item	MAPE	MAD	MSE	Bias
350.001185	9	10	986	-10
399.000691	9	10	959	-10
399.000700	9	24	5992	-24
350.000780	15	39	2929	1
335.000408	8	208	112521	15
335.000759	7	70	6142	38
335.000760	7	78	7878	40
350.001629	7	13	211	7
370.000267	7	52	3376	27
399.000213	9	16	706	4
399.001941	7	13	217	7
399.001942	7	41	2100	23
399.001945	7	13	211	7
370.000283	6	10	173	5
399.002430	6	10	173	5
399.002431	6	10	173	5
399.002530	6	10	173	5
399.001695	3	13	190	10
310.001593	7	5	45	1
355.001113	7	5	45	1
310.000994	49	10206	3248903564	-8988
350.001526	6	14	244	8
Average	8	213	60168764	-163
Variance	42	1920756	195469419875227000	1497150

A.16.6 Forecast accuracy measures BZ-items

Table A.22: Forecast accuracy measures BZ-items

Item	MAPE	MAD	MSE	Bias
345.001719	12	23	3952	-9
365.000008	9	1	1	0
365.000040	9	1	1	0
399.000060	9	1	1	0
399.001770	15	79	11519	3
315.001444	15	120	25886	6
399.002423	15	40	2897	2
335.000409	3	245	324716	60
355.000212	5	4	40	1
340.000507	9	76	53400	-38

Continued on next page

Table A.22 – Forecast accuracy measures BZ-items

Item	MAPE	MAD	MSE	Bias
350.001282	3	3	22	1
355.001053	4	1	5	0
355.001017	5	1	5	0
335.000651	7	21	12685	-19
355.001043	4	1	5	0
350.002372	4	3	133	-1
399.002665	2	3	32	1
399.002666	2	3	32	1
399.002667	2	3	32	1
399.002668	2	3	32	1
355.001307	7	5	305	-4
399.002219	7	10	1244	-9
350.002444	9	39	13570	-19
350.002445	9	38	13427	-19
350.002446	9	38	13343	-19
350.002447	9	38	13427	-19
399.002750	9	76	53373	-37
Average	7	32	20151	-4
Variance	16	2778	3918809542	308

A.16.7 Forecast accuracy measures CX-items

Table A.23: Forecast accuracy measures CX-items

Item	MAPE	MAD	MSE	Bias
350.000724	22	63	15629	-25
310.000249	9	6	471	-5
315.000614	7	3	144	-3
340.000251	17	6	198	-5
350.000135	10	12	658	-2
375.000044	80	139	31430	51
375.000071	68	214	51021	106
375.000106	152	254	73626	159
375.000200	8	163	35620	85
399.000022	5	6	46	3
399.000299	6	6	86	2
350.000043	0	9	92	9
350.000534	16	31	1825	11
350.000535	42	38	2061	-4
399.000163	16	96	11879	51

Continued on next page

Table A.23 – Forecast accuracy measures CX-items

Item	MAPE	MAD	MSE	Bias
310.000060	9	7	282	-3
399.000300	5	6	45	3
330.000020	55	34	4605	1
315.000209	19	29	1825	-8
320.000061	9	26	1168	8
375.000408	14	68	9072	2
315.000091	7	7	576	-6
315.000134	7	7	613	-7
350.000718	23	58	12940	-33
375.000081	17	68	8708	14
350.001373	11	56	5235	11
350.000964	2	9	84	8
370.000204	2	33	1256	33
375.000014	2	70	5415	67
375.000152	6	151	25320	127
375.000246	2	17	338	17
375.000291	2	103	11858	99
375.000382	2	17	338	17
375.000386	2	9	85	8
375.000389	2	123	16765	118
399.001221	0	3	9	3
399.001222	2	9	84	8
365.000335	2	9	92	9
375.000064	2	109	13219	105
350.000866	14	10	299	-1
365.000357	0	3	12	3
310.000719	48	2019	21826079	-2007
310.000727	43	423	1004331	-421
310.000545	47	383	779749	-382
310.000978	41	196	216380	-194
399.000331	5	7	188	1
375.000057	2	1	7	0
375.000063	17	54	20262	-52
375.000350	15	14	1131	-10
399.001868	16	28	2790	-13
399.001870	16	82	25116	-40
395.000518	16	7	174	-3
375.000046	13	16	2438	-13
399.002459	16	76	9720	10
399.002460	16	76	9720	10
399.002469	16	76	9720	10
399.002473	16	76	9720	10
399.002474	16	76	9720	10

Continued on next page

Table A.23 – Forecast accuracy measures CX-items

Item	MAPE	MAD	MSE	Bias
399.002475	16	76	9720	10
399.002476	16	228	87478	31
399.002479	16	76	9720	10
399.002480	16	76	9720	10
399.002485	16	76	9720	10
399.002494	15	75	9658	11
Average	18	99	381380	-31
Variance	546	65629	7,32E+12	69443

A.16.8 Forecast accuracy measures CY-items

Table A.24: Forecast accuracy measures CY-items

Item	MAPE	MAD	MSE	Bias
320.000095	12	25	4721	-10
399.000316	10	8	432	-3
375.000050	11	9	539	-2
399.000074	12	1	9	0
310.000204	14	17	2391	-14
310.000210	6	11	2090	-10
310.000229	5	6	193	0
315.000155	4	1	59	-1
320.000025	8	66	15277	12
340.000137	0	0	0	0
350.000213	28	36	6668	-24
350.000246	9	2	34	-2
350.000251	26	12	1565	-12
375.000017	8	3	146	-3
375.000065	21	31	7494	-28
399.000413	12	63	5667	16
310.000011	0	7	56	7
345.000052	0	5	23	5
375.000276	0	9	92	9
375.000463	0	9	92	9
399.000137	0	6	78	6
335.000021	9	7	535	-7
315.000132	0	5	23	5
335.000052	0	2	9	2
375.000353	9	5	304	-5
310.000113	0	7	56	7

Continued on next page

Table A.24 – Forecast accuracy measures CY-items

Item	MAPE	MAD	MSE	Bias
315.000211	0	7	56	7
375.000118	6	36	2331	14
399.000156	0	15	224	15
399.000157	0	7	56	7
350.001303	12	32	1416	8
310.001393	9	51	4070	20
310.001394	9	77	9157	30
310.001395	15	13	1061	-11
310.001397	6	2	34	-1
310.001398	6	4	137	-2
310.001399	6	2	34	-1
310.001400	6	3	210	-2
310.001446	6	3	210	-2
315.000030	16	53	8641	-17
315.001080	6	3	210	-2
330.000105	6	4	241	-3
350.001206	6	2	34	-1
350.001207	6	2	34	-1
350.001227	6	4	137	-2
350.001228	6	2	34	-1
350.001229	6	2	34	-1
375.000422	11	119	20496	37
399.001525	6	10	1250	-7
399.001526	5	13	1218	-4
399.001527	6	11	1232	-5
310.000002	7	3	119	-3
310.000003	7	3	119	-3
310.000004	7	3	119	-3
310.000372	7	3	144	-3
315.000131	7	3	119	-3
315.000214	7	3	138	-3
315.000285	7	7	576	-6
335.000011	14	6	337	-6
340.000252	17	5	166	-5
345.000024	11	23	5251	-19
345.000043	7	3	119	-3
345.000045	7	3	135	-3
350.000131	11	9	694	-6
350.000271	7	3	119	-3
350.000290	7	22	5822	-20
399.000023	17	6	215	-6
399.000033	13	5	233	-5
399.000263	7	6	475	-6

Continued on next page

Table A.24 – Forecast accuracy measures CY-items

Item	MAPE	MAD	MSE	Bias
350.000132	7	9	931	-5
350.000136	7	9	931	-5
399.000266	6	5	326	-3
310.000327	9	5	303	-5
315.000359	13	9	663	-9
315.000564	9	5	240	-5
315.000690	9	5	264	-5
315.000693	9	5	250	-5
320.000729	9	10	1158	-10
325.000180	9	5	302	-5
330.000088	9	5	288	-5
350.000752	9	5	240	-5
350.000815	9	10	959	-10
350.001186	9	5	240	-5
375.000018	0	0	0	0
399.000702	9	5	240	-5
399.000703	9	10	1013	-10
375.000028	17	7	338	-7
395.000233	9	5	240	-5
399.001842	9	5	256	-5
330.000100	12	92	20726	-7
350.000700	5	11	349	3
310.000211	11	41	6956	-2
335.000071	4	171	132692	44
370.000055	6	0	4	0
330.000021	0	0	0	0
375.000203	7	10	808	-4
350.000046	16	39	16370	-37
399.000877	2	0	0	0
350.000912	3	3	22	1
399.000310	11	4	50	0
310.001008	11	37	25950	-35
310.001077	27	46	10046	-15
315.000817	27	695	4689364	-692
315.000949	6	12	474	2
315.000581	23	216	701152	-214
315.000988	16	30	10720	-27
310.001079	32	378	1043815	-372
315.000624	30	174	207296	-172
335.000662	6	56	49472	-50
310.000717	41	1012	16663666	-1001
310.000721	34	357	1089060	-353
315.000821	9	22	6765	-18

Continued on next page

Table A.24 – Forecast accuracy measures CY-items

Item	MAPE	MAD	MSE	Bias
375.000007	2	13	390	9
315.001252	7	39	1899	21
350.002136	7	13	211	7
395.000480	7	13	211	7
399.000101	10	24	810	12
399.001943	7	52	3376	27
399.001944	7	13	211	7
370.000284	6	10	173	5
315.000666	5	7	188	1
350.000590	5	7	188	1
350.000604	6	19	1600	4
350.000611	5	9	382	1
350.000779	5	7	188	1
350.000858	5	43	5385	12
350.000934	5	51	9718	11
350.001115	5	7	188	1
350.001116	5	7	188	1
350.001117	5	17	1528	3
399.000247	5	9	382	1
399.000330	5	7	188	1
399.001396	5	9	382	1
399.001464	5	9	382	1
375.000107	8	37	21906	-35
375.000295	26	222	281320	-221
399.001900	3	7	51	5
399.002041	3	13	190	10
310.001594	7	9	198	3
310.001595	7	6	131	0
310.001596	7	9	182	3
320.000384	7	10	208	2
330.000109	7	10	217	2
399.001815	8	5	48	1
399.001901	7	6	139	0
310.000871	43	643	5984538	-643
350.000288	9	44	25474	-44
310.001609	0	0	0	0
350.001545	16	14	698	-7
350.001546	16	14	698	-7
375.000473	16	28	2805	-14
375.000474	17	59	13416	-31
375.000475	17	58	12921	-30
399.001867	16	14	704	-7
399.001871	16	14	698	-7

Continued on next page

Table A.24 – Forecast accuracy measures CY-items

Item	MAPE	MAD	MSE	Bias
335.000798	14	17	910	-3
335.000799	14	17	910	-3
315.000599	13	35	1810	6
399.001849	6	14	244	8
399.001853	6	28	978	17
399.001858	6	14	244	8
399.001859	6	14	244	8
399.001860	6	14	244	8
399.001861	6	14	244	8
399.001862	6	14	244	8
399.001863	6	14	244	8
399.001864	6	14	244	8
399.001865	6	14	244	8
399.002021	6	14	244	8
399.002022	6	14	244	8
399.002023	6	14	244	8
350.000256	5	3	31	1
375.000039	7	5	192	-2
399.002150	6	34	2237	13
375.000553	11	20	1875	-9
375.000554	11	20	1875	-9
375.000555	11	20	1875	-9
399.002477	16	152	38879	21
399.002484	15	64	6808	8
399.002488	12	26	1324	3
Average	9	37	173546	-22
Variance	51	12404	1860204808354	12426

A.16.9 Forecast accuracy measures CZ-items

Table A.25: Forecast accuracy measures CZ-items

Item	MAPE	MAD	MSE	Bias
315.000088	2	5	104	3
399.000067	0	20	406	20
315.000080	10	22	4698	-11
310.000347	2	0	0	0
370.000043	0	3	11	3
375.000030	9	1	1	0
375.000031	9	1	1	0

Continued on next page

Table A.25 – Forecast accuracy measures CZ-items

Item	MAPE	MAD	MSE	Bias
375.000099	9	1	1	0
375.000111	9	2	5	0
375.000112	9	2	13	0
399.000061	2	0	0	0
399.000065	9	1	1	0
399.000066	9	0	0	0
310.000342	4	0	1	0
310.000349	5	1	1	0
310.000346	0	0	0	0
399.000064	0	0	0	0
310.000188	0	0	0	0
310.000206	0	0	0	0
310.000222	6	8	1150	-7
310.000234	0	6	33	6
310.000236	0	0	0	0
310.000238	4	5	1177	-5
310.000257	0	0	0	0
310.000353	8	4	272	-4
310.000397	0	0	0	0
310.000398	0	0	0	0
310.000680	0	0	0	0
315.000064	2	1	14	0
315.000154	0	0	0	0
315.000284	0	0	0	0
320.000026	4	1	30	-1
320.000043	0	0	0	0
330.000019	0	0	0	0
330.000023	0	0	0	0
335.000002	6	6	599	-6
335.000386	0	0	0	0
340.000130	4	1	31	-1
340.000213	2	2	114	-1
340.000301	0	0	0	0
340.000304	0	0	0	0
340.000305	0	0	0	0
345.000001	0	0	0	0
350.000206	0	0	0	0
350.000209	0	0	0	0
350.000244	0	0	0	0
355.000100	0	0	0	0
375.000021	0	0	0	0
375.000045	0	0	0	0
399.000158	0	0	0	0

Continued on next page

Table A.25 – Forecast accuracy measures CZ-items

Item	MAPE	MAD	MSE	Bias
399.000165	0	0	0	0
399.000167	0	0	0	0
399.000261	0	0	0	0
399.000410	0	0	0	0
375.000145	0	0	0	0
310.000066	0	0	0	0
315.000210	0	0	0	0
350.000004	0	0	0	0
375.000464	0	0	0	0
310.000082	0	7	56	7
350.001126	0	0	0	0
350.001620	0	0	0	0
350.001621	0	0	0	0
345.000327	0	1	0	1
350.001205	6	4	137	-2
350.001222	0	1	1	1
350.001223	0	1	0	1
350.001224	0	1	0	1
350.001230	0	1	0	1
350.001231	0	1	0	1
375.000109	0	2	3	2
375.000110	5	6	50	3
375.000187	5	4	40	1
375.000233	0	2	3	2
375.000411	0	2	3	2
375.000413	6	2	40	-1
375.000414	5	4	42	2
399.001522	6	2	39	-1
399.001540	0	3	7	3
399.001541	0	2	3	2
350.001956	11	27	910	16
399.000555	5051	23	554	23
315.001143	0	0	0	0
350.001044	0	0	0	0
350.001524	15	40	2897	2
310.000259	3	6	244	1
310.000263	5	53	18354	7
335.000073	0	27	711	27
310.000224	0	0	0	0
310.000261	2	1	68	-1
370.000037	0	0	0	0
320.000178	0	0	0	0
335.000422	0	1	1	1

Continued on next page

Table A.25 – Forecast accuracy measures CZ-items

Item	MAPE	MAD	MSE	Bias
355.000913	0	0	0	0
370.000050	0	0	0	0
375.000421	0	0	0	0
335.000411	0	196	41848	196
350.000865	4	6	364	-1
350.001585	4	7	364	-1
370.000194	0	0	0	0
350.000601	6	202	1085791	-202
350.000605	2	0	0	0
370.000110	0	0	0	0
335.000621	0	0	0	0
370.000205	0	0	0	0
375.000043	0	0	0	0
375.000383	0	0	0	0
375.000384	0	0	0	0
375.000416	2	144	23380	142
399.001707	0	0	0	0
310.001743	2	1	12	0
310.001744	2	1	12	0
315.001242	2	2	105	-1
340.001759	2	1	12	0
340.001760	4	1	16	-1
365.000348	2	1	47	-1
365.000349	2	1	47	-1
315.001341	5	17	989	5
320.000978	4	2	26	0
335.000663	4	4	103	0
375.000530	5	8	452	-1
399.002127	7	7	157	1
399.002128	7	7	157	1
340.000253	2	0	4	0
350.002091	2	6	192	3
350.002475	0	0	0	0
350.002476	0	0	0	0
350.002478	0	0	0	0
365.000431	0	0	0	0
365.000432	0	0	0	0
370.000301	0	0	0	0
399.002787	0	0	0	0
399.002788	0	0	0	0
399.002789	0	0	0	0
399.002792	0	0	0	0
350.001164	0	0	0	0

Continued on next page

Table A.25 – Forecast accuracy measures CZ-items

Item	MAPE	MAD	MSE	Bias
375.000038	2	2	228	-2
350.000033	2	0	3	0
399.001536	0	0	0	0
350.001280	3	3	22	1
350.001323	3	3	22	1
399.001594	3	3	22	1
399.001597	3	3	22	1
310.001082	14	196	963658	-189
310.001421	4	5	145	1
310.001422	4	2	16	0
310.001423	4	3	64	0
315.000943	4	12	953	1
315.001071	8	9	410	0
350.001278	4	2	22	0
310.001454	9	9	2065	-6
315.000113	9	20	8927	-17
350.001277	5	3	22	1
350.000065	2	5	160	2
325.000722	6	10	705	-2
350.001279	4	2	21	0
350.001332	4	2	51	0
315.001117	7	13	1268	-3
315.001118	5	4	60	1
315.001119	4	4	60	1
315.001120	4	4	60	1
315.001121	9	8	726	-6
315.001122	5	8	1040	-4
315.001123	7	11	2712	-9
315.001124	4	2	15	0
315.001125	7	3	72	-1
315.001126	4	2	15	0
350.001369	4	2	30	0
399.002710	4	5	94	1
350.001796	2	4	269	-1
350.002381	2	2	119	-1
350.002382	2	1	30	0
315.001580	2	2	119	-1
350.002384	2	1	30	0
355.001822	2	3	32	1
399.002672	2	20	703	15
399.002673	2	7	479	1
399.002675	2	6	129	3
399.002676	2	6	129	3

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Table A.25 – Forecast accuracy measures CZ-items

Item	MAPE	MAD	MSE	Bias
399.002678	2	9	290	4
399.002679	2	14	804	7
399.002680	2	6	129	3
399.002681	2	23	2059	12
399.002682	2	14	804	7
399.002740	2	6	129	3
350.000777	5	9	382	1
310.000420	0	0	4	0
399.001974	0	1	61	1
350.001999	0	0	2	0
350.002000	0	0	2	0
375.000356	0	1	27	1
350.000031	0	0	0	0
399.002758	4	2	51	-1
399.002805	2	1	23	-1
350.000121	0	0	0	0
350.000956	0	0	0	0
350.000960	0	0	0	0
310.001608	0	0	0	0
335.000724	0	6	35	6
310.001643	4	20	11621	-18
335.000723	2	137	994483	-137
350.001528	0	0	0	0
350.001529	0	0	0	0
350.001547	2	0	0	0
395.000432	0	0	0	0
395.000435	0	0	0	0
395.000436	0	0	0	0
395.000437	0	0	0	0
395.000438	0	4	18	4
350.001958	0	4	18	4
395.000425	0	0	0	0
395.000434	0	0	0	0
395.000439	0	0	0	0
395.000440	0	0	0	0
395.000449	0	0	0	0
395.000484	0	0	0	0
395.000486	0	1	1	1
395.000487	0	1	2	1
395.000488	0	4	18	4
365.000435	1	2	5	2
399.001964	0	1	1	1
399.002106	0	0	0	0

Continued on next page

Table A.25 – Forecast accuracy measures CZ-items

Item	MAPE	MAD	MSE	Bias
399.002193	0	1	0	1
399.002210	0	0	0	0
399.002205	0	1	1	1
399.002207	0	0	0	0
399.002212	0	0	0	0
399.002213	0	0	0	0
399.002239	0	5	27	5
395.000543	0	1	0	1
399.002267	0	0	0	0
399.002354	0	0	0	0
399.002356	0	0	0	0
399.002358	0	0	0	0
399.002426	4	13	1921	-4
335.001823	0	322	107041	322
335.001824	0	322	107041	322
335.001825	2	3684	660751430	-3378
399.002427	4	14	225	9
350.000719	0	4	18	4
350.001666	0	4	18	4
350.001667	0	4	18	4
350.001668	0	4	18	4
399.001374	0	4	18	4
399.002004	0	4	18	4
350.001961	0	2	4	2
399.002329	0	2	4	2
399.000279	4	8	691	-2
399.002536	4	8	638	-2
350.002474	2	8	3264	-8
325.000928	4	3	91	0
345.001653	4	3	101	-1
399.000478	4	3	91	0
399.002559	4	3	91	0
399.002560	4	3	99	-1
365.000409	0	1	1	1
399.002223	11	92	73508	-63
399.002442	0	1	1	1
350.001262	4	3	91	0
350.002003	4	14	1456	-1
399.002367	4	4	100	0
399.001391	0	1	0	1
399.002491	0	1	0	1
399.002808	10	75	9284	24
399.002795	6	7	1119	-7

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Table A.25 – Forecast accuracy measures CZ-items

Item	MAPE	MAD	MSE	Bias
399.002820	0	0	0	0
345.001624	0	3	7	3
350.000781	0	3	7	3
399.002534	0	32	1060	32
315.001596	9	38	13343	-19
320.001182	9	39	14220	-20
350.002448	9	38	13349	-19
399.002747	6	15	1958	-6
399.002749	9	38	13343	-19
Average	21	24	2424450	-10
Variance	93031	50614	1593351722551030	43047

A.17 Results total inventory value proposed policies

A.17.1 Results AX-items

A.17.2 Results AY-items

Table A.27: Results AY-items

Item	**# out of stock**	**Inventory proposed policy**	**Inventory current policy**	**# orders**	**Annual demand**	**Improvement (euro)**
399.001521	3	259	199	12	802	-1762
345.000317	3	313	450	4	575	750
399.000608	5	132	700	5	801	1051
325.000179	9	793	698	2	2074	-110
365.000342	0	15	77	5	252	848
350.001298	0	611	547	5	2515	-90
350.001485	0	416	310	4	1517	-213
365.000415	0	58	40	4	60	-385
399.002628	0	47	44	10	72	-200
315.001070	0	2179	11325	5	30274	2618
399.001946	0	187	235	1	210	434
399.001948	0	72	79	1	60	189
399.002524	0	182	231	1	210	961
399.002428	0	160	83	2	180	-2013
399.002529	0	103	117	5	180	260
365.000337	0	140	105	4	266	-156
365.000378	0	111	94	2	90	-194
365.000379	0	75	98	4	197	241

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Table A.27 – Results AY-items

Item	# out of stock	Inventory proposed policy	Inventory current policy	# orders	Annual demand	Improvement (euro)
350.001571	0	326	337	2	400	52
399.001848	2	168	158	6	355	-98
399.001850	1	653	262	5	855	-582
350.002075	8	253	451	12	2884	1273
350.002076	15	234	463	12	2850	1153
350.002077	8	279	518	11	2965	1064
350.002078	9	340	522	9	2910	954

A.17.3 Results AZ-items

Table A.28: Results AZ-items static

Item	# out of stock	Inventory proposed policy	Inventory current policy	# orders	Annual demand	Improvement (euro)
320.000069	0	1719,54717	2518,964	0	5048	463,6617615
399.000063	2	14,17523774	7,143	1	12	-2427,247179
350.002469	11	549,4111154	1010,833	41	1935	530,6351673
350.002088	0	779,0959213	625,444	11	3754	-170,5536327
350.002089	4	802,5210396	624,158	11	3758	-347,8079273
399.002741	0	27,04513913	40	3	20	3135,076331
399.001601	2	75,27372518	164,4	2	316	891,2627482
399.002670	0	6,333740149	11,5	1	5	176,9443999
399.002328	0	113,8459998	54,5	2	105	-474,7679986
365.000380	16	56,53151022	90,5	5	506	208,9062121
399.002748	0	930,0754717	1490,8	0	1800	813,050566

Table A.29: Results AZ-items dynamic

Item	# out of stock	Inventory proposed policy	Inventory current policy	# orders	Annual demand	Improvement (euro)
320.000069	0	1720	2519	0	5048	464
399.000063	2	14	7	1	12	-2204
350.002469	14	296	1011	6	1935	823

Continued on next page

Table A.29 – Results AZ-items dynamic

Item	# out of stock	Inventory proposed policy	Inventory current policy	# orders	Annual demand	Improvement (euro)
350.002088	4	766	625	11	3754	-156
350.002089	6	760	624	10	3758	-265
399.002741	0	15	40	9	20	6073
399.001601	2	72	164	2	316	927
399.002670	0	3	12	1	5	278
399.002328	0	95	55	2	105	-327
365.000380	16	45	91	4	506	282
399.002748	0	970	1491	3	1800	755

A.17.4 Results BX-items

Table A.30: Results BX-items

Item	# out of stock	Inventory proposed policy	Inventory current policy	# orders	Annual demand	Improvement (euro)
330.000006	11	205	3604	2	2824	408
350.000174	6	3586	4715	1	10083	34
350.000176	25	876	3122	3	5590	281
399.000664	0	27392	14971	0	2755	0
335.000009	0	396	902	0	0	238
350.001374	18	770	1146	2	2720	132
370.000229	0	158	28	4	68	-651
399.001219	0	1076	527	3	272	-698
350.001399	0	419	100	3	136	-446
370.000249	0	167	33	4	68	-669
399.001968	0	110	26	6	68	-1341
315.000574	0	14632	8900	0	38263	0
399.002481	0	38827	6389	1	16050	-616
399.002483	0	45860	10283	1	32100	-889
399.002490	0	1167	870	3	2675	-57

A.17.5 Results BY-items

Table A.26: Resuls AX-items

Item	**# out of stock**	**Inventory proposed policy**	**Inventory current policy**	**#Orders**	**Annual demand**	**Improvement (euro)**
395.000226	0	250	292	0	267	293
365.000029	0	1030	1379	0	1780	412
345.000163	41	15	40	5	160	194
399.001703	3	246	284	5	1360	117
399.001705	9	553	549	4	2720	-3
395.000384	20	19	100	7	203	3730
335.000692	0	43	56	4	68	311
370.000206	0	28	62	3	68	568
365.000334	0	64	44	2	68	-1821
335.000761	0	68	48	4	68	-3843
399.001967	0	37	58	4	68	508
399.002383	0	109	64	3	68	-11499
315.000062	3	23696	86997	3	248123	804
399.002455	4	227	508	10	2675	1046
399.002456	4	204	547	10	2675	2069
399.002457	2	1298	1940	4	5350	739
399.002461	5	240	515	9	2675	1756
399.002462	4	451	990	10	5351	2240
399.002463	2	298	479	9	2675	207
399.002464	8	379	444	9	2675	60
399.002465	6	689	957	9	5350	181
399.002467	4	2654	3789	9	16050	306
399.002468	2	601	1278	7	5350	405
399.002470	3	311	540	7	2675	983
399.002471	7	6588	5367	4	29425	-79

Table A.31: Results BY-items

Item	# out of stock	Inventory proposed policy	Inventory current policy	# orders	Annual demand	Improvement (euro)
315.000084	0	819	385	6	976	-130
399.000010	7	467	469	13	911	1
399.000014	0	216	389	1	314	154
370.000021	0	133	253	0	0	153
399.000154	0	120	205	0	0	162
399.000159	0	258	282	0	0	90
399.000160	0	151	147	0	0	0
399.001929	0	236	551	1	800	397
315.001050	2	792	1180	2	1728	49
315.001051	0	353	641	2	575	303
315.001053	0	501	293	2	825	-177
335.000676	0	244	295	2	450	86
345.000315	0	371	353	2	593	-14
345.000318	19	82	320	4	902	345
350.001197	1	386	423	2	875	21
350.001204	1	448	715	2	950	264
350.001225	1	448	702	2	1150	129
350.001308	0	611	791	3	1151	34
315.001416	1	156	361	3	800	100
345.000019	0	71	59	8	160	-92
345.000053	0	209	777	3	1584	216
345.000161	13	29	73	12	160	369
345.000162	15	25	55	14	160	252
350.000735	0	492	1030	2	1023	592
399.000265	2	13	37	7	160	99
315.000034	3	69	203	5	684	126
345.000164	21	48	56	14	211	61
345.000165	7	39	52	13	172	106
345.000166	7	30	56	13	172	221
315.000563	12	159	64	1	260	-445
320.000186	23	96	273	6	524	224
350.000556	0	108	221	3	504	65
350.001185	9	56	170	3	511	157
399.000691	0	564	454	0	504	0
399.000700	0	791	870	0	1260	29
350.000780	0	464	492	2	1348	21
335.000408	0	2776	4600	5	5750	260
335.000759	0	977	1222	2	1135	174
335.000760	0	1005	1160	3	1296	76

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Table A.31 – Results BY-items

Item	**# out of stock**	**Inventory proposed policy**	**Inventory current policy**	**# orders**	**Annual demand**	**Improvement (euro)**
350.001629	0	121	233	0	210	175
370.000267	0	992	1903	0	840	574
399.000213	0	246	404	1	385	182
399.001941	0	151	268	0	214	181
399.001942	0	576	873	0	660	502
399.001945	0	183	224	1	210	272
370.000283	0	182	179	0	180	0
399.002430	0	98	130	4	180	83
399.002431	0	140	118	1	180	-72
399.002530	0	94	123	6	180	134
399.001695	0	224	102	1	150	-264
310.001593	0	222	202	0	125	0
355.001113	0	73	29	3	125	-194
310.000994	2	111495	120071	2	518626	8
350.001526	0	115	110	7	200	-26

A.17.6 Results BZ-items

Table A.32: Results BZ-items static

Item	**# out of stock**	**Inventory proposed policy**	**Inventory current policy**	**# orders**	**Annual demand**	**Improvement (euro)**
345.001719	50	0	421	53	907	290
365.000008	0	10	53	1	20	887
365.000040	0	41	39	0	20	0
399.000060	0	40	38	0	20	0
399.001770	11	353	717	8	2500	145
315.001444	0	676	936	3	3748	42
399.002423	2	185	209	3	1253	9
335.000409	0	1584	7283	2	5200	1140
355.000212	8	17	17	6	74	15
340.000507	44	106	1397	45	3600	191
350.001282	30	4	16	35	47	74
355.001053	25	2	8	25	23	319
355.001017	16	2	8	11	27	291
335.000651	4	377	783	1	1085	70
355.001043	24	2	12	24	22	533

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Table A.32 – Results BZ-items static

Item	# out of stock	Inventory proposed policy	Inventory current policy	# orders	Annual demand	Improvement (euro)
350.002372	6	17	59	2	115	257
399.002665	0	195	200	0	40	57
399.002666	0	195	200	0	40	11
399.002667	0	195	200	0	40	16
399.002668	0	195	200	0	40	13
355.001307	13	33	54	5	256	137
399.002219	0	59	196	4	516	164
350.002444	44	28	676	53	1833	109
350.002445	44	73	653	53	1803	229
350.002446	44	51	692	53	1800	226
350.002447	44	66	726	53	1803	192
399.002750	44	56	1527	53	3600	413

Table A.33: Results BZ-items dynamic

Item	# out of stock	Inventory proposed policy	Inventory current policy	# orders	Annual demand	Improvement (euro)
345.001719	50	0	421	53	907	290
365.000008	0	10	53	1	20	887
365.000040	0	41	39	0	20	0
399.000060	0	40	38	0	20	0
399.001770	0	544	717	9	2500	69
315.001444	0	1111	936	3	3748	-28
399.002423	0	424	209	3	1253	-86
335.000409	0	5564	7283	7	5200	344
355.000212	8	17	17	6	74	15
340.000507	44	152	1397	53	3600	184
350.001282	29	4	16	37	47	72
355.001053	25	2	8	25	23	319
355.001017	15	2	8	12	27	276
335.000651	4	377	783	1	1085	70
355.001043	24	2	12	24	22	533
350.002372	6	17	59	2	115	257
399.002665	0	195	200	0	40	57
399.002666	0	195	200	0	40	11
399.002667	0	195	200	0	40	16
399.002668	0	195	200	0	40	13

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Table A.33 – Results BZ-items dynamic

Item	# out of stock	Inventory proposed policy	Inventory current policy	# orders	Annual demand	Improvement (euro)
355.001307	13	33	54	5	256	137
399.002219	0	59	196	4	516	164
350.002444	44	28	676	53	1833	109
350.002445	44	73	653	53	1803	229
350.002446	44	51	692	53	1800	226
350.002447	44	66	726	53	1803	192
399.002750	44	56	1527	53	3600	413

A.17.7 Results CX-items

Table A.34: Results CX-items

Item	# out of stock	Inventory proposed policy	Inventory current policy	# orders	Annual demand	Improvement (euro)
350.000724	0	1199	1767	1	3560	13
310.000249	0	5600	5287	0	297	0
315.000614	0	541	537	0	176	0
340.000251	0	111	133	1	314	2
350.000135	2	222	518	1	413	59
375.000044	1	7854	4210	1	4003	-12
375.000071	1	8232	5565	1	6290	-12
375.000106	0	5038	6945	1	7884	21
375.000200	0	2973	5863	0	3435	93
399.000022	0	341	415	0	100	18
399.000299	0	267	345	0	150	7
350.000043	0	1141	490	0	0	0
350.000534	0	1011	1514	0	816	8
350.000535	0	1276	3039	1	1812	62
399.000163	0	7451	7028	0	2788	0
310.000060	0	5554	5305	0	277	0
399.000300	0	304	328	0	100	2
330.000020	1	476	980	1	1198	41
315.000209	0	750	1269	1	1180	78
320.000061	0	655	947	1	658	20
375.000408	1	2652	1581	1	2080	-11
315.000091	0	1111	1104	0	352	0
315.000134	0	171	526	2	363	49

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Table A.34 – Results CX-items

Item	# out of stock	Inventory proposed policy	Inventory current policy	# orders	Annual demand	Improvement (euro)
350.000718	1	1448	1841	1	2805	8
375.000081	0	1469	1243	1	2235	-4
350.001373	1	967	1444	1	1560	17
350.000964	0	252	239	0	68	0
370.000204	0	268	408	0	272	5
375.000014	0	503	1190	0	598	9
375.000152	0	2904	3711	0	2031	34
375.000246	0	737	709	0	148	0
375.000291	0	1021	2199	0	892	20
375.000382	0	590	577	0	148	0
375.000386	0	94	861	0	74	124
375.000389	0	1635	1778	1	1030	6
399.001221	0	21	12	1	0	-466
399.001222	0	214	200	0	68	0
365.000335	0	8208	35	1	68	-8
375.000064	0	824	1686	0	892	5
350.000866	0	1172	1155	0	360	0
365.000357	0	63	12	1	0	-1111
310.000719	1	28783	47638	1	112035	30
310.000727	0	13471	15136	1	22571	2
310.000545	0	9696	6420	1	20637	-7
310.000978	1	7092	14106	1	10462	28
399.000331	1	75	128	1	170	7
375.000057	0	120	120	0	5	0
375.000063	0	5905	2441	1	2831	-20
375.000350	1	1173	353	1	645	-11
399.001868	0	389	919	0	1334	1
399.001870	0	2844	2841	1	4002	0
395.000518	5	4097	265	1	331	-4
375.000046	0	426	995	0	774	18
399.002459	0	1132	1646	1	2675	14
399.002460	0	3295	1655	1	2675	-6
399.002469	0	4945	512	1	2675	-4
399.002473	0	5364	851	1	2675	-5
399.002474	0	5858	656	1	2675	-5
399.002475	1	4987	1748	1	2675	-39
399.002476	0	6628	4737	1	8025	-34
399.002479	0	3295	1909	1	2675	-28
399.002480	0	2579	1884	1	2675	-21
399.002485	0	5606	771	1	2675	-5

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Table A.34 – Results CX-items

Item	# out of stock	Inventory proposed policy	Inventory current policy	# orders	Annual demand	Improvement (euro)
399.002494	1	5884	837	1	2619	-5

A.17.8 Results CY-items

Table A.35: Results CY-items

Item	# out of stock	Inventory proposed policy	Inventory current policy	# orders	Annual demand	Improvement (euro)
320.000095	12	127	490	3	978	51
399.000316	0	85	156	0	287	7
375.000050	0	665	699	0	329	2
399.000074	0	914	906	0	44	0
310.000204	1	1648	459	1	830	-12
310.000210	0	4586	4320	0	542	0
310.000229	0	1477	342	1	172	-28
315.000155	0	694	31	1	65	-27
320.000025	1	3740	500	1	1743	-23
340.000137	0	0	156	0	0	445
350.000213	0	1991	1502	0	1720	0
350.000246	0	125	163	0	82	8
350.000251	0	770	783	0	652	2
375.000017	0	3539	3546	0	176	0
375.000065	0	966	1015	1	1580	1
399.000413	1	548	458	2	1600	-10
310.000011	0	57	208	0	0	105
345.000052	0	525	496	0	0	0
375.000276	0	983	464	0	0	0
375.000463	0	1524	464	0	0	0
399.000137	0	1623	997	0	0	0
335.000021	0	1885	1835	0	361	0
315.000132	0	199	331	0	0	88
335.000052	0	289	362	0	0	7
375.000353	0	497	426	0	275	0
310.000113	0	1396	1308	0	0	0
315.000211	0	188	233	0	0	6
375.000118	0	842	1017	0	704	5
399.000156	0	252	382	0	0	38

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Table A.35 – Results CY-items

Item	# out of stock	Inventory proposed policy	Inventory current policy	# orders	Annual demand	Improvement (euro)
399.000157	0	265	300	0	0	12
350.001303	0	414	308	1	800	-15
310.001393	1	732	1850	1	1150	130
310.001394	0	1003	1410	1	1725	31
310.001395	1	350	265	1	750	-12
310.001397	1	158	48	1	75	-23
310.001398	0	243	110	1	150	-22
310.001399	0	134	55	1	75	-23
310.001400	1	208	76	1	225	-16
310.001446	1	172	70	1	225	-20
315.000030	0	563	1354	1	2436	49
315.001080	0	68	83	0	225	10
330.000105	0	75	92	0	241	11
350.001206	0	36	32	0	75	0
350.001207	1	102	175	1	75	37
350.001227	0	109	101	0	150	0
350.001228	1	78	86	1	75	5
350.001229	0	67	63	0	75	0
375.000422	1	3113	2621	1	2860	-7
399.001525	1	441	265	1	450	-7
399.001526	0	244	206	1	450	-23
399.001527	0	217	191	1	450	-14
310.000002	0	281	333	0	160	5
310.000003	0	322	337	0	160	1
310.000004	0	944	903	0	160	0
310.000372	0	1859	1856	0	176	0
315.000131	2	49	53	2	160	4
315.000214	0	1190	1187	0	172	0
315.000285	2	104	463	2	352	43
335.000011	0	328	343	0	323	2
340.000252	1	108	98	1	255	-1
345.000024	3	192	469	3	1130	60
345.000043	12	38	499	3	160	419
345.000045	12	29	486	3	170	416
350.000131	4	91	243	3	413	85
350.000271	0	529	522	0	160	0
350.000290	2	497	1477	2	1120	14
399.000023	2	92	191	2	330	66
399.000033	2	97	170	2	285	28
399.000263	0	635	620	0	320	0
350.000132	5	66	256	3	383	161

Continued on next page

Table A.35 – Results CY-items

Item	# out of stock	Inventory proposed policy	Inventory current policy	# orders	Annual demand	Improvement (euro)
350.000136	4	74	218	2	383	42
399.000266	23	26	148	5	211	215
310.000327	1	186	121	1	283	-4
315.000359	0	438	151	1	467	-32
315.000564	0	120	192	1	252	59
315.000690	4	101	352	1	264	67
315.000693	0	245	163	0	257	0
320.000729	1	261	178	1	554	-4
325.000180	5	93	112	3	279	15
330.000088	2	132	754	2	276	54
350.000752	0	184	203	0	252	4
350.000815	3	220	232	1	504	3
350.001186	3	141	116	1	252	-27
375.000018	0	300	300	0	0	0
399.000702	0	114	129	1	252	12
399.000703	3	126	148	3	518	6
375.000028	0	244	526	1	354	11
395.000233	0	1848	1793	0	252	0
399.001842	6	37	301	3	260	221
330.000100	1	661	1285	1	2964	28
350.000700	0	173	56	1	219	-58
310.000211	1	1502	953	1	1308	-5
335.000071	0	6412	5408	0	3600	0
370.000055	0	110	54	0	20	0
330.000021	0	37	32	0	0	0
375.000203	0	277	552	0	407	11
350.000046	0	515	931	1	2046	47
399.000877	0	742	764	0	2	0
350.000912	0	36	23	1	47	-2
399.000310	0	714	593	0	130	0
310.001008	1	7772	4221	1	2126	-3
310.001077	0	4169	4069	0	1736	0
315.000817	2	11252	12861	2	36773	10
315.000949	0	892	766	0	281	0
315.000581	1	8582	13653	1	12306	13
315.000988	0	896	3033	0	1529	8
310.001079	1	12259	10415	1	20104	-3
315.000624	2	2680	4722	2	9195	19
335.000662	2	1147	1378	2	4800	8
310.000717	0	27917	19888	1	54982	-11
310.000721	1	10960	10678	1	23591	0

Continued on next page

Table A.35 – Results CY-items

Item	# out of stock	Inventory proposed policy	Inventory current policy	# orders	Annual demand	Improvement (euro)
315.000821	0	5301	4853	0	1070	0
375.000007	0	298	454	0	132	31
315.001252	0	567	802	0	630	18
350.002136	0	93	415	1	210	332
395.000480	0	256	188	0	210	0
399.000101	0	339	799	0	511	127
399.001943	0	475	1404	1	840	217
399.001944	0	176	223	0	210	37
370.000284	0	182	186	0	180	3
315.000666	1	65	158	1	170	66
350.000590	0	157	145	1	170	-8
350.000604	1	213	324	1	450	18
350.000611	1	360	167	1	220	-28
350.000779	1	93	319	1	170	46
350.000858	0	740	536	1	950	-49
350.000934	1	390	585	1	1210	42
350.001115	0	173	245	1	170	9
350.001116	0	130	119	2	170	-2
350.001117	0	313	430	2	440	27
399.000247	0	159	156	1	220	-1
399.000330	0	162	148	2	170	-11
399.001396	5	67	174	3	220	244
399.001464	0	82	216	1	220	95
375.000107	1	6412	2250	1	1886	-24
375.000295	0	2520	14816	1	12349	235
399.001900	0	165	112	0	85	0
399.002041	0	274	201	0	150	0
310.001594	0	209	101	1	259	-19
310.001595	0	427	46	1	174	-15
310.001596	1	818	128	1	250	-16
320.000384	1	132	89	1	265	-15
330.000109	0	183	160	0	275	0
399.001815	0	75	31	1	141	-52
399.001901	1	98	119	1	194	5
310.000871	0	25521	32571	0	34482	11
350.000288	1	1684	1605	1	2328	-3
310.001609	0	5389	5389	0	0	0
350.001545	0	3706	417	1	667	-3
350.001546	0	3706	397	1	667	-3
375.000473	0	799	1017	0	1344	10
375.000474	1	1926	1188	1	2920	-22

Continued on next page

Table A.35 – Results CY-items

Item	# out of stock	Inventory proposed policy	Inventory current policy	# orders	Annual demand	Improvement (euro)
375.000475	1	3166	1469	1	2883	-12
399.001867	0	5172	214	1	669	-5
399.001871	0	5022	340	1	667	-5
335.000798	0	321	611	0	690	0
335.000799	0	275	546	0	690	0
315.000599	2	164	565	2	990	38
399.001849	0	79	119	1	200	32
399.001853	0	3758	171	1	400	-4
399.001858	0	2693	83	1	200	-3
399.001859	0	2693	83	1	200	-3
399.001860	0	2693	83	1	200	-3
399.001861	0	2693	83	1	200	-3
399.001862	0	2699	89	1	200	-3
399.001863	0	2703	93	1	200	-3
399.001864	0	1887	93	1	200	-2
399.001865	0	2693	83	1	200	-3
399.002021	0	2693	83	1	200	-3
399.002022	0	2061	133	1	200	-2
399.002023	0	2693	83	1	200	-3
350.000256	0	650	667	0	70	1
375.000039	0	333	352	0	187	0
399.002150	0	1142	430	1	660	-70
375.000553	2	349	467	2	800	46
375.000554	2	732	460	1	800	-31
375.000555	1	1955	509	1	800	-44
399.002477	0	5393	3524	1	5350	-24
399.002484	0	4101	265	1	1929	-4
399.002488	0	3019	282	1	750	-3

A.17.9 Results CZ-items

Table A.36: Results CZ-items static

Item	# out of stock	Inventory proposed policy	Inventory current policy	# orders	Annual demand	Improvement (euro)
315.000088	0	5414	5409	0	72	0
399.000067	0	9933	10000	0	72	4888

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Table A.36 – Results CZ-items static

Item	# out of stock	Inventory proposed policy	Inventory current policy	# orders	Annual demand	Improvement (euro)
315.000080	50	308	430	51	912	17
310.000347	0	1	1	2	1	-1
370.000043	0	322	322	0	0	0
375.000030	0	479	477	0	20	0
375.000031	0	116	114	0	20	0
375.000099	0	138	137	0	20	0
375.000111	0	42	37	0	40	0
375.000112	0	75	63	0	61	0
399.000061	0	5	4	0	1	0
399.000065	0	42	40	0	20	0
399.000066	0	42	41	0	3	0
310.000342	0	4	2	0	7	0
310.000349	1	20	5	1	12	-41
310.000346	0	4	9	0	0	13
399.000064	0	3	34	0	0	11309
310.000188	0	149	574	0	0	7
310.000206	0	168	170	0	0	0
310.000222	0	3681	3536	0	402	0
310.000234	0	1714	1714	0	0	0
310.000236	0	878	878	0	0	0
310.000238	0	1548	1314	0	260	0
310.000257	0	685	685	0	0	0
310.000353	0	174	136	0	230	0
310.000397	0	100	100	0	0	0
310.000398	0	144	144	0	0	0
310.000680	0	1502	1502	0	0	0
315.000064	0	172	137	0	27	0
315.000154	0	84	84	0	0	0
315.000284	0	380	369	0	0	0
320.000026	0	1750	1674	0	57	0
320.000043	0	262	262	0	0	0
330.000019	0	278	278	0	0	0
330.000023	0	760	595	0	0	0
335.000002	3	90	172	1	425	36
335.000386	0	80	80	0	0	0
340.000130	0	77	35	1	45	-12
340.000213	1	33	81	1	78	11
340.000301	0	5	105	0	0	36
340.000304	0	2	2	0	0	0
340.000305	0	50	100	0	0	8
345.000001	0	107	157	0	0	32

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Table A.36 – Results CZ-items static

Item	# out of stock	Inventory proposed policy	Inventory current policy	# orders	Annual demand	Improvement (euro)
350.000206	0	1	1	0	0	0
350.000209	0	74	148	0	0	20
350.000244	0	150	53	0	0	0
355.000100	0	30	30	0	0	0
375.000021	0	312	300	0	0	0
375.000045	0	195	195	0	0	0
399.000158	0	460	307	0	0	0
399.000165	0	158	4	0	0	0
399.000167	0	157	5	0	0	0
399.000261	0	912	912	0	0	0
399.000410	0	20	16	0	0	0
375.000145	0	812	477	0	0	0
310.000066	0	239	74	0	0	0
315.000210	0	185	129	0	0	0
350.000004	0	357	247	0	0	0
375.000464	0	670	335	0	0	0
310.000082	0	192	0	0	0	0
350.001126	0	322	329	0	0	14
350.001620	0	696	707	0	0	4
350.001621	0	2576	2576	0	0	0
345.000327	0	11	27	0	0	597
350.001205	2	40	77	2	150	56
350.001222	0	153	153	0	0	0
350.001223	0	83	134	0	0	29
350.001224	0	65	121	0	0	23
350.001230	0	51	51	0	0	0
350.001231	0	56	56	0	0	0
375.000109	0	261	251	0	0	0
375.000110	0	431	425	0	81	0
375.000187	0	341	336	0	81	0
375.000233	0	174	174	0	0	0
375.000411	0	221	221	0	0	0
375.000413	0	151	146	0	81	0
375.000414	0	417	429	0	81	1
399.001522	3	10	33	4	80	36
399.001540	0	53	203	0	0	105
399.001541	0	147	350	0	0	99
350.001956	0	701	613	0	396	0
399.000555	0	100	32	0	0	0
315.001143	0	631	649	0	0	27
350.001044	0	59	184	0	0	89

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Table A.36 – Results CZ-items static

Item	# out of stock	Inventory proposed policy	Inventory current policy	# orders	Annual demand	Improvement (euro)
350.001524	0	394	382	2	1256	-3
310.000259	0	3381	3326	0	143	0
310.000263	0	1480	3105	1	1339	34
335.000073	0	3000	3000	0	0	0
310.000224	0	3243	3243	0	0	0
310.000261	0	145	45	1	60	-2
370.000037	0	142	154	0	60	4
320.000178	0	4	5	0	0	0
335.000422	0	128	698	0	0	51
355.000913	0	1	3	0	0	48
370.000050	0	23	23	0	0	0
375.000421	0	987	976	0	0	0
335.000411	0	2219	800	1	0	-155
350.000865	0	98	33	2	200	-49
350.001585	0	130	50	1	200	-58
370.000194	30	20	33	31	200	940
350.000601	5	1825	5776	5	10723	40
350.000605	0	125	126	0	2	0
370.000110	0	68	70	0	2	19
335.000621	0	1	1	0	0	0
370.000205	0	16	16	0	0	0
375.000043	0	475	467	0	0	0
375.000383	0	1295	1273	0	0	0
375.000384	0	845	845	0	0	0
375.000416	0	4009	4248	0	1088	4
399.001707	0	210	189	0	0	0
310.001743	0	89	75	0	25	0
310.001744	0	28	63	1	25	34
315.001242	1	58	51	1	75	-5
340.001759	2	5	23	2	25	67
340.001760	1	24	44	1	40	51
365.000348	0	112	175	1	50	41
365.000349	0	400	475	1	50	6
315.001341	0	302	100	2	350	-47
320.000978	0	156	28	1	50	-32
335.000663	0	203	220	0	100	1
375.000530	0	367	180	1	260	-15
399.002127	1	161	67	1	180	-61
399.002128	1	688	119	1	180	-44
340.000253	1	5	43	4	15	5
350.002091	0	155	144	1	100	-1

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Table A.36 – Results CZ-items static

Item	# out of stock	Inventory proposed policy	Inventory current policy	# orders	Annual demand	Improvement (euro)
350.002475	20	20	20	21	100	0
350.002476	20	0	5	21	100	101
350.002478	20	0	5	21	100	59
365.000431	8	0	3	4	100	273
365.000432	8	0	3	4	100	0
370.000301	20	0	5	21	100	100
399.002787	20	0	5	21	100	1085
399.002788	20	0	5	21	100	224
399.002789	20	0	5	21	100	205
399.002792	20	0	4	21	100	4607
350.001164	0	219	257	0	100	8
375.000038	0	261	253	1	110	0
350.000033	0	104	93	0	12	0
399.001536	0	39	40	0	12	2
350.001280	0	50	37	0	47	0
350.001323	1	22	16	3	47	-3
399.001594	30	3	15	36	47	45
399.001597	30	3	15	39	47	29
310.001082	1	6432	5342	1	10346	-2
310.001421	0	81	84	2	123	0
310.001422	0	48	35	0	41	0
310.001423	13	9	121	14	82	56
315.000943	0	3098	3000	0	316	0
315.001071	9	68	294	17	248	7
350.001278	26	9	19	29	48	28
310.001454	0	1660	1581	0	409	0
315.000113	0	3278	3102	0	998	0
350.001277	0	158	26	0	60	0
350.000065	40	28	83	41	90	9
325.000722	1	402	237	1	314	-2
350.001279	36	7	31	38	47	44
350.001332	6	20	36	3	75	32
315.001117	1	551	225	1	457	-9
315.001118	0	1653	1631	0	83	0
315.001119	0	40	16	1	77	-3
315.001120	16	21	151	21	77	15
315.001121	0	828	788	0	359	0
315.001122	1	613	155	1	307	-14
315.001123	1	744	252	1	512	-10
315.001124	33	2	129	38	39	4
315.001125	0	579	100	1	119	-8

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Table A.36 – Results CZ-items static

Item	# out of stock	Inventory proposed policy	Inventory current policy	# orders	Annual demand	Improvement (euro)
315.001126	0	134	122	0	39	0
350.001369	34	9	28	37	54	26
399.002710	0	78	77	1	105	0
350.001796	0	118	85	1	120	-31
350.002381	0	131	46	1	80	-62
350.002382	0	98	33	1	40	-62
315.001580	1	24	43	2	80	59
350.002384	0	15	30	0	40	10
355.001822	0	85	174	0	40	361
399.002672	0	983	877	0	160	0
399.002673	0	1021	703	0	160	0
399.002675	0	381	398	0	80	7
399.002676	0	491	464	0	80	0
399.002678	0	586	600	0	120	0
399.002679	0	976	1000	0	200	1
399.002680	0	691	640	0	80	0
399.002681	0	762	1320	0	320	15
399.002682	0	226	825	0	200	8
399.002740	0	331	280	0	80	0
350.000777	0	446	521	1	220	8
310.000420	0	20	30	0	0	9
399.001974	0	147	49	1	0	-25
350.001999	0	17	42	0	0	7
350.002000	0	242	242	0	0	0
375.000356	0	182	182	0	0	0
350.000031	0	130	130	0	0	0
399.002758	0	77	103	0	71	0
399.002805	7	0	53	7	35	53
350.000121	0	20	30	0	0	3
350.000956	0	49	50	0	0	0
350.000960	0	399	399	0	0	0
310.001608	0	31489	31489	0	0	0
335.000724	0	5000	5000	0	0	0
310.001643	1	1016	655	1	1004	-51
335.000723	0	42646	47769	0	7260	5
350.001528	0	1385	1385	0	0	0
350.001529	0	139	139	0	0	0
350.001547	0	579	577	0	5	0
395.000432	0	55	38	0	0	0
395.000435	0	9	9	0	0	0
395.000436	0	3	3	0	0	0

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Table A.36 – Results CZ-items static

Item	# out of stock	Inventory proposed policy	Inventory current policy	# orders	Annual demand	Improvement (euro)
395.000437	0	27	37	0	0	87
395.000438	0	1956	407	0	0	0
350.001958	0	2608	250	0	0	0
395.000425	0	2	2	0	0	0
395.000434	0	50	50	0	0	0
395.000439	0	593	793	0	0	116
395.000440	0	81	81	0	0	0
395.000449	0	6458	6458	0	0	0
395.000484	0	79	43	0	0	0
395.000486	0	356	338	0	0	0
395.000487	0	715	320	0	0	0
395.000488	0	201	201	0	0	0
365.000435	2	3	7	9	6	0
399.001964	0	282	282	0	0	0
399.002106	0	69	69	0	0	0
399.002193	0	1440	1440	0	0	0
399.002210	0	77	77	0	0	0
399.002205	0	4350	4350	0	0	0
399.002207	0	1100	1100	0	0	0
399.002212	0	160	160	0	0	0
399.002213	0	330	330	0	0	0
399.002239	0	20000	20000	0	0	0
395.000543	0	16	16	0	0	0
399.002267	0	173	173	0	0	0
399.002354	0	3	3	0	0	0
399.002356	0	20	185	0	0	0
399.002358	0	6	6	0	0	0
399.002426	0	8982	418	1	456	-9
335.001823	0	176	150	53	0	0
335.001824	0	176	150	53	0	0
335.001825	40	6	183233	53	187200	183
399.002427	0	1996	100	1	150	-2
350.000719	0	397	394	0	0	0
350.001666	0	405	403	0	0	0
350.001667	0	204	204	0	0	0
350.001668	0	97	100	1	0	3
399.001374	0	50	50	0	0	0
399.002004	0	206	167	0	0	0
350.001961	0	5	59	0	0	66
399.002329	0	5	5	0	0	0
399.000279	2	117	67	2	268	-21

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Table A.36 – Results CZ-items static

Item	# out of stock	Inventory proposed policy	Inventory current policy	# orders	Annual demand	Improvement (euro)
399.002536	0	168	116	1	259	-9
350.002474	40	1	392	42	416	172
325.000928	1	57	59	1	100	1
345.001653	1	40	56	2	105	39
399.000478	1	240	89	1	100	-23
399.002559	0	111	55	1	100	-24
399.002560	0	105	55	1	104	-23
365.000409	0	1	51	0	0	280
399.002223	0	7408	2167	1	4200	-5
399.002442	0	1	51	0	0	0
350.001262	1	42	102	1	100	78
350.002003	0	128	212	1	400	29
399.002367	0	40	61	3	105	36
399.001391	43	8	9	44	105	5
399.002491	43	2	5	45	105	69
399.002808	30	10	1326	53	1925	1
399.002795	33	1	89	35	355	0
399.002820	33	1	133	35	355	0
345.001624	0	40	40	0	0	0
350.000781	0	46	46	0	0	0
399.002534	0	615	625	0	0	2
315.001596	44	378	1202	45	1800	29
320.001182	44	164	1020	45	1865	39
350.002448	44	79	1270	45	1801	60
399.002747	0	316	470	0	650	48
399.002749	44	749	1765	45	1800	66
399.002534	0	615	625	2		0
315.001596	44	378	1202	29		45
320.001182	44	164	1020	39		45
350.002448	44	79	1270	60		45
399.002747	0	316	470	48		0
399.002749	44	749	1765	66		45

Table A.37: Results CZ-items dynamic

Item	**# out of stock**	**Inventory proposed policy**	**Inventory current policy**	**# orders**	**Annual demand**	**Improvement (euro)**
315.000088	0	5414	5409	0	72	0
399.000067	0	9933	10000	0	72	4888
315.000080	50	308	430	53	912	17
310.000347	0	1	1	2	1	-1
370.000043	0	322	322	0	0	0
375.000030	0	479	477	0	20	0
375.000031	0	116	114	0	20	0
375.000099	0	138	137	0	20	0
375.000111	0	42	37	0	40	0
375.000112	0	75	63	0	61	0
399.000061	0	5	4	0	1	0
399.000065	0	42	40	0	20	0
399.000066	0	42	41	0	3	0
310.000342	0	4	2	0	7	0
310.000349	1	20	5	1	12	-41
310.000346	0	4	9	0	0	13
399.000064	0	3	34	0	0	11309
310.000188	0	149	574	0	0	7
310.000206	0	168	170	0	0	0
310.000222	0	3681	3536	0	402	0
310.000234	0	1714	1714	0	0	0
310.000236	0	878	878	0	0	0
310.000238	0	1548	1314	0	260	0
310.000257	0	685	685	0	0	0
310.000353	0	174	136	0	230	0
310.000397	0	100	100	0	0	0
310.000398	0	144	144	0	0	0
310.000680	0	1502	1502	0	0	0
315.000064	0	172	137	0	27	0
315.000154	0	84	84	0	0	0
315.000284	0	380	369	0	0	0
320.000026	0	1750	1674	0	57	0
320.000043	0	262	262	0	0	0
330.000019	0	278	278	0	0	0
330.000023	0	760	595	0	0	0
335.000002	0	299	172	2	425	-56
335.000386	0	80	80	0	0	0
340.000130	0	77	35	1	45	-12
340.000213	1	33	81	1	78	11

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Table A.37 – Results CZ-items dynamic

Item	# out of stock	Inventory proposed policy	Inventory current policy	# orders	Annual demand	Improvement (euro)
340.000301	0	5	105	0	0	36
340.000304	0	2	2	0	0	0
340.000305	0	50	100	0	0	8
345.000001	0	107	157	0	0	32
350.000206	0	1	1	0	0	0
350.000209	0	74	148	0	0	20
350.000244	0	150	53	0	0	0
355.000100	0	30	30	0	0	0
375.000021	0	312	300	0	0	0
375.000045	0	195	195	0	0	0
399.000158	0	460	307	0	0	0
399.000165	0	158	4	0	0	0
399.000167	0	157	5	0	0	0
399.000261	0	912	912	0	0	0
399.000410	0	20	16	0	0	0
375.000145	0	812	477	0	0	0
310.000066	0	239	74	0	0	0
315.000210	0	185	129	0	0	0
350.000004	0	357	247	0	0	0
375.000464	0	670	335	0	0	0
310.000082	0	192	0	0	0	0
350.001126	0	322	329	0	0	14
350.001620	0	696	707	0	0	4
350.001621	0	2576	2576	0	0	0
345.000327	0	11	27	0	0	597
350.001205	2	40	77	2	150	56
350.001222	0	153	153	0	0	0
350.001223	0	83	134	0	0	29
350.001224	0	65	121	0	0	23
350.001230	0	51	51	0	0	0
350.001231	0	56	56	0	0	0
375.000109	0	261	251	0	0	0
375.000110	0	431	425	0	81	0
375.000187	0	341	336	0	81	0
375.000233	0	174	174	0	0	0
375.000411	0	221	221	0	0	0
375.000413	0	151	146	0	81	0
375.000414	0	417	429	0	81	1
399.001522	3	10	33	4	80	36
399.001540	0	53	203	0	0	105
399.001541	0	147	350	0	0	99

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Table A.37 – Results CZ-items dynamic

Item	# out of stock	Inventory proposed policy	Inventory current policy	# orders	Annual demand	Improvement (euro)
350.001956	0	701	613	0	396	0
399.000555	0	100	32	0	0	0
315.001143	0	631	649	0	0	27
350.001044	0	59	184	0	0	89
350.001524	0	769	382	2	1256	-78
310.000259	0	3381	3326	0	143	0
310.000263	0	1571	3105	1	1339	32
335.000073	0	3000	3000	0	0	0
310.000224	0	3243	3243	0	0	0
310.000261	0	145	45	1	60	-2
370.000037	0	142	154	0	60	4
320.000178	0	4	5	0	0	0
335.000422	0	128	698	0	0	51
355.000913	0	1	3	0	0	48
370.000050	0	23	23	0	0	0
375.000421	0	987	976	0	0	0
335.000411	0	2219	800	1	0	-155
350.000865	0	98	33	2	200	-49
350.001585	0	130	50	1	200	-58
370.000194	30	20	33	31	200	940
350.000601	5	1825	5776	5	10723	40
350.000605	0	125	126	0	2	0
370.000110	0	68	70	0	2	19
335.000621	0	1	1	0	0	0
370.000205	0	16	16	0	0	0
375.000043	0	475	467	0	0	0
375.000383	0	1295	1273	0	0	0
375.000384	0	845	845	0	0	0
375.000416	0	4009	4248	0	1088	4
399.001707	0	210	189	0	0	0
310.001743	0	89	75	0	25	0
310.001744	0	28	63	1	25	34
315.001242	1	58	51	1	75	-5
340.001759	2	5	23	2	25	67
340.001760	1	24	44	1	40	51
365.000348	0	112	175	1	50	41
365.000349	0	400	475	1	50	6
315.001341	0	308	100	2	350	-48
320.000978	0	156	28	1	50	-32
335.000663	0	203	220	0	100	1
375.000530	0	367	180	1	260	-15

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Table A.37 – Results CZ-items dynamic

Item	# out of stock	Inventory proposed policy	Inventory current policy	# orders	Annual demand	Improvement (euro)
399.002127	1	161	67	1	180	-61
399.002128	1	688	119	1	180	-44
340.000253	1	5	43	4	15	5
350.002091	0	155	144	1	100	-1
350.002475	20	20	20	21	100	0
350.002476	20	0	5	21	100	101
350.002478	20	0	5	21	100	59
365.000431	8	0	3	4	100	273
365.000432	8	0	3	4	100	0
370.000301	20	0	5	21	100	100
399.002787	20	0	5	21	100	1085
399.002788	20	0	5	21	100	224
399.002789	20	0	5	21	100	205
399.002792	20	0	4	21	100	4607
350.001164	0	219	257	0	100	8
375.000038	0	261	253	1	110	0
350.000033	0	104	93	0	12	0
399.001536	0	39	40	0	12	2
350.001280	0	50	37	0	47	0
350.001323	1	22	16	3	47	-3
399.001594	29	4	15	38	47	44
399.001597	29	3	15	41	47	28
310.001082	0	6664	5342	1	10346	-2
310.001421	0	81	84	2	123	0
310.001422	0	48	35	0	41	0
310.001423	13	9	121	15	82	56
315.000943	0	3098	3000	0	316	0
315.001071	9	68	294	20	248	7
350.001278	26	9	19	30	48	27
310.001454	0	1660	1581	0	409	0
315.000113	0	3278	3102	0	998	0
350.001277	0	158	26	0	60	0
350.000065	40	28	83	41	90	9
325.000722	1	402	237	1	314	-2
350.001279	36	7	31	38	47	44
350.001332	6	20	36	3	75	32
315.001117	1	551	225	1	457	-9
315.001118	0	1653	1631	0	83	0
315.001119	0	40	16	4	77	-3
315.001120	16	21	151	23	77	15
315.001121	0	828	788	0	359	0

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Table A.37 – Results CZ-items dynamic

Item	# out of stock	Inventory proposed policy	Inventory current policy	# orders	Annual demand	Improvement (euro)
315.001122	1	613	155	1	307	-14
315.001123	1	744	252	1	512	-10
315.001124	32	2	129	38	39	4
315.001125	0	579	100	1	119	-8
315.001126	0	134	122	0	39	0
350.001369	34	9	28	38	54	26
399.002710	0	78	77	1	105	0
350.001796	0	118	85	1	120	-31
350.002381	0	131	46	1	80	-62
350.002382	0	98	33	1	40	-62
315.001580	1	24	43	2	80	59
350.002384	0	15	30	0	40	10
355.001822	0	85	174	0	40	361
399.002672	0	983	877	0	160	0
399.002673	0	1021	703	0	160	0
399.002675	0	381	398	0	80	7
399.002676	0	491	464	0	80	0
399.002678	0	586	600	0	120	0
399.002679	0	976	1000	0	200	1
399.002680	0	691	640	0	80	0
399.002681	0	762	1320	0	320	15
399.002682	0	226	825	0	200	8
399.002740	0	331	280	0	80	0
350.000777	0	446	521	1	220	8
310.000420	0	20	30	0	0	9
399.001974	0	9	49	0	0	10
350.001999	0	17	42	0	0	7
350.002000	0	242	242	0	0	0
375.000356	0	182	182	0	0	0
350.000031	0	130	130	0	0	0
399.002758	0	77	103	0	71	0
399.002805	7	0	53	7	35	53
350.000121	0	20	30	0	0	3
350.000956	0	49	50	0	0	0
350.000960	0	399	399	0	0	0
310.001608	0	31489	31489	0	0	0
335.000724	0	5000	5000	0	0	0
310.001643	1	1016	655	1	1004	-51
335.000723	0	42646	47769	0	7260	5
350.001528	0	1385	1385	0	0	0
350.001529	0	139	139	0	0	0

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Table A.37 – Results CZ-items dynamic

Item	# out of stock	Inventory proposed policy	Inventory current policy	# orders	Annual demand	Improvement (euro)
350.001547	0	579	577	0	5	0
395.000432	0	55	38	0	0	0
395.000435	0	9	9	0	0	0
395.000436	0	3	3	0	0	0
395.000437	0	27	37	0	0	87
395.000438	0	1956	407	0	0	0
350.001958	0	2608	250	0	0	0
395.000425	0	2	2	0	0	0
395.000434	0	50	50	0	0	0
395.000439	0	593	793	0	0	116
395.000440	0	81	81	0	0	0
395.000449	0	6458	6458	0	0	0
395.000484	0	79	43	0	0	0
395.000486	0	356	338	0	0	0
395.000487	0	715	320	0	0	0
395.000488	0	201	201	0	0	0
365.000435	0	4	7	11	6	0
399.001964	0	282	282	0	0	0
399.002106	0	69	69	0	0	0
399.002193	0	1440	1440	0	0	0
399.002210	0	77	77	0	0	0
399.002205	0	4350	4350	0	0	0
399.002207	0	1100	1100	0	0	0
399.002212	0	160	160	0	0	0
399.002213	0	330	330	0	0	0
399.002239	0	20000	20000	0	0	0
395.000543	0	16	16	0	0	0
399.002267	0	173	173	0	0	0
399.002354	0	3	3	0	0	0
399.002356	0	20	185	0	0	0
399.002358	0	6	6	0	0	0
399.002426	0	8982	418	1	456	-9
335.001823	0	176	150	53	0	0
335.001824	0	176	150	53	0	0
335.001825	40	6	183233	53	187200	183
399.002427	0	1996	100	1	150	-2
350.000719	0	397	394	0	0	0
350.001666	0	405	403	0	0	0
350.001667	0	204	204	0	0	0
350.001668	0	97	100	1	0	3
399.001374	0	50	50	0	0	0

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Table A.37 – Results CZ-items dynamic

Item	# out of stock	Inventory proposed policy	Inventory current policy	# orders	Annual demand	Improvement (euro)
399.002004	0	206	167	0	0	0
350.001961	0	5	59	0	0	66
399.002329	0	5	5	0	0	0
399.000279	2	117	67	2	268	-21
399.002536	0	168	116	1	259	-9
350.002474	40	1	392	42	416	172
325.000928	1	57	59	1	100	1
345.001653	1	40	56	2	105	39
399.000478	1	240	89	1	100	-23
399.002559	0	111	55	1	100	-24
399.002560	0	105	55	1	104	-23
365.000409	0	2	51	1	0	275
399.002223	0	7408	2167	1	4200	-5
399.002442	0	2	51	1	0	0
350.001262	1	42	102	1	100	78
350.002003	0	347	212	1	400	-46
399.002367	0	40	61	3	105	36
399.001391	43	8	9	44	105	5
399.002491	43	1	5	44	105	86
399.002808	30	10	1326	53	1925	1
399.002795	33	1	89	35	355	0
399.002820	33	1	133	35	355	0
345.001624	0	40	40	0	0	0
350.000781	0	46	46	0	0	0
399.002534	0	615	625	0	0	2
315.001596	44	400	1202	53	1800	28
320.001182	44	179	1020	53	1865	38
350.002448	44	94	1270	53	1801	59
399.002747	0	323	470	28	650	45
399.002749	44	749	1765	45	1800	66
399.002534	0	615	625	0	0	2
315.001596	44	400	1202	53	1800	28
320.001182	44	179	1020	53	1865	38
350.002448	44	94	1270	53	1801	59
399.002747	0	323	470	28	650	45
399.002749	44	749	1765	45	1800	66

A.18 Total annual cycle inventory cost

A.18.1 Total annual cycle inventory cost AX-items

Table A.38: Results inventory ordering cost AX-items

Item	Holding cost proposed	Ordering cost proposed	Holding cost current	Ordering cost current	Total inventory cost Proposed	Total inventory cost current	Improvement
395.000226	378	0	443	20	378	463	84
365.000029	267	0	358	10	267	368	101
345.000163	25	50	68	50	75	118	43
399.001703	166	50	192	40	216	232	16
399.001705	79	40	78	70	119	148	29
395.000384	195	70	1016	120	265	1136	871
335.000692	227	40	295	110	267	405	138
370.000206	104	30	229	110	134	339	205
365.000334	1281	20	881	40	1301	921	-381
335.000761	2809	40	1963	90	2849	2053	-796
399.001967	195	40	307	110	235	417	182
399.002383	6167	30	3637	50	6197	3687	-2510
315.000062	66	30	243	120	96	363	267
399.002455	185	100	416	340	285	756	470
399.002456	270	100	725	240	370	965	595
399.002457	328	40	491	30	368	521	153
399.002461	337	90	723	270	427	993	566
399.002462	412	100	905	220	512	1125	613
399.002463	75	90	120	180	165	300	135
399.002464	76	90	89	210	166	299	133
399.002465	102	90	142	200	192	342	150
399.002467	158	90	225	70	248	295	47
399.002468	79	70	168	110	149	278	129
399.002470	294	70	510	220	364	730	366
399.002471	94	40	77	160	134	237	103
Total	14370	1410	14300	3190	15780	17490	1710

A.18.2 Total annual cycle inventory cost AY-items

Table A.39: Results inventory ordering cost AY-items

Item	Holding cost proposed	Ordering cost proposed	Holding cost current	Ordering cost current	Total inventory cost Proposed	Total inventory cost current	Improvement
399.001521	1679	120	1291	30	1799	1321	-478
345.000317	378	40	543	80	418	623	205
399.000608	54	50	285	0	104	285	181
325.000179	202	20	178	50	222	228	6
365.000342	44	50	230	60	94	290	197
350.001298	188	50	168	80	238	248	10
350.001485	182	40	136	90	222	226	3
365.000415	276	40	191	50	316	241	-75
399.002628	736	100	692	110	836	802	-34
315.001070	137	50	713	80	187	793	606
399.001946	367	10	462	50	377	512	135
399.001948	409	10	451	60	419	511	92
399.002524	782	10	993	50	792	1043	251
399.002428	923	20	481	60	943	541	-403
399.002529	404	50	461	50	454	511	57
365.000337	138	40	104	30	178	134	-44
365.000378	279	20	237	20	299	257	-43
365.000379	175	40	228	20	215	248	33
350.001571	336	20	347	10	356	357	1
399.001848	366	60	344	70	426	414	-12
399.001850	214	50	86	90	264	176	-88
350.002075	360	120	640	130	480	770	290
350.002076	259	120	513	130	379	643	264
350.002077	273	110	507	140	383	647	264
350.002078	393	90	603	120	483	723	240
Total	9556	1330	10885	1660	10886	12545	1660

A.18.3 Total annual cycle inventory cost AZ-items

Table A.40: Results inventory ordering cost AZ-items static

Item	Holding cost proposed	Ordering cost proposed	Holding cost current	Ordering cost current	Total inventory cost Proposed	Total inventory cost current	Improvement
320.000069	219	0	321	10	219	331	112

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Table A.40 – Results inventory ordering cost AZ-items static

Item	Holding cost proposed	Ordering cost proposed	Holding cost current	Ordering cost current	Total inventory cost Proposed	Total inventory cost current	Improvement
399.000063	1076	10	542	20	1086	562	-524
350.002469	139	410	256	10	549	266	-283
350.002088	190	110	153	80	300	233	-68
350.002089	344	110	268	80	454	348	-107
399.002741	1440	30	2130	70	1470	2200	730
399.001601	166	20	362	0	186	362	176
399.002670	48	10	87	20	58	107	49
399.002328	200	20	96	10	220	106	-114
365.000380	76	50	122	40	126	162	36
399.002748	297	0	476	10	297	486	189
Total	4196	770	4812	350	4966	5162	196

Table A.41: Results inventory ordering cost AZ-items dynamic

Item	Holding cost proposed	Ordering cost proposed	Holding cost current	Ordering cost current	Total inventory cost Proposed	Total inventory cost current	Improvement
320.000069	219	0	321	10	219	331	112
399.000063	1027	10	542	20	1037	562	-475
350.002469	75	60	256	10	135	266	131
350.002088	187	110	153	80	297	233	-64
350.002089	326	100	268	80	426	348	-78
399.002741	793	90	2130	70	883	2200	1316
399.001601	158	20	362	0	178	362	184
399.002670	26	10	87	20	36	107	71
399.002328	168	20	96	10	188	106	-82
365.000380	60	40	122	40	100	162	62
399.002748	309	30	476	10	339	486	146
Total	3349	490	4812	350	3839	5162	1323

A.18.4 Total annual cycle inventory cost BX-items

Table A.42: Results inventory ordering cost BX-items

Item	Holding cost proposed	Ordering cost proposed	Holding cost current	Ordering cost current	Total inventory cost Proposed	Total inventory cost current	Improvement
330.000006	5	20	95	30	25	125	100
350.000174	24	10	31	20	34	51	17
350.000176	24	30	86	40	54	126	72
399.000664	930	0	509	80	930	589	-342
335.000009	41	0	93	10	41	103	62
350.001374	59	20	88	10	79	98	19
370.000229	173	40	30	110	213	140	-73
399.001219	301	30	147	10	331	157	-174
350.001399	129	30	31	40	159	71	-88
370.000249	184	40	36	110	224	146	-77
399.001968	387	60	92	110	447	202	-245
315.000574	16	0	10	40	16	50	34
399.002481	162	10	27	20	172	47	-126
399.002483	252	10	57	20	262	77	-186
399.002490	49	30	37	30	79	67	-13
Total	2738	330	1369	680	3068	2049	-1019

A.18.5 Total annual cycle inventory cost BY-items

Table A.43: Results inventory ordering cost BY-items

Item	Holding cost proposed	Ordering cost proposed	Holding cost current	Ordering cost current	Total inventory cost Proposed	Total inventory cost current	Improvement
315.000084	54	60	25	20	114	45	-69
399.000010	46	130	46	20	176	66	-110
399.000014	42	10	76	10	52	86	34
370.000021	37	0	71	10	37	81	44
399.000154	50	0	86	10	50	96	46
399.000159	215	0	235	0	215	235	20
399.000160	113	0	110	20	113	130	17
399.001929	65	10	153	20	75	173	97
315.001050	22	20	32	60	42	92	51
315.001051	82	20	148	60	102	208	107
315.001053	94	20	55	10	114	65	-49

Continued on next page

Table A.43 – Results inventory ordering cost BY-items

Item	Holding cost proposed	Ordering cost proposed	Holding cost current	Ordering cost current	Total inventory cost Proposed	Total inventory cost current	Improvement
335.000676	91	20	110	30	111	140	29
345.000315	65	20	62	70	85	132	47
345.000318	26	40	102	60	66	162	96
350.001197	50	20	54	80	70	134	65
350.001204	98	20	156	100	118	256	138
350.001225	50	20	79	100	70	179	108
350.001308	25	30	33	80	55	113	57
315.001416	17	30	39	10	47	49	2
345.000019	123	80	102	60	203	162	-40
345.000053	17	30	65	20	47	85	38
345.000161	54	120	135	50	174	185	11
345.000162	46	140	102	50	186	152	-35
350.000735	119	20	249	20	139	269	130
399.000265	11	70	33	50	81	83	2
315.000034	14	50	42	50	64	92	28
345.000164	82	140	96	30	222	126	-97
345.000165	68	130	91	30	198	121	-77
345.000166	56	130	105	30	186	135	-51
315.000563	164	10	66	20	174	86	-88
320.000186	26	30	76	40	56	116	59
350.000556	14	30	28	60	44	88	44
350.001185	17	0	51	50	17	101	85
399.000691	174	0	140	0	174	140	-34
399.000700	64	20	71	10	84	81	-4
350.000780	75	50	80	40	125	120	-5
335.000408	87	20	145	0	107	145	37
335.000759	153	30	191	80	183	271	88
335.000760	108	0	125	80	108	205	97
350.001629	41	0	80	80	41	160	118
370.000267	138	10	264	20	148	284	136
399.000213	62	0	102	60	62	162	100
399.001941	52	0	91	70	52	161	110
399.001942	214	10	325	100	224	425	200
399.001945	261	0	320	50	261	370	110
370.000283	141	40	139	10	181	149	-33
399.002430	56	10	75	40	66	115	48
399.002431	104	60	88	10	164	98	-66
399.002530	95	10	125	50	105	175	70
399.001695	107	0	49	10	107	59	-48
310.001593	93	30	85	0	123	85	-38

Continued on next page

Table A.43 – Results inventory ordering cost BY-items

Item	Holding cost proposed	Ordering cost proposed	Holding cost current	Ordering cost current	Total inventory cost Proposed	Total inventory cost current	Improvement
355.001113	71	20	28	20	91	48	-43
310.000994	22	70	24	40	92	64	-28
350.001526	142	0	137	30	142	167	24
Total	4315	1830	5594	2130	6145	7724	1579

A.18.6 Total annual cycle inventory cost BZ-items

Table A.44: Results inventory ordering cost BZ-items static

Item	Holding cost proposed	Ordering cost proposed	Holding cost current	Ordering cost current	Total inventory cost Proposed	Total inventory cost current	Improvement
345.001719	0	530	64	10	530	74	-456
365.000008	45	10	240	10	55	250	195
365.000040	144	0	135	0	144	135	-9
399.000060	289	0	271	0	289	271	-18
399.001770	31	80	63	20	111	83	-28
315.001444	24	30	33	40	54	73	19
399.002423	16	30	18	80	46	98	52
335.000409	70	20	320	10	90	330	241
355.000212	78	60	81	20	138	101	-37
340.000507	3	450	45	80	453	125	-328
350.001282	5	350	21	20	355	41	-314
355.001053	17	250	87	10	267	97	-170
355.001017	23	110	87	20	133	107	-26
335.000651	14	10	30	10	24	40	15
355.001043	16	240	134	10	256	144	-113
350.002372	23	20	79	20	43	99	56
399.002665	518	0	530	10	518	540	23
399.002666	101	0	103	10	101	113	12
399.002667	142	0	145	10	142	155	13
399.002668	114	0	117	10	114	127	13
355.001307	49	50	79	30	99	109	10
399.002219	15	40	51	20	55	71	16
350.002444	1	530	25	70	531	95	-436
350.002445	6	530	57	70	536	127	-410

Continued on next page

Table A.44 – Results inventory ordering cost BZ-items static

Item	Holding cost proposed	Ordering cost proposed	Holding cost current	Ordering cost current	Total inventory cost Proposed	Total inventory cost current	Improvement
350.002446	4	530	54	70	534	124	-410
350.002447	4	530	46	70	534	116	-418
399.002750	3	530	94	90	533	184	-349
Total	1754	4930	3010	820	6684	3830	-2854

Table A.45: Results inventory ordering cost BZ-items dynamic

Item	Holding cost proposed	Ordering cost proposed	Holding cost current	Ordering cost current	Total inventory cost Proposed	Total inventory cost current	Improvement
345.001719	0	530	64	10	530	74	-456
365.000008	45	10	240	10	55	250	195
365.000040	144	0	135	0	144	135	-9
399.000060	289	0	271	0	289	271	-18
399.001770	48	90	63	20	138	83	-55
315.001444	39	30	33	40	69	73	4
399.002423	37	30	18	80	67	98	31
335.000409	245	70	320	10	315	330	16
355.000212	78	60	81	20	138	101	-37
340.000507	5	530	45	80	535	125	-409
350.001282	5	370	21	20	375	41	-334
355.001053	17	250	87	10	267	97	-170
355.001017	26	120	87	20	146	107	-39
335.000651	14	10	30	10	24	40	15
355.001043	16	240	134	10	256	144	-113
350.002372	23	20	79	20	43	99	56
399.002665	518	0	530	10	518	540	23
399.002666	101	0	103	10	101	113	12
399.002667	142	0	145	10	142	155	13
399.002668	114	0	117	10	114	127	13
355.001307	49	50	79	30	99	109	10
399.002219	15	40	51	20	55	71	16
350.002444	1	530	25	70	531	95	-436
350.002445	6	530	57	70	536	127	-410
350.002446	4	530	54	70	534	124	-410
350.002447	4	530	46	70	534	116	-418

Continued on next page

Table A.45 – Results inventory ordering cost BZ-items dynamic

Item	Holding cost proposed	Ordering cost proposed	Holding cost current	Ordering cost current	Total inventory cost Proposed	Total inventory cost current	Improvement
399.002750	3	530	94	90	533	184	-349
Total	1987	5100	3010	820	7087	3830	-3257

A.18.7 Total annual cycle inventory cost CX-items

Table A.46: Results inventory ordering cost CX-items

Item	Holding cost proposed	Ordering cost proposed	Holding cost current	Ordering cost current	Total inventory cost Proposed	Total inventory cost current	Improvement
350.000724	6	10	9	20	16	29	13
310.000249	12	0	12	0	12	12	-1
315.000614	6	0	6	0	6	6	0
340.000251	2	10	3	50	12	53	40
350.000135	10	10	23	30	20	53	33
375.000044	6	10	3	30	16	33	17
375.000071	8	10	5	60	18	65	47
375.000106	12	10	17	70	22	87	65
375.000200	21	0	42	20	21	62	40
399.000022	19	0	23	10	19	33	14
399.000299	5	0	7	10	5	17	12
350.000043	34	0	15	0	34	15	-19
350.000534	4	0	5	10	4	15	12
350.000535	10	10	23	20	20	43	24
399.000163	10	0	9	0	10	9	-1
310.000060	31	0	29	0	31	29	-1
399.000300	5	0	5	10	5	15	10
330.000020	9	10	18	30	19	48	29
315.000209	25	10	42	30	35	72	37
320.000061	10	10	14	10	20	24	4
375.000408	6	10	4	50	16	54	38
315.000091	11	0	11	0	11	11	0
315.000134	5	20	16	70	25	86	61
350.000718	7	10	9	30	17	39	22
375.000081	6	10	5	40	16	45	29
350.001373	8	10	11	20	18	31	14

Continued on next page

Table A.46 – Results inventory ordering cost CX-items

Item	Holding cost proposed	Ordering cost proposed	Holding cost current	Ordering cost current	Total inventory cost Proposed	Total inventory cost current	Improvement
350.000964	69	0	66	0	69	66	-4
370.000204	2	0	3	30	2	33	31
375.000014	2	0	4	10	2	14	12
375.000152	27	0	34	30	27	64	37
375.000246	2	0	2	0	2	2	0
375.000291	4	0	8	20	4	28	24
375.000382	3	0	3	10	3	13	10
375.000386	3	0	31	10	3	41	37
375.000389	16	10	17	40	26	57	31
399.001221	237	10	135	0	247	135	-112
399.001222	4	0	3	0	4	3	0
365.000335	2	10	0	30	12	30	18
375.000064	1	0	2	20	1	22	21
350.000866	12	0	12	0	12	12	0
365.000357	301	10	57	0	311	57	-254
310.000719	10	10	17	110	20	127	107
310.000727	4	10	4	30	14	34	20
310.000545	4	10	3	40	14	43	29
310.000978	6	10	12	40	16	52	36
399.000331	2	10	4	10	12	14	2
375.000057	5	0	5	0	5	5	0
375.000063	7	10	3	40	17	43	26
375.000350	4	10	1	20	14	21	8
399.001868	0	0	0	20	0	20	20
399.001870	6	10	6	20	16	26	10
395.000518	1	10	0	20	11	20	9
375.000046	3	0	7	20	3	27	24
399.002459	7	10	10	20	17	30	13
399.002460	3	10	1	20	13	21	9
399.002469	1	10	0	50	11	50	39
399.002473	1	10	0	50	11	50	39
399.002474	1	10	0	100	11	100	89
399.002475	13	10	5	20	23	25	1
399.002476	26	10	19	20	36	39	3
399.002479	14	10	8	20	24	28	4
399.002480	17	10	12	20	27	32	5
399.002485	1	10	0	70	11	70	59
399.002494	1	10	0	20	11	20	9
Total	1109	400	860	1600	1509	2460	951

A.18.8 Total annual cycle inventory cost CY-items

Table A.47: Results inventory ordering cost CY-items

Item	Holding cost proposed	Ordering cost proposed	Holding cost current	Ordering cost current	Total inventory cost Proposed	Total inventory cost current	Improvement
320.000095	4	30	15	20	34	35	1
399.000316	2	0	4	20	2	24	22
375.000050	9	0	10	0	9	10	0
399.000074	2	0	2	0	2	2	0
310.000204	4	10	1	10	14	11	-3
310.000210	10	0	10	0	10	10	-1
310.000229	8	10	2	10	18	12	-6
315.000155	6	10	0	20	16	20	4
320.000025	6	10	1	30	16	31	15
340.000137	0	0	98	0	0	98	98
350.000213	7	0	5	10	7	15	8
350.000246	6	0	8	20	6	28	22
350.000251	32	0	32	0	32	32	1
375.000017	17	0	17	0	17	17	0
375.000065	5	10	5	40	15	45	30
399.000413	14	20	12	90	34	102	68
310.000011	9	0	32	10	9	42	33
345.000052	67	0	64	0	67	64	-4
375.000276	1	0	1	0	1	1	-1
375.000463	17	0	5	0	17	5	-12
399.000137	19	0	12	0	19	12	-7
335.000021	16	0	15	10	16	25	10
315.000132	29	0	48	10	29	58	29
335.000052	6	0	7	20	6	27	21
375.000353	1	0	1	0	1	1	0
310.000113	9	0	8	0	9	8	-1
315.000211	6	0	7	10	6	17	11
375.000118	5	0	6	10	5	16	11
399.000156	16	0	24	10	16	34	18
399.000157	20	0	23	10	20	33	13
350.001303	13	10	10	40	23	50	27
310.001393	19	10	47	60	29	107	79
310.001394	17	10	24	20	27	44	17
310.001395	11	10	8	70	21	78	57
310.001397	7	10	2	60	17	62	45
310.001398	9	10	4	20	19	24	5

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Table A.47 – Results inventory ordering cost CY-items

Item	Holding cost proposed	Ordering cost proposed	Holding cost current	Ordering cost current	Total inventory cost Proposed	Total inventory cost current	Improvement
310.001399	8	10	3	20	18	23	5
310.001400	5	10	2	10	15	12	-3
310.001446	7	10	3	10	17	13	-4
315.000030	8	10	18	30	18	48	31
315.001080	10	0	12	10	10	22	12
330.000105	11	0	13	10	11	23	12
350.001206	3	0	3	10	3	13	10
350.001207	11	10	19	10	21	29	8
350.001227	26	0	24	0	26	24	-2
350.001228	12	10	14	10	22	24	1
350.001229	13	0	12	0	13	12	-1
375.000422	10	10	8	40	20	48	28
399.001525	4	10	2	10	14	12	-1
399.001526	32	10	27	30	42	57	15
399.001527	25	10	22	40	35	62	27
310.000002	6	0	7	0	6	7	1
310.000003	7	0	7	0	7	7	0
310.000004	47	0	45	0	47	45	-2
310.000372	4	0	4	0	4	4	0
315.000131	11	20	12	30	31	42	11
315.000214	71	0	71	0	71	71	0
315.000285	3	20	12	10	23	22	0
335.000011	9	0	9	0	9	9	0
340.000252	2	10	2	40	12	42	30
345.000024	9	30	22	40	39	62	23
345.000043	8	30	100	10	38	110	72
345.000045	6	30	97	10	36	107	71
350.000131	11	30	30	40	41	70	29
350.000271	63	0	62	0	63	62	-1
350.000290	2	20	5	20	22	25	3
399.000023	14	20	28	60	34	88	55
399.000033	8	20	14	30	28	44	16
399.000263	5	0	5	0	5	5	0
350.000132	12	30	48	30	42	78	35
350.000136	5	20	14	20	25	34	9
399.000266	10	50	57	30	60	87	27
310.000327	3	10	2	40	13	42	29
315.000359	11	10	4	50	21	54	33
315.000564	21	10	34	10	31	44	13
315.000690	6	10	21	20	16	41	25

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Table A.47 – Results inventory ordering cost CY-items

Item	Holding cost proposed	Ordering cost proposed	Holding cost current	Ordering cost current	Total inventory cost Proposed	Total inventory cost current	Improvement
315.000693	26	0	17	20	26	37	11
320.000729	3	10	2	50	13	52	39
325.000180	16	30	20	50	46	70	23
330.000088	2	20	14	20	22	34	12
350.000752	9	0	10	10	9	20	11
350.000815	14	10	15	30	24	45	21
350.001186	34	10	28	30	44	58	14
375.000018	2	0	2	0	2	2	0
399.000702	21	10	24	20	31	44	13
399.000703	7	30	8	40	37	48	11
375.000028	2	10	5	30	12	35	22
395.000233	0	0	0	0	0	0	0
399.001842	7	30	55	20	37	75	39
330.000100	7	10	13	20	17	33	16
350.000700	19	10	6	30	29	36	7
310.000211	3	10	2	40	13	42	29
335.000071	192	0	162	0	192	162	-30
370.000055	128	0	63	0	128	63	-65
330.000021	1	0	1	0	1	1	0
375.000203	2	0	5	10	2	15	12
350.000046	13	10	23	80	23	103	80
399.000877	3	0	3	0	3	3	0
350.000912	1	10	1	0	11	1	-10
399.000310	1	0	1	0	1	1	0
310.001008	1	10	1	10	11	11	-1
310.001077	2	0	2	0	2	2	0
315.000817	16	20	18	70	36	88	52
315.000949	5	0	5	0	5	5	-1
315.000581	5	10	8	20	15	28	13
315.000988	1	0	3	10	1	13	12
310.001079	4	10	4	40	14	44	29
315.000624	6	20	10	20	26	30	4
335.000662	8	20	10	0	28	10	-18
310.000717	9	10	6	60	19	66	48
310.000721	3	10	3	50	13	53	40
315.000821	11	0	10	0	11	10	-1
375.000007	13	0	20	10	13	30	17
315.001252	10	0	14	70	10	84	74
350.002136	21	10	94	30	31	124	93
395.000480	49	0	36	0	49	36	-13

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Table A.47 – Results inventory ordering cost CY-items

Item	Holding cost proposed	Ordering cost proposed	Holding cost current	Ordering cost current	Total inventory cost Proposed	Total inventory cost current	Improvement
399.000101	21	0	49	30	21	79	58
399.001943	24	10	72	20	34	92	58
399.001944	31	0	39	50	31	89	58
370.000284	26	0	27	10	26	37	11
315.000666	10	10	25	20	20	45	24
350.000590	24	10	22	10	34	32	-2
350.000604	8	10	12	20	18	32	14
350.000611	12	10	5	40	22	45	24
350.000779	4	10	14	10	14	24	10
350.000858	39	10	28	30	49	58	9
350.000934	19	10	28	40	29	68	39
350.001115	5	10	7	10	15	17	2
350.001116	4	20	4	20	24	24	0
350.001117	16	20	22	20	36	42	6
399.000247	14	10	14	20	24	34	10
399.000330	29	20	26	10	49	36	-12
399.001396	34	30	87	30	64	117	54
399.001464	13	10	34	20	23	54	31
375.000107	8	10	3	20	18	23	5
375.000295	11	10	62	40	21	102	82
399.001900	8	0	6	0	8	6	-3
399.002041	16	0	12	0	16	12	-4
310.001594	8	10	4	20	18	24	6
310.001595	4	10	0	50	14	50	37
310.001596	4	10	1	30	14	31	17
320.000384	10	10	7	20	20	27	7
330.000109	2	0	2	10	2	12	10
399.001815	20	10	8	40	30	48	18
399.001901	5	10	6	10	15	16	1
310.000871	9	0	11	50	9	61	52
350.000288	14	10	13	60	24	73	49
310.001609	140	0	140	0	140	140	0
350.001545	1	10	0	10	11	10	-1
350.001546	1	10	0	10	11	10	-1
375.000473	8	0	10	0	8	10	2
375.000474	12	10	8	20	22	28	5
375.000475	5	10	2	10	15	12	-3
399.001867	1	10	0	60	11	60	49
399.001871	1	10	0	10	11	10	-1
335.000798	0	0	0	20	0	20	20

Continued on next page

Table A.47 – Results inventory ordering cost CY-items

Item	Holding cost proposed	Ordering cost proposed	Holding cost current	Ordering cost current	Total inventory cost Proposed	Total inventory cost current	Improvement
335.000799	0	0	0	20	0	20	20
315.000599	3	20	12	60	23	72	48
399.001849	14	10	21	10	24	31	7
399.001853	1	10	0	10	11	10	-1
399.001858	1	10	0	10	11	10	-1
399.001859	1	10	0	10	11	10	-1
399.001860	1	10	0	10	11	10	-1
399.001861	1	10	0	10	11	10	-1
399.001862	1	10	0	10	11	10	-1
399.001863	1	10	0	10	11	10	-1
399.001864	0	10	0	10	10	10	0
399.001865	1	10	0	10	11	10	-1
399.002021	1	10	0	10	11	10	-1
399.002022	0	10	0	10	10	10	0
399.002023	1	10	0	10	11	10	-1
350.000256	8	0	8	0	8	8	0
375.000039	2	0	2	0	2	2	0
399.002150	25	10	9	10	35	19	-15
375.000553	30	20	40	30	50	70	20
375.000554	18	10	11	30	28	41	13
375.000555	13	10	3	30	23	33	10
399.002477	15	10	10	20	25	30	5
399.002484	1	10	0	180	11	180	169
399.002488	1	10	0	100	11	100	89
Total	2398	1540	3111	3760	3938	6871	2933

A.18.9 Total annual cycle inventory cost CZ-items

Table A.48: Results inventory ordering cost CZ-items static

Item	Holding cost proposed	Ordering cost proposed	Holding cost current	Ordering cost current	Total inventory cost Proposed	Total inventory cost current	Improvement
315.000088	49	0	49	0	49	49	0
399.000067	160471	0	161546	0	160471	161546	1075
315.000080	10	510	13	20	520	33	-486

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Table A.48 – Results inventory ordering cost CZ-items static

Item	Holding cost proposed	Ordering cost proposed	Holding cost current	Ordering cost current	Total inventory cost Proposed	Total inventory cost current	Improvement
310.000347	1	20	0	10	21	10	-10
370.000043	38	0	38	0	38	38	0
375.000030	1	0	1	0	1	1	0
375.000031	137	0	134	0	137	134	-3
375.000099	16	0	16	0	16	16	0
375.000111	1	0	1	0	1	1	0
375.000112	1	0	1	0	1	1	0
399.000061	324	0	264	0	324	264	-60
399.000065	28	0	27	0	28	27	-2
399.000066	87	0	86	0	87	86	-1
310.000342	2	0	1	0	2	1	-1
310.000349	12	10	3	30	22	33	11
310.000346	2	0	5	0	2	5	3
399.000064	241	0	321	0	241	321	80
310.000188	1	0	2	0	1	2	2
310.000206	1	0	1	0	1	1	0
310.000222	8	0	8	0	8	8	0
310.000234	4	0	4	0	4	4	0
310.000236	2	0	2	0	2	2	0
310.000238	3	0	3	0	3	3	-1
310.000257	1	0	1	0	1	1	0
310.000353	4	0	3	20	4	23	19
310.000397	2	0	2	0	2	2	0
310.000398	1	0	1	0	1	1	0
310.000680	17	0	17	0	17	17	0
315.000064	3	0	3	0	3	3	-1
315.000154	3	0	3	0	3	3	0
315.000284	0	0	0	0	0	0	0
320.000026	1	0	1	0	1	1	0
320.000043	1	0	1	0	1	1	0
330.000019	5	0	5	0	5	5	0
330.000023	30	0	24	0	30	24	-7
335.000002	9	10	17	20	19	37	18
335.000386	1	0	1	0	1	1	0
340.000130	5	10	2	20	15	22	7
340.000213	2	10	4	10	12	14	2
340.000301	0	0	8	0	0	8	8
340.000304	1	0	1	0	1	1	0
340.000305	2	0	3	0	2	3	2
345.000001	15	0	22	0	15	22	7

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Table A.48 – Results inventory ordering cost CZ-items static

Item	Holding cost proposed	Ordering cost proposed	Holding cost current	Ordering cost current	Total inventory cost Proposed	Total inventory cost current	Improvement
350.000206	0	0	0	0	0	0	0
350.000209	4	0	9	0	4	9	4
350.000244	8	0	3	10	8	13	5
355.000100	60	0	60	0	60	60	0
375.000021	4	0	4	0	4	4	0
375.000045	3	0	3	0	3	3	0
399.000158	384	0	256	0	384	256	-128
399.000165	164	0	4	0	164	4	-160
399.000167	401	0	13	0	401	13	-388
399.000261	13	0	13	0	13	13	0
399.000410	11	0	9	0	11	9	-2
375.000145	20	0	12	0	20	12	-8
310.000066	3	0	1	0	3	1	-2
315.000210	15	0	10	10	15	20	6
350.000004	2	0	1	0	2	1	-1
375.000464	13	0	6	0	13	6	-6
310.000082	1	0	0	0	1	0	-1
350.001126	138	0	141	0	138	141	3
350.001620	52	0	53	0	52	53	1
350.001621	30	0	30	0	30	30	0
345.000327	90	0	222	20	90	242	151
350.001205	13	20	26	20	33	46	12
350.001222	48	0	48	0	48	48	0
350.001223	10	0	17	0	10	17	6
350.001224	6	0	11	0	6	11	5
350.001230	16	0	16	0	16	16	0
350.001231	22	0	22	0	22	22	0
375.000109	1	0	1	0	1	1	0
375.000110	1	0	1	0	1	1	0
375.000187	2	0	2	0	2	2	0
375.000233	0	0	0	0	0	0	0
375.000411	32	0	32	0	32	32	0
375.000413	21	0	20	0	21	20	-1
375.000414	5	0	5	0	5	5	0
399.001522	4	40	12	20	44	32	-12
399.001540	8	0	31	10	8	41	33
399.001541	16	0	38	0	16	38	22
350.001956	6	0	6	0	6	6	-1
399.000555	19	0	6	0	19	6	-13
315.001143	204	0	210	0	204	210	6

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Table A.48 – Results inventory ordering cost CZ-items static

Item	Holding cost proposed	Ordering cost proposed	Holding cost current	Ordering cost current	Total inventory cost Proposed	Total inventory cost current	Improvement
350.001044	9	0	29	0	9	29	20
350.001524	17	20	17	40	37	57	19
310.000259	7	0	7	0	7	7	0
310.000263	7	10	14	20	17	34	18
335.000073	92	0	92	0	92	92	0
310.000224	11	0	11	0	11	11	0
310.000261	0	10	0	20	10	20	10
370.000037	9	0	10	0	9	10	1
320.000178	0	0	0	10	0	10	10
335.000422	3	0	14	10	3	24	21
355.000913	5	0	16	10	5	26	20
370.000050	2	0	2	0	2	2	0
375.000421	13	0	12	0	13	12	0
335.000411	53	10	19	0	63	19	-44
350.000865	16	20	6	10	36	16	-21
350.001585	21	10	8	0	31	8	-23
370.000194	300	310	507	0	610	507	-103
350.000601	4	50	13	20	54	33	-21
350.000605	1	0	1	0	1	1	0
370.000110	160	0	164	0	160	164	4
335.000621	41	0	41	0	41	41	0
370.000205	64	0	64	0	64	64	0
375.000043	2	0	2	0	2	2	0
375.000383	35	0	35	0	35	35	-1
375.000384	42	0	42	0	42	42	0
375.000416	15	0	16	0	15	16	1
399.001707	5	0	4	0	5	4	0
310.001743	20	0	16	0	20	16	-3
310.001744	6	10	14	10	16	24	8
315.001242	8	10	7	10	18	17	-1
340.001759	4	20	19	10	24	29	5
340.001760	14	10	25	10	24	35	11
365.000348	16	10	25	10	26	35	9
365.000349	7	10	8	10	17	18	1
315.001341	15	20	5	20	35	25	-10
320.000978	9	10	2	40	19	42	23
335.000663	3	0	4	0	3	4	0
375.000530	6	10	3	20	16	23	7
399.002127	23	10	10	20	33	30	-3
399.002128	12	10	2	10	22	12	-10

Continued on next page

Table A.48 – Results inventory ordering cost CZ-items static

Item	Holding cost proposed	Ordering cost proposed	Holding cost current	Ordering cost current	Total inventory cost Proposed	Total inventory cost current	Improvement
340.000253	0	40	1	10	40	11	-29
350.002091	4	10	4	10	14	14	0
350.002475	2	210	2	10	212	12	-200
350.002476	0	210	22	10	210	32	-178
350.002478	0	210	13	10	210	23	-187
365.000431	0	40	60	10	40	70	30
365.000432	0	40	0	10	40	10	-30
370.000301	0	210	22	10	210	32	-178
399.002787	0	210	239	10	210	249	39
399.002788	0	210	49	10	210	59	-151
399.002789	0	210	45	10	210	55	-155
399.002792	0	210	1014	0	210	1014	804
350.001164	11	0	13	0	11	13	2
375.000038	1	10	1	10	11	11	0
350.000033	5	0	4	0	5	4	-1
399.001536	27	0	28	0	27	28	0
350.001280	2	0	1	0	2	1	0
350.001323	2	30	2	30	32	32	-1
399.001594	3	360	13	20	363	33	-330
399.001597	2	390	8	30	392	38	-354
310.001082	2	10	2	10	12	12	0
310.001421	0	20	0	10	20	10	-10
310.001422	0	0	0	0	0	0	0
310.001423	1	140	13	10	141	23	-118
315.000943	34	0	33	0	34	33	-1
315.001071	0	170	2	20	170	22	-148
350.001278	5	290	11	20	295	31	-264
310.001454	0	0	0	0	0	0	0
315.000113	9	0	8	0	9	8	0
350.001277	54	0	9	30	54	39	-15
350.000065	1	410	3	10	411	13	-398
325.000722	1	10	1	20	11	21	9
350.001279	3	380	12015	20	383	12035	11652
350.001332	8	30	16	20	38	36	-3
315.001117	3	10	1	10	13	11	-2
315.001118	1	0	1	0	1	1	0
315.001119	1	10	0	0	11	0	-11
315.001120	1	210	4	10	211	14	-197
315.001121	1	0	1	0	1	1	0
315.001122	4	10	1	30	14	31	17

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Table A.48 – Results inventory ordering cost CZ-items static

Item	Holding cost proposed	Ordering cost proposed	Holding cost current	Ordering cost current	Total inventory cost Proposed	Total inventory cost current	Improvement
315.001123	3	10	1	10	13	11	-2
315.001124	0	380	1	10	380	11	-369
315.001125	2	10	0	20	12	20	8
315.001126	1	0	1	0	1	1	0
350.001369	3	370	9	10	373	19	-354
399.002710	5	10	5	10	15	15	0
350.001796	24	10	17	20	34	37	3
350.002381	21	10	7	20	31	27	-4
350.002382	21	10	7	20	31	27	-4
315.001580	15	20	28	10	35	38	3
350.002384	2	0	4	0	2	4	2
355.001822	76	0	156	20	76	176	99
399.002672	31	0	28	0	31	28	-3
399.002673	31	0	22	20	31	42	10
399.002675	31	0	32	10	31	42	11
399.002676	1	0	1	10	1	11	10
399.002678	3	0	3	10	3	13	10
399.002679	6	0	6	10	6	16	10
399.002680	4	0	3	0	4	3	0
399.002681	4	0	8	10	4	18	13
399.002682	1	0	2	10	1	12	12
399.002740	0	0	0	0	0	0	0
350.000777	11	10	12	20	21	32	12
310.000420	4	0	6	0	4	6	2
399.001974	8	10	3	0	18	3	-15
350.001999	1	0	2	0	1	2	1
350.002000	4	0	4	0	4	4	0
375.000356	5	0	5	0	5	5	0
350.000031	6	0	6	0	6	6	0
399.002758	0	0	0	0	0	0	0
399.002805	0	70	12	10	70	22	-48
350.000121	1	0	2	0	1	2	1
350.000956	2	0	2	0	2	2	0
350.000960	7	0	7	0	7	7	0
310.001608	74	0	74	0	74	74	0
335.000724	1	0	1	0	1	1	0
310.001643	31	10	20	0	41	20	-21
335.000723	9	0	11	0	9	11	1
350.001528	51	0	51	0	51	51	0
350.001529	5	0	5	0	5	5	0

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Table A.48 – Results inventory ordering cost CZ-items static

Item	Holding cost proposed	Ordering cost proposed	Holding cost current	Ordering cost current	Total inventory cost Proposed	Total inventory cost current	Improvement
350.001547	16	0	16	0	16	16	0
395.000432	166	0	114	50	166	164	-2
395.000435	48	0	48	0	48	48	0
395.000436	29	0	29	0	29	29	0
395.000437	54	0	73	10	54	83	29
395.000438	0	0	0	0	0	0	0
350.001958	81	0	8	10	81	18	-63
395.000425	7	0	7	0	7	7	0
395.000434	7	0	7	0	7	7	0
395.000439	76	0	101	10	76	111	36
395.000440	2	0	2	0	2	2	0
395.000449	32	0	32	0	32	32	0
395.000484	908	0	492	30	908	522	-386
395.000486	0	0	0	0	0	0	0
395.000487	0	0	0	0	0	0	0
395.000488	9	0	9	0	9	9	0
365.000435	0	90	0	20	90	20	-70
399.001964	0	0	0	0	0	0	0
399.002106	0	0	0	0	0	0	0
399.002193	0	0	0	0	0	0	0
399.002210	0	0	0	0	0	0	0
399.002205	1	0	1	0	1	1	0
399.002207	0	0	0	0	0	0	0
399.002212	0	0	0	0	0	0	0
399.002213	0	0	0	0	0	0	0
399.002239	4	0	4	0	4	4	0
395.000543	0	0	0	30	0	30	30
399.002267	0	0	0	0	0	0	0
399.002354	0	0	0	0	0	0	0
399.002356	0	0	0	0	0	0	0
399.002358	0	0	0	0	0	0	0
399.002426	2	10	0	20	12	20	8
335.001823	0	530	0	0	530	0	-530
335.001824	0	530	0	0	530	0	-530
335.001825	0	530	40	30	530	70	-460
399.002427	0	10	0	10	10	10	0
350.000719	7	0	7	0	7	7	0
350.001666	7	0	7	0	7	7	0
350.001667	4	0	4	0	4	4	0
350.001668	29	10	30	0	39	30	-9

Continued on next page

Table A.48 – Results inventory ordering cost CZ-items static

Item	Holding cost proposed	Ordering cost proposed	Holding cost current	Ordering cost current	Total inventory cost Proposed	Total inventory cost current	Improvement
399.001374	9	0	9	0	9	9	0
399.002004	0	0	0	0	0	0	0
350.001961	1	0	16	0	1	16	15
399.002329	2	0	2	0	2	2	0
399.000279	11	20	6	20	31	26	-5
399.002536	6	10	4	30	16	34	18
350.002474	0	420	38	10	420	48	-372
325.000928	8	10	9	10	18	19	0
345.001653	21	20	29	20	41	49	9
399.000478	8	10	3	10	18	13	-5
399.002559	10	10	5	10	20	15	-5
399.002560	11	10	6	10	21	16	-5
365.000409	1	0	63	0	1	63	62
399.002223	2	10	0	20	12	20	9
399.002442	0	0	0	0	0	0	0
350.001262	12	10	29	10	22	39	17
350.002003	10	10	16	10	20	26	6
399.002367	15	30	23	20	45	43	-2
399.001391	15	440	16	50	455	66	-389
399.002491	9	450	24	80	459	104	-355
399.002808	0	530	0	40	530	40	-490
399.002795	0	350	0	20	350	20	-330
399.002820	0	350	0	0	350	0	-350
345.001624	13	0	13	0	13	13	0
350.000781	2	0	2	0	2	2	0
399.002534	22	0	22	0	22	22	0
315.001596	3	450	9	30	453	39	-414
320.001182	2	450	10	50	452	60	-391
350.002448	1	450	14	20	451	34	-417
399.002747	21	0	32	20	21	52	30
399.002749	11	450	25	10	461	35	-426
Total	6475	12630	19486	1930	19105	21416	2311

Table A.49: Results inventory ordering cost CZ-items dynamic

Item	Holding cost proposed	Ordering cost proposed	Holding cost current	Ordering cost current	Total inventory cost Proposed	Total inventory cost current	Improvement
315.000088	49	0	49	0	49	49	0
399.000067	66	0	66	0	66	66	0
315.000080	10	530	13	20	540	33	-506
310.000347	1	20	0	10	21	10	-10
370.000043	38	0	38	0	38	38	0
375.000030	1	0	1	0	1	1	0
375.000031	137	0	134	0	137	134	-3
375.000099	16	0	16	0	16	16	0
375.000111	1	0	1	0	1	1	0
375.000112	1	0	1	0	1	1	0
399.000061	324	0	264	0	324	264	-60
399.000065	28	0	27	0	28	27	-2
399.000066	87	0	86	0	87	86	-1
310.000342	2	0	1	0	2	1	-1
310.000349	12	10	3	30	22	33	11
310.000346	2	0	5	0	2	5	3
399.000064	241	0	321	0	241	321	80
310.000188	1	0	2	0	1	2	2
310.000206	1	0	1	0	1	1	0
310.000222	8	0	8	0	8	8	0
310.000234	4	0	4	0	4	4	0
310.000236	2	0	2	0	2	2	0
310.000238	3	0	3	0	3	3	-1
310.000257	1	0	1	0	1	1	0
310.000353	4	0	3	20	4	23	19
310.000397	2	0	2	0	2	2	0
310.000398	1	0	1	0	1	1	0
310.000680	17	0	17	0	17	17	0
315.000064	3	0	3	0	3	3	-1
315.000154	3	0	3	0	3	3	0
315.000284	0	0	0	0	0	0	0
320.000026	1	0	1	0	1	1	0
320.000043	1	0	1	0	1	1	0
330.000019	5	0	5	0	5	5	0
330.000023	30	0	24	0	30	24	-7
335.000002	29	20	17	20	49	37	-12
335.000386	1	0	1	0	1	1	0
340.000130	5	10	2	20	15	22	7

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Table A.49 – Results inventory ordering cost CZ-items dynamic

Item	Holding cost proposed	Ordering cost proposed	Holding cost current	Ordering cost current	Total inventory cost Proposed	Total inventory cost current	Improvement
340.000213	2	10	4	10	12	14	2
340.000301	0	0	8	0	0	8	8
340.000304	1	0	1	0	1	1	0
340.000305	2	0	3	0	2	3	2
345.000001	15	0	22	0	15	22	7
350.000206	0	0	0	0	0	0	0
350.000209	4	0	9	0	4	9	4
350.000244	8	0	3	10	8	13	5
355.000100	60	0	60	0	60	60	0
375.000021	4	0	4	0	4	4	0
375.000045	3	0	3	0	3	3	0
399.000158	384	0	256	0	384	256	-128
399.000165	164	0	4	0	164	4	-160
399.000167	401	0	13	0	401	13	-388
399.000261	13	0	13	0	13	13	0
399.000410	11	0	9	0	11	9	-2
375.000145	20	0	12	0	20	12	-8
310.000066	3	0	1	0	3	1	-2
315.000210	15	0	10	10	15	20	6
350.000004	2	0	1	0	2	1	-1
375.000464	13	0	6	0	13	6	-6
310.000082	1	0	0	0	1	0	-1
350.001126	138	0	141	0	138	141	3
350.001620	52	0	53	0	52	53	1
350.001621	30	0	30	0	30	30	0
345.000327	90	0	222	20	90	242	151
350.001205	13	20	26	20	33	46	12
350.001222	48	0	48	0	48	48	0
350.001223	10	0	17	0	10	17	6
350.001224	6	0	11	0	6	11	5
350.001230	16	0	16	0	16	16	0
350.001231	22	0	22	0	22	22	0
375.000109	1	0	1	0	1	1	0
375.000110	1	0	1	0	1	1	0
375.000187	2	0	2	0	2	2	0
375.000233	0	0	0	0	0	0	0
375.000411	32	0	32	0	32	32	0
375.000413	21	0	20	0	21	20	-1
375.000414	5	0	5	0	5	5	0
399.001522	4	40	12	20	44	32	-12

Continued on next page

Table A.49 – Results inventory ordering cost CZ-items dynamic

Item	Holding cost proposed	Ordering cost proposed	Holding cost current	Ordering cost current	Total inventory cost Proposed	Total inventory cost current	Improvement
399.001540	8	0	31	10	8	41	33
399.001541	16	0	38	0	16	38	22
350.001956	6	0	6	0	6	6	-1
399.000555	19	0	6	0	19	6	-13
315.001143	204	0	210	0	204	210	6
350.001044	9	0	29	0	9	29	20
350.001524	34	20	17	40	54	57	3
310.000259	7	0	7	0	7	7	0
310.000263	7	10	14	20	17	34	17
335.000073	92	0	92	0	92	92	0
310.000224	11	0	11	0	11	11	0
310.000261	0	10	0	20	10	20	10
370.000037	9	0	10	0	9	10	1
320.000178	0	0	0	10	0	10	10
335.000422	3	0	14	10	3	24	21
355.000913	5	0	16	10	5	26	20
370.000050	2	0	2	0	2	2	0
375.000421	13	0	12	0	13	12	0
335.000411	53	10	19	0	63	19	-44
350.000865	16	20	6	10	36	16	-21
350.001585	21	10	8	0	31	8	-23
370.000194	300	310	507	0	610	507	-103
350.000601	4	50	13	20	54	33	-21
350.000605	1	0	1	0	1	1	0
370.000110	160	0	164	0	160	164	4
335.000621	41	0	41	0	41	41	0
370.000205	64	0	64	0	64	64	0
375.000043	2	0	2	0	2	2	0
375.000383	35	0	35	0	35	35	-1
375.000384	42	0	42	0	42	42	0
375.000416	15	0	16	0	15	16	1
399.001707	5	0	4	0	5	4	0
310.001743	20	0	16	0	20	16	-3
310.001744	6	10	14	10	16	24	8
315.001242	8	10	7	10	18	17	-1
340.001759	4	20	19	10	24	29	5
340.001760	14	10	25	10	24	35	11
365.000348	16	10	25	10	26	35	9
365.000349	7	10	8	10	17	18	1
315.001341	16	20	5	20	36	25	-11

Continued on next page

Table A.49 – Results inventory ordering cost CZ-items dynamic

Item	Holding cost proposed	Ordering cost proposed	Holding cost current	Ordering cost current	Total inventory cost Proposed	Total inventory cost current	Improvement
320.000978	9	10	2	40	19	42	23
335.000663	3	0	4	0	3	4	0
375.000530	6	10	3	20	16	23	7
399.002127	23	10	10	20	33	30	-3
399.002128	12	10	2	10	22	12	-10
340.000253	0	40	1	10	40	11	-29
350.002091	4	10	4	10	14	14	0
350.002475	2	210	2	10	212	12	-200
350.002476	0	210	22	10	210	32	-178
350.002478	0	210	13	10	210	23	-187
365.000431	0	40	60	10	40	70	30
365.000432	0	40	0	10	40	10	-30
370.000301	0	210	22	10	210	32	-178
399.002787	0	210	239	10	210	249	39
399.002788	0	210	49	10	210	59	-151
399.002789	0	210	45	10	210	55	-155
399.002792	0	210	1014	0	210	1014	804
350.001164	11	0	13	0	11	13	2
375.000038	1	10	1	10	11	11	0
350.000033	5	0	4	0	5	4	-1
399.001536	27	0	28	0	27	28	0
350.001280	2	0	1	0	2	1	0
350.001323	2	30	2	30	32	32	-1
399.001594	3	380	13	20	383	33	-350
399.001597	2	410	8	30	412	38	-374
310.001082	2	10	2	10	12	12	0
310.001421	0	20	0	10	20	10	-10
310.001422	0	0	0	0	0	0	0
310.001423	1	150	13	10	151	23	-128
315.000943	34	0	33	0	34	33	-1
315.001071	0	200	2	20	200	22	-178
350.001278	5	300	11	20	305	31	-274
310.001454	0	0	0	0	0	0	0
315.000113	9	0	8	0	9	8	0
350.001277	54	0	9	30	54	39	-15
350.000065	1	410	3	10	411	13	-398
325.000722	1	10	1	20	11	21	9
350.001279	3	380	12015	20	383	12035	11652
350.001332	8	30	16	20	38	36	-3
315.001117	3	10	1	10	13	11	-2

Continued on next page

Table A.49 – Results inventory ordering cost CZ-items dynamic

Item	Holding cost proposed	Ordering cost proposed	Holding cost current	Ordering cost current	Total inventory cost Proposed	Total inventory cost current	Improvement
315.001118	1	0	1	0	1	1	0
315.001119	1	40	0	0	41	0	-41
315.001120	1	230	4	10	231	14	-217
315.001121	1	0	1	0	1	1	0
315.001122	4	10	1	30	14	31	17
315.001123	3	10	1	10	13	11	-2
315.001124	0	380	1	10	380	11	-369
315.001125	2	10	0	20	12	20	8
315.001126	1	0	1	0	1	1	0
350.001369	3	380	9	10	383	19	-364
399.002710	5	10	5	10	15	15	0
350.001796	24	10	17	20	34	37	3
350.002381	21	10	7	20	31	27	-4
350.002382	21	10	7	20	31	27	-4
315.001580	15	20	28	10	35	38	3
350.002384	2	0	4	0	2	4	2
355.001822	76	0	156	20	76	176	99
399.002672	31	0	28	0	31	28	-3
399.002673	31	0	22	20	31	42	10
399.002675	31	0	32	10	31	42	11
399.002676	1	0	1	10	1	11	10
399.002678	3	0	3	10	3	13	10
399.002679	6	0	6	10	6	16	10
399.002680	4	0	3	0	4	3	0
399.002681	4	0	8	10	4	18	13
399.002682	1	0	2	10	1	12	12
399.002740	0	0	0	0	0	0	0
350.000777	11	10	12	20	21	32	12
310.000420	4	0	6	0	4	6	2
399.001974	0	0	3	0	0	3	2
350.001999	1	0	2	0	1	2	1
350.002000	4	0	4	0	4	4	0
375.000356	5	0	5	0	5	5	0
350.000031	6	0	6	0	6	6	0
399.002758	0	0	0	0	0	0	0
399.002805	0	70	12	10	70	22	-48
350.000121	1	0	2	0	1	2	1
350.000956	2	0	2	0	2	2	0
350.000960	7	0	7	0	7	7	0
310.001608	74	0	74	0	74	74	0

Continued on next page

Table A.49 – Results inventory ordering cost CZ-items dynamic

Item	Holding cost proposed	Ordering cost proposed	Holding cost current	Ordering cost current	Total inventory cost Proposed	Total inventory cost current	Improvement
335.000724	1	0	1	0	1	1	0
310.001643	31	10	20	0	41	20	-21
335.000723	9	0	11	0	9	11	1
350.001528	51	0	51	0	51	51	0
350.001529	5	0	5	0	5	5	0
350.001547	16	0	16	0	16	16	0
395.000432	166	0	114	50	166	164	-2
395.000435	48	0	48	0	48	48	0
395.000436	29	0	29	0	29	29	0
395.000437	54	0	73	10	54	83	29
395.000438	0	0	0	0	0	0	0
350.001958	81	0	8	10	81	18	-63
395.000425	7	0	7	0	7	7	0
395.000434	7	0	7	0	7	7	0
395.000439	76	0	101	10	76	111	36
395.000440	2	0	2	0	2	2	0
395.000449	32	0	32	0	32	32	0
395.000484	908	0	492	30	908	522	-386
395.000486	0	0	0	0	0	0	0
395.000487	0	0	0	0	0	0	0
395.000488	9	0	9	0	9	9	0
365.000435	0	110	0	20	110	20	-90
399.001964	0	0	0	0	0	0	0
399.002106	0	0	0	0	0	0	0
399.002193	0	0	0	0	0	0	0
399.002210	0	0	0	0	0	0	0
399.002205	1	0	1	0	1	1	0
399.002207	0	0	0	0	0	0	0
399.002212	0	0	0	0	0	0	0
399.002213	0	0	0	0	0	0	0
399.002239	4	0	4	0	4	4	0
395.000543	0	0	0	30	0	30	30
399.002267	0	0	0	0	0	0	0
399.002354	0	0	0	0	0	0	0
399.002356	0	0	0	0	0	0	0
399.002358	0	0	0	0	0	0	0
399.002426	2	10	0	20	12	20	8
335.001823	0	530	0	0	530	0	-530
335.001824	0	530	0	0	530	0	-530
335.001825	0	530	40	30	530	70	-460

Continued on next page

Table A.49 – Results inventory ordering cost CZ-items dynamic

Item	Holding cost proposed	Ordering cost proposed	Holding cost current	Ordering cost current	Total inventory cost Proposed	Total inventory cost current	Improvement
399.002427	0	10	0	10	10	10	0
350.000719	7	0	7	0	7	7	0
350.001666	7	0	7	0	7	7	0
350.001667	4	0	4	0	4	4	0
350.001668	29	10	30	0	39	30	-9
399.001374	9	0	9	0	9	9	0
399.002004	0	0	0	0	0	0	0
350.001961	1	0	16	0	1	16	15
399.002329	2	0	2	0	2	2	0
399.000279	11	20	6	20	31	26	-5
399.002536	6	10	4	30	16	34	18
350.002474	0	420	38	10	420	48	-372
325.000928	8	10	9	10	18	19	0
345.001653	21	20	29	20	41	49	9
399.000478	8	10	3	10	18	13	-5
399.002559	10	10	5	10	20	15	-5
399.002560	11	10	6	10	21	16	-5
365.000409	2	10	63	0	12	63	50
399.002223	2	10	0	20	12	20	9
399.002442	0	10	0	0	10	0	-10
350.001262	12	10	29	10	22	39	17
350.002003	26	10	16	10	36	26	-10
399.002367	15	30	23	20	45	43	-2
399.001391	15	440	16	50	455	66	-389
399.002491	5	440	24	80	445	104	-341
399.002808	0	530	0	40	530	40	-490
399.002795	0	350	0	20	350	20	-330
399.002820	0	350	0	0	350	0	-350
345.001624	13	0	13	0	13	13	0
350.000781	2	0	2	0	2	2	0
399.002534	22	0	22	0	22	22	0
315.001596	3	530	9	30	533	39	-494
320.001182	2	530	10	50	532	60	-472
350.002448	1	530	14	20	531	34	-497
399.002747	22	280	32	20	302	52	-250
399.002749	11	450	25	10	461	35	-426
Total	6520	13350	19486	1930	19870	21416	1546

A.19 Results BY-items best selected policy

Table A.50: Results BY-items best policy selection

Item	Improvement	Selected policy
315.000084	976	(s,S)
399.000010	911	(s,Q)
399.000014	154	(sk,Q)
370.000021	153	(sk,Q)
399.000154	162	(sk,Q)
399.000159	90	(sk,Q)
399.000160	0	(sk,Q)
399.001929	800	(s,Q)
315.001050	1728	(s,Q)
315.001051	575	(s,Q)
315.001053	-177	(sk,Q)
335.000676	450	(R,S)
345.000315	593	(s,Q)
345.000318	902	(s,Q)
350.001197	875	(s,Q)
350.001204	950	(s,Q)
350.001225	1150	(s,S)
350.001308	1151	(s,Q)
315.001416	800	(s,Q)
345.000019	160	(R,S)
345.000053	1584	(R,s,S)
345.000161	160	(s,Q)
345.000162	160	(s,Q)
350.000735	1023	(s,Q)
399.000265	160	(R,S)
315.000034	126	(sk,Q)
345.000164	61	(sk,Q)
345.000165	106	(sk,Q)
345.000166	221	(sk,Q)
315.000563	-445	(sk,Q)
320.000186	224	(sk,Q)
350.000556	65	(sk,Q)
350.001185	157	(sk,Q)
399.000691	0	(sk,Q)
399.000700	29	(sk,Q)
350.000780	21	(sk,Q)
335.000408	260	(sk,Q)
335.000759	174	(sk,Q)
335.000760	76	(sk,Q)

Continued on next page

Table A.50 – Results BY-items

Item	Improvement	Selected policy
350.001629	175	(sk,Q)
370.000267	574	(sk,Q)
399.000213	182	(sk,Q)
399.001941	181	(sk,Q)
399.001942	502	(sk,Q)
399.001945	272	(sk,Q)
370.000283	0	(sk,Q)
399.002430	83	(sk,Q)
399.002431	-72	(sk,Q)
399.002530	134	(sk,Q)
399.001695	-264	(sk,Q)
310.001593	0	(sk,Q)
355.001113	-194	(sk,Q)
310.000994	8	(sk,Q)
350.001526	-26	(sk,Q)