

New Journey to reduce cost of inventory

Bachelor assignment Industrial Engineering & Management

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Preface

In front of you is my bachelor assignment 'New journey to reduce cost of inventory'. The research focusses on reducing the total costs of inventory. During this research I worked at RGBV from April 2019 to July 2019.

Hereby I want to thank all people who have supported me in the past few months. First, I would like to thank all employees of Rotork Gears B.V., especially Robbin Goosen and Harm Meijering. Robbin Goosen, a purchasing manager of RGBV who always made time to answer my questions and providing me with data needed to conduct this research. Harm Meijering, the plant manager, for giving me the opportunity to apply my knowledge at RGBV. Next, I want to thank my supervisor Ipek Seryan Topan for always providing me with critical feedback and helping me to get the most out of my research. Finally, I would like to thank my fellow student Sven Stienissen for his feedback in the earlier parts of this research.

Kind regards,

Thom Rikken

Losser, July 2019

Management summary

Rotork Gears B.V. (RGBV) manufactures a wide range of quarter-turn gearboxes, which are used in various applications such as water, gas, chemical, power and industrial applications. Rotork's general leadership has started to focus on reducing the inventory costs. RGBV has already reduced the inventory of the slow/non-moving stock in 2018, now RGBV wants to know if it is possible to reduce the cost of inventory by improving inventory management of safety stocks of the A class product range. This research is focussed on reducing the total cost of inventory by improving the inventory management of the safety stock of the A class product range, to accomplish this the following research question has been made:

'How can RGBV reduce the total cost of inventory by improving the inventory management of safety stock of the A class product range?'

The research starts with analysing the current situation. The steps taken by the purchasing model are mapped out, as well as the formulas used, the inventory classification method and the inventory control policy used.

During the literature research, methods and formulas which could contribute to answering the research question, were found. Here, an alternative safety stock formula which takes lead time variability into account was found, it is believed that this formula could lead to lower inventory costs. A classification method has also been found, that has proven to outperform other classification methods. With this method, the ratio between the shortage and holding costs is vital for the classification of items and providing items with the appropriate service level. During this literature study, we also looked at which method is best for testing possible solutions, a Monte Carlo simulation turned out to be the best method.

Several things have been experimented with use of the simulation model. Firstly, the new safety stock formula has been experimented with, the output of these experiments has been compared with the base model, this experiment is called intervention 1. Secondly, we looked at the impact of the new safety stock formula in combination with the service level between 85% and 99% which leads to the lowest costs, this experiment is called intervention 2.

The results of the simulation model indicated that intervention 1 would result in a cost reduction of approximately €16,779 per year if it was used for all class A items. If this were used for all items, the saved costs would probably be higher. Product availability also increases with intervention 1, the average order fill rate will increase with 0.55% and the average product fill rate with 0.60%. The average inventory position would increase with 2.57%.

With intervention 2, a cost reduction of around €45,457 per year will be possible if it is done for all class A items. The average product availability would also increase, the average order fill rate increases with 0.94% and the average product fill rate with 1.00%. The average inventory position would drop with 0.83%.

It also becomes clear that if service level is changed, the total costs change, mostly due to the changes in shortage and holding costs. The handling, shipping and ordering costs remain fairly constant. From this can be concluded that the classification method in which the shortage and holding costs are taken into account leads to the cost reduction of intervention 2.

Based on the results, we give the following recommendations:

- Changing the current safety stock formula in the new safety stock formula, which includes lead time variability.
- Changing the current classification methods in classification method of (Teunter, Babai, & Syntetos, 2010). Also, RGBV now acquire methods to calculate inventory management costs, so it is feasible to use this method. If this classification method is used, they will approximately save the costs of intervention 2.

Another important recommendation that is made is about measuring the performance of the company. At present, there is little use of performance indicators. For example, it is not determined how often stock outs occur. For instance, by means of product fill rate and order fill rate. It would also be useful to conduct a research regarding the forecasting methods of RGBV. For instance, RGBV does not if demand is dependent on the season.

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Readers guide

This project plan consists of several different chapters which will be shortly discussed below.

Chapter 1 – Introduction and Research Design
In chapter 1 includes the introduction to the thesis. It contains the introduction of the company and problem context. Based on this, a theoretical perspective has been chosen and the a problem approach has been constructed.

Chapter 2 – literature review
This chapter contains literature research about methods and formulas of inventory management. There is looked at which methods and formulas might improve the inventory management of RGBV and how these alternatives can be tested.

Chapter 3 – current situation analysis
In this chapter the current working regarding the inventory management process of RGBV is described and analysed.

Chapter 4 – The model
In this chapter the model is constructed. First the conceptual model is made, then the decisions of the programming are outlined. Next, the warmup period, run length and number of replications are determined. Last, the model validation and verification has been done.

Chapter 5 - Results
In chapter 5 the results of the experiments are given. This includes the impact of the experiments on the total costs of inventory, order fill rate, product fill rate, average end inventory and the average inventory in transit.

Chapter 6 – conclusions and recommendations, discussion
In the final chapter, conclusions will be drawn from the experiments that have been executed in this research. Based on these conclusions, recommendations are made. Finally, a discussion about the research is given.

Definitions

Annual dollar usage

The annual dollar usage is the quantity of a component or material used in a year multiplied by its unit cost.

Economic order quantity

The Economic Order quantity is the number of units should add to inventory each time they order to minimize the costs of inventory.

Inventory management calculations

The formulas which are used to calculate inventory management parameters, such as safety stock, economic order quantity and Kanban level at the suppliers.

Inventory position

the amount of inventory on hand plus the amount of inventory on order.

Kanban

The level of inventory held at the suppliers, which is property of the company.

Lead times

The time between the ordering of a product and having the product in stock.

Minimum order quantity

The minimum order quantity is the lowest number of products or parts that a supplier is willing to sell.

Order fill rate

Order fill rate is the fraction of orders that are filled from available inventory.

Product availability

Product availability reflects a firm’s ability to fill a customer order out of available inventory.

Product fill rate

Product fill rate is the fraction of a product that is satisfied form product in inventory.

Rotork Gears B.V.

The name of the establishment of Rotork in Losser.

Rotork Gears

Division within Rotork.

Rotork

Universal name for all companies within Rotork.

Safety stock

Safety stock is an additional quantity of an products held in inventory in order to reduce the risk that the product will be out of stock.

Service level

The desired probability of meeting demand during lead time without having to little stock.

Stock keeping unit
A stock keeping unit (SKU) is an item of stock that is completely specified as to function, style, size and colour. So, the same shoe in two different sizes results in two different stock keeping units.

Abbreviations table

EOQ	Economic order quantity
MOQ	Minimum order quantity
RGBV	Rotork Gears B.V.
SS	Safety stock
SL	Service level
SKU	Stock keeping unit

1 Introduction

In this chapter the following sections will be discussed: the company description, the research motivation, the problem identification and the research questions and the problem approach for answering these research questions.

1.1 About Rotork

When you switch on a light, turn on the kettle, or put fuel in your car at the gas station a flow control product is being used to deliver that service. For more than sixty years, Rotork has been a leading designer and manufacturer of industrial valve actuation and flow control equipment. The business of Rotork is divided in four divisions, Rotork Gears is one of them. Rotork Gears is a division within Rotork which makes gearboxes, adaptions and accessories to the international valve and actuator industry. Rotork Gears has plants over multiple plants all over the world, including Rotork Gears B.V. in Losser.
Rotork Gears B.V. (RGBV) manufactures a wide range of quarter-turn gearboxes, which are used in various applications such as water, gas, chemical, power and industrial applications.

Figure 1.1 - Some examples of quater-turn gearboxes

1.2 Research motivation

Rotork's general leadership has started to focus on reducing the inventory costs. RGBV has already reduced the inventory of the slow/non-moving stock in 2018, and as a result the value of the slow/non-moving stock reduced from 350. 000 euro to 120. 000 euro. Now Rotork Gears B.V. wants to look for possibilities to reduce the inventory costs of the class A products.

1.3 Identification of the core problem

Before the research can be started, the problems must be clearly identified. The managerial problem solving method will be used to do so (Heerkens & van Winden, 2012). This process starts with action problem, the action problem is the initial problem presented by the company. An action problem is a discrepancy between the norm and reality perceived by the problem-holder. The action problem of RGBV is that the total cost of inventory is too high. At this moment the management of RGBV has the idea that the total cost of inventory management are too high, but there is not enough information available to determine the norm.

The first step in the managerial problem-problem solving method is the problem identification step. In this step all problems related to the action problem are acquired. The problems that were found during this step were found by interviewing various stakeholders and by looking at the purchasing model and purchasing schedule. Now that the problems have been identified, it is important to state the causes and consequences of the problems (Heerkens & van Winden, 2012). This is done by dis-playing the problems and the relations between the problems in a problem cluster, this problem cluster can be seen in figure 1.2. In this problem cluster the initial problem is given in the blue box, in the white boxes the general problems are given, in the red box a root cause problem which cannot be solved is given, and in the green boxes root cause problems which can be solved are given.

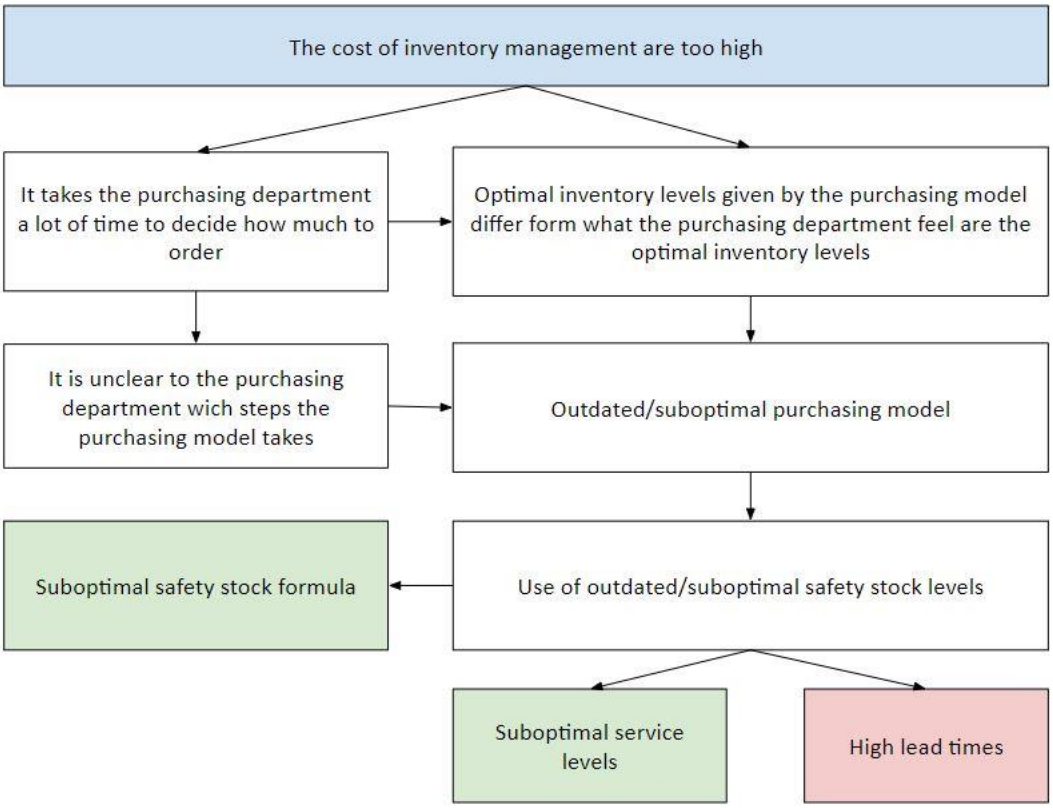


Figure 1.2 - Problem cluster

<u>Root cause 1: suboptimal safety stock formula</u>
The current safety stock formula has not been updated in the last six years. The management of RGBV has the idea that there are better formula's available which would lead to lower costs. For example, the formula currently used to determine safety stock does not take the variability of deliveries into account, while this can have a major impact on the costs of inventory management.

<u>Root cause 2: suboptimal service levels</u>
Setting the right service level is a complex task. When the service level is increased, the holding cost will also increase. On the other hand, the chance of a stock out will decrease, and therefore the shortage costs. Currently, RGBV has not yet identified costs related to inventory management such as: holding cost, shortage cost, handling cost, shipping cost and ordering cost. This makes it difficult to determine a service level per item based on costs.

<u>Root cause 3: high lead times</u>
Most of RGBV's ordering overseas, which results in very high lead times. To compensate for these high lead times more stock is held, which results in higher inventory management costs. However, it is not within the scope of this research to look for alternative suppliers or decrease lead time at the suppliers.

After using the using four rules of thumb (Heerkens & van Winden, 2012) two potential core problems remain:

1. Suboptimal safety stock formula
2. Suboptimal service levels

Management cannot say which of these problems has a greater impact. That is why both core problems will be a part of this research. It is believed that these problems can both be solved using simulation within the ten weeks that stand for this research. To make this core problem measurable, we will use the KPI total cost to assess the effects of the experiments. This total cost will consist of the following: holding cost, shortage cost, handling cost, shipping cost and ordering cost. More KPIs will be added later in this research.

1.4 Goal of the research and Stakeholders

The goal of this research is to analyse the current working methods and stock levels of RGBV and explore if it is possible for RGBV to reduce the total cost of inventory, by improving the inventory management of the A class products.

There are multiple people involved in this research:

- *The plant manager*
  The plant manager is responsible for everything that happens within the company. Also, the plant managers is in contact with Rotork's general leadership and they started the focus on reducing inventory. For this research he is a valuable source of information because he knows a lot about the company.

- *The purchasing department*
  The purchasing department is the department which deals with purchasing of products. They are the ones who use the current methods, and thus have a lot of knowledge about the state of affairs regarding the purchasing and inventory management process. The people in this department can help me gather the right historical data. Employees in this department were responsible for reducing the inventory levels of the slow/non-moving stock in 2018.

1.5 Research questions

Based on the core problems the following research question is made:

How can RGBV reduce the total cost of inventory by improving the inventory management of safety stock of the A class product range?

The main research question cannot be answered directly, because we lack the knowledge to do so. To make it easier to tackle the main research question multiple research questions are defined, which are divided in multiple sub-questions. These sub-questions will be answered throughout the chapters.

Chapter 2 - Literature research

This sub-question has been asked to gather information about methods and formulas that can contribute to answering the main research question.

1. <u>Which methods and formulas are available in literature to improve the inventory management of the A class product range and reduce the total cost of inventory?</u>
    a. Which inventory control policies are described in literature?
    b. Which formulas are available to calculate safety stock?
    c. Which inventory classification methods are available?
    d. What are preconditions, restrictions and assumptions of those methods/formulas?
    e. What are preferences, restrictions and limitations of the company?
    f. Which methods/formulas might reduce the total cost of inventory of the A class of RGBV given the preconditions, assumptions and limitations?

Chapter 3 - Current situation

This sub-question was asked to find out what the current inventory management process looks like. To improve this current process, the current process must first be understood and analysed. The first sub-question is divided in four parts that together must give a good overview of the current process of inventory management at RGBV.

2. *<u>What does the current process of inventory management look like?</u>*
    a. Which inventory classification method is used?
    b. Which kind of inventory management policy is used?
    c. Which people are involved in the purchasing process?
    d. Which steps are taken by the purchasing model and which formulas are used?

Chapter 4 - The model

A model will be used to test potential solutions. In this chapter will be discussed how the simulation model should be set up, what data is required to run the simulation model, what assumptions and simplifications are made in order to construct the model, what variables are used to assess the experiments and when the results are suitable for use and if the simulation model is

3. *<u>How can the inventory management process be displayed in a model?</u>*
    a. What are the input and output variables of the model?
    b. What are limitations of the model?
    c. What data is required to execute the model?
    d. Is our model valid?

Chapter 5 - Results

With the help of the KPIs the current situation process can be compared with the result of the experiments. To compare the current situation with possible solutions, both the output for the possible solutions and the output for the current situation must be determined.

4. *<u>What are the effects of the experiments?</u>*
    a. What does the output of the base model look like?
    b. What does the output from the experiments look like?

Chapter 6 - Conclusions and recommendations

Conclusions and recommendations will be made based on the results of the simulation.

5. *How can the current inventory management process be optimized?*
    a. What conclusions can be drawn based on the results of the simulation?
    b. Which recommendations can we make based on the research?

1.6 Theoretical perspective

This inventory management problem will be approached with the theoretical perspective of supply chain management and operations research. Supply chain management is making decisions related to the supply of information, products and funds with the aim of improving these processes and increasing supply chain surplus (Chopra & Meindl, 2016). Operations research is a scientific approach to decision making that seeks to best design and operate a system, usually under conditions requiring allocation of scare resources (Winston, 2004). Within these fields, relevant theory can be found, which helps can help to solve our problem.

The total costs of inventory are given in the book Supply Chain Management (Chopra & Meindl, 2016) as the sum of holding and ordering costs. The following costs fall under holding costs: the opportunity costs, the obsolescence costs, the handling costs and the occupancy costs. The opportunity costs represent the benefits that the company is missing out on. In this case, it means that every euro spend on inventory will not yield interest. The obsolescence cost estimates the rate at which the value of the stored product drops. Perishable products have high obsolescence rates. Handling costs are the incremental receiving cost that vary with quantity. The occupancy costs are incremental change in space cost due to a change in the amount of inventory kept. The holding costs are often estimated as a percentage of a product. The ordering costs are the sum of the buyer time, transportation costs and receiving costs. Buyer time means the extra time that a buyer needs to place the extra order. The costs involved are part of the ordering costs. The receiving costs are the costs associated with ordering, regardless the size of the order. This includes any administrative work done such as purchase order matching and updating the inventory records. In the book Inventory and Production Planning in Supply Chains (Silver, Pyke, & Thomas, 2017) another inventory related cost is mentioned: The costs occurred when a stockout occurs, also called shortage costs. These are the expenses that result from not meeting demand. For instance, the cost of placing an emergency order at the supplier.

Safety stock can be defined as the inventory kept to satisfy demand that exceeds the amount forecast (Chopra & Meindl, 2016). There are multiple formulas to calculate the required level of safety stock. Mostly three or more of the following elements are included in the safety stock formulas: (cycle) service level, demand, demand variability, lead time and lead time variability. (Cycle) service level is the fraction of replenishment cycles that end with all the customer demand being met (Chopra & Meindl, 2016). The higher the service level, the higher is the amount of demand being met immediately from stock. The demand is the average required items by customers per period and demand variability is the measure of how much variability there is in customer demand. Lead time is the time between deciding to place an order and the time it is stored physically on the shelf (Silver et al., 2017) and lead time variability is the measure of how much variability there is in the supply of items.

The A class product range can be defined as the most important items within the company. Most often their company's use three priority ratings A (most important), B (intermediate in importance) and C (least importance), but it is not uncommon to have more ratings. Class A items should receive the most personalized attention from management (Silver et al., 2017). There are multiple methods for classifying the items.

1.7 Problem solving approach

The second phase of the Managerial Problem Solving approach is the formulation of the problem approach. A design will be made in order to answer the research question. The problem solving approach made to answer the research question is given below. A Gantt chart of the thesis planning can be seen in Appendix A.

Phase 1: Current situation analysis

In phase 1, the current situation is analysed to answer sub-question 2. This analysis provides insight into how inventory management is currently being done, which steps are taken by the simulation model and which formulas are used. Through this step, the current process will be understood and mapped. Also, possible points for improvement can be found during this phase. The sub-questions will be answered through discussions with stakeholders, being present during the purchasing process and analysing the current purchasing model.

Phase 2: literature research

In phase 2, the literature research will be done. It will become clear what inventory management exactly entails, which methods and formulas are available, and which could possibly contribute to this research. Most of the theory that will be consulted to answer the sub questions will be obtained from the books Inventory and Production Management in Supply Chains (Silver et al., 2017), Supply Chain Management (Chopra & Meindl, 2016) and Operations Research (Winston, 2004).

Phase 3: Testing solutions in a simulation model

In this phase, the simulation model will be made. Here, various possible solutions will be tested and compared with the current situation based on KPIs. There are multiple reasons for choosing to use a simulation in this research: simulation makes it possible to analyse interventions using multiple scenario's, it is possible to model variability easily and simulation requires few simplifying assumptions. It is also possible to experiment in reality, but this is very costly and time consuming. Next to simulation, there are other methods available which can be used: spreadsheet calculations, spreadsheet models or developing an algorithm. These alternatives often require so many simplifying assumptions that the solutions are likely to be inadequate or inferior.
Before the experiments can be done, several steps must first be taken:

1. Creating the conceptual model
2. Programming the model
3. Verification and validation of the model

Constructing the conceptual model requires a number of steps: understanding the problem identification, determining the modelling and general objectives, determining the model input and output and outlining the model content (Robinson, 2014). After this the model will have to be programmed, this will be done with the programming language Visual Basic. Finally, the model will have to be validated and verified. In validation and verification the goal is to create enough confidence to use the model in decision-processes (Sterman, 2000). The information needed to construct a quality simulation model will mostly be obtained from the book Simulation (Robinson, 2014).

Phase 4: Results, Conclusions, recommendations and discussion

In phase 4, the results of the experiments will be compared with the results of the current situation. Based on the difference in the output of the simulation, conclusions can be drawn about the impact of the interventions. Recommendations can then be made to RGBV based on the conclusions. Assumptions and simplifications will be made in the research, this is necessary for the simulation to work. The influence of these assumptions and simplifications will also be explained during this phase.

1.8 Type of research and research subjects

In this research we will look for existing methods/formulas and test if they may work on Rotork, so this research is of exploratory nature.

The goal of this research is to analyse the current working methods and stock levels of Rotork Gears B.V. and explore if it is possible for RGBV to reduce the total cost of inventory by improving the inventory management of the A class products. The performance of alternative solutions will be measured with a simulation model. It will not be possible to analyse all products of the A class, so a selection of class A items has been made in discussion with the purchasing department and the plant manager. These items are chosen so that they are a representative sample for all the A class items. That's why there are parts, spares and complete gearboxes included. The selection can be seen in Appendix C.

1.9 Validity and reliability issues

In this research some validity and reliability issues might occur. For example, you want to make the simulation as reliable as possible. To do this you need information about items such as historical demand, price and delivery time. However, at RGBV they have only been tracking the delivery times of the suppliers for a relatively short time. As a result, the results for the variability of the delivery time may be less reliable. The solution for this is to present the results of the calculations of the variation in delivery times to the purchasing department to see if they think these results are reliable enough to work with. Through this expert opinion, adjustments can be made where necessary.

The assumptions and simplifications made when building the simulation model can also have a negative contribution to the validity and reliability of the research. To prevent this, all assumptions and simplifications that must be made to make the simulation model will be made in consultation with stakeholders of the company.

1.10 Limitations and deliverables

The following limitations are present during this research:

- *Time frame*: This research must be carried out in ten weeks.
- *Restrictions from RGBV*: Rotork has a global sourcing team which is responsible for the number of suppliers, optimizing prices, standardization of products, improving lead times at the suppliers, which is not in the scope for the assignment.

The deliverables of this research are:

- Analysis of the current situation.
- Literature research about alternative solutions/formulas.
- Analysis and insight in optimizations on current safety stock calculations.
- A conclusion whether reduction of the total cost of inventory is possible by changing the inventory management calculations for the A class products.
- An advice whether a possible solution is suitable for Rotork.

1.11 Summary and conclusions

The core problems which contribute to the high cost of inventory management are the suboptimal safety stock formula and the suboptimal service levels. It is believed that both these core problems can be solved within the time period of 10 weeks. To be able to do this, a problem approach has been constructed with the following phases: current situation analysis, literature research, testing solutions in a simulation model and giving the results, conclusions, recommendations and discussion.

2 Literature research

In the following chapter, several methods and formulas will be discussed that might help RGBV to reduce the total cost associated with inventory management.

2.1 What is inventory?

Inventory are items kept in storage. Inventory exists in the supply chain because there is a mismatch between supply and demand. This mismatch is sometimes intentional, for instance when it is economical to produce is large lots. This mismatch is also intentional for a retail store which expects demand to go up rapidly during the holiday season. In these examples inventory is held to reduce costs and increase the level of products available to customers. However, in a lot of cases high levels of inventory result in high costs. The higher the inventory levels of a company the higher their holding costs will be, and the risk that you are unable to sell your products increases. In general, managers should aim to reduce inventory in ways that do not increase costs or reduce responsiveness (Chopra & Meindl, 2016).

The formula for total inventory in stock is (Chopra & Meindl, 2016):

$$Total\ inventory\ in\ stock = cycle\ stock\ inventory + the\ safety\ stock\ inventory \tag{2.1}$$

2.1.1 Cycle Stock

Cycle stock inventory, also known as working stock, is the portion of inventory available to meet normal demand during a given period. It is the amount of inventory needed to meet customer needs. The cycle inventory is the first inventory where a customer's order will be fulfilled from.

However, there are differences in agreements between suppliers and buyers when the inventory is property of the buyer or the supplier. For instance, at RGBV, the inventory is theirs from the moment it is shipped.

2.1.2 Safety stock

Safety stock is the extra quantity of products held in the inventory to reduce the risk that the item will be out of stock. A stock out often results in extra costs and lower customer satisfaction levels, it is therefore in the best interest of companies to prevent stock outs. The three main causes for stock outs are (Chopra & Meindl, 2016):

1. There is an unforeseen variation in demand.
2. There is an unforeseen variation in the lead time of an order.
3. The desired level of product availability.

Safety stock acts as a buffer in case of a stock out. This does not mean that safety stock is meant to eliminate all stock outs, just the majority of them (King, 2011). To illustrate this the figure below is given.

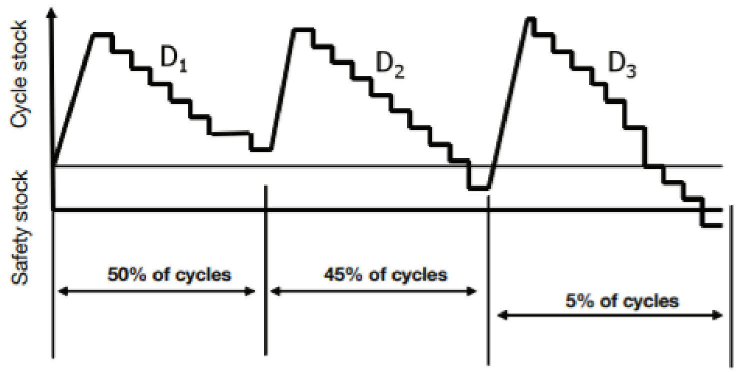


Figure 2.1 - Inventory designed for a 95 percent service level (King, 2011)

2.2 Alternative formula for the calculation of safety's stock

The amount of safety stock needed can be calculated with several formulas. Formula 2.2 does take lead time variability into account. According to (King, 2011) if a company has to deal with demand variability and lead time variability this formula should be used:

$$Safety\ stock = Z * \sqrt{L * \sigma_D^2 + (D * \sigma_l)^2} \quad (2.2)$$

$Z = number\ of\ standard\ normal\ deviations\ (Z - score)$
$L = average\ lead\ time$
$D = average\ demand$
$\sigma_d\ =\ standard\ deviation\ of\ demand$
$\sigma_L = standard\ deviation\ of\ the\ lead\ time$

RGBV has to do with both demand variability and lead time variability, which means that formula 2.2 should be more suitable for calculating the safety stock levels of RGBVs items. Therefore, there will be experimented with formula 2.2 to see what the effects are on the total costs of inventory management.

2.3 Inventory control policies

An inventory control policy determines when and how much should be ordered. The determination of when and how much to order should be based on the inventory position, the anticipated demand and the lead time (Axsäter, 2015). The inventory position is the sum of the physical stock in the warehouse and the orders in transit, minus the backorders. Backorders are the items that have been ordered but have not been delivered yet. There are several different inventory control policies. The most important difference between these policies is if the inventory position is monitored continuously or periodically.

How often the inventory status should be determined, is specified by the review interval R, which is the time that passes between two moments of ordering. In continuous review each transaction is reported, and the inventory status is updated. Therefore, in a continuous review system, the review interval R = 0. In periodic review the stock status is only determined every R time units, for instance at the end of each day. RGBV has a periodic review policy, where they review the inventory position every two weeks (R = 2 weeks).

The four most used inventory control policies are: the (S, Q) policy, the (s, S) policy, the (R, s) policy and the (R, s, S) policy (Silver et al., 2017). These policies will be explained in the next chapters.

2.3.1 (s, Q) policy

The (s,Q) system is a continuous review system, where a fixed quantity Q is ordered every time whenever the inventory position drops below the reorder point s. The benefits of using a (s, Q) system is that it is quite simple and because of this the chance of errors is small and the production requirements for the supplier are predictable (Silver et al., 2017). The main disadvantage of the (s, Q) system is that it may not be able to deal with large orders. If an order is large enough, it may be possible that the replenishment size of Q will not even raise the inventory position above the reorder point. In this kind of situation, the multiple of Q is often ordered. Figure 2.2 gives an example of a typical replenishment cycle in a (S, Q) system. The reorder point can be calculated with the following formula (Bernard, 2015):

$$s = d * L + ss \tag{2.3}$$

$s = reorder\ point$
$d = average\ demand$
$L = average\ lead\ time$
$ss = the\ amount\ of\ safety\ stock\ held\ for\ the\ item$

So, when the inventory position drops below this reorder point a fixed quantity Q is ordered. Mostly this fixed order quantity Q, is determined by the EOQ formula. The formula for the Economic Order Quantity is (Winston, 2004):

$$Q^* = \sqrt{\frac{2DK}{h}} \tag{2.4}$$

$D = Annual\ demand\ (units)$
$K = Cost\ per\ order$
$H = Holding\ costs$

For further explanation of EOQ formula see chapter 2.5.

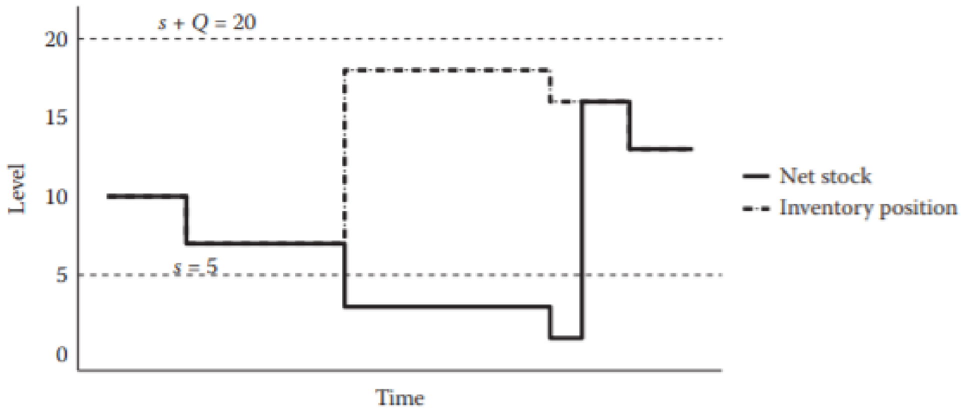


Figure 2.2 - Example of an replenishment cycle in a (S, Q) system (Silver et al., 2017)

2.3.2 (s,S) policy

The (s, S) System is a continuous review system, where every time the inventory position drops below reorder point s or lower, a variable replenishment quantity is used to order enough items to raise the inventory position to order-up-to-level S. Figure 2.3 gives an example of a typical replenishment cycle in a (s, S) system.

The order up to level point S can be calculated with the following formula:

$$S = s + Q^* \tag{2.5}$$

$s = reorder\ point$
$Q^* = Economic\ Order\ Quantity$

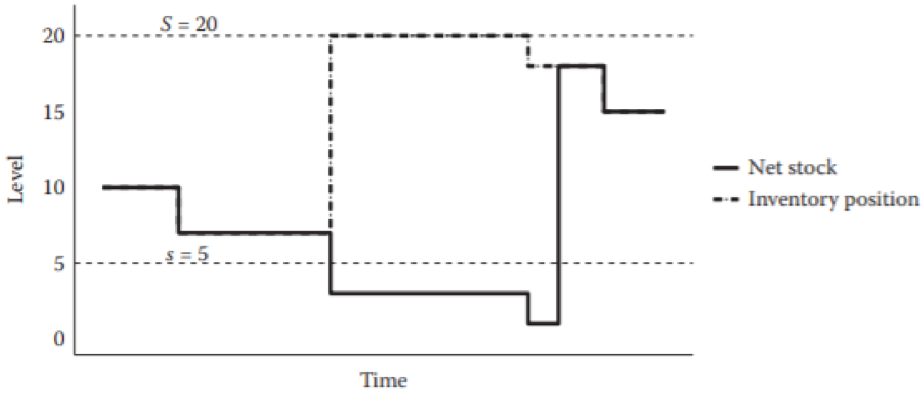


Figure 2.3 - Example of an replenishment cycle in a (s, S) system (Silver et al., 2017)

2.3.3 (R,S) policy

The (R, S) system is a periodic review system where every R units of time enough is ordered to raise the inventory position to level S. Because of this periodic-review property, this system is much preferred to order point systems in terms of coordinating the replenishment of related items. For instance, when ordering overseas, it is often necessary to fill a shipping container to keep shipping costs under control. This coordination can save a significant amount of cost. The main disadvantage of the (R, S) system is that the amount which is ordered varies and that the holding costs are higher than in a continuous review system. The typical behaviour of a (R, S) system can be seen in figure 2.4. RGBV currently uses a (R, S) system with R = 2, the S differs per product. The order quantity which is needed to raise the inventory level to S, can be calculated by the following formula (Bernard, 2015):

$$O = d * (R + L) + ss - I \tag{2.6}$$

$d = average\ demand$
$R = the\ review\ period$
$ss = the\ amount\ of\ safety\ stock\ held\ for\ the\ item$
$I = the\ amount\ of\ inventory\ on\ hand\ when\ the\ inventory\ level\ is\ checked$

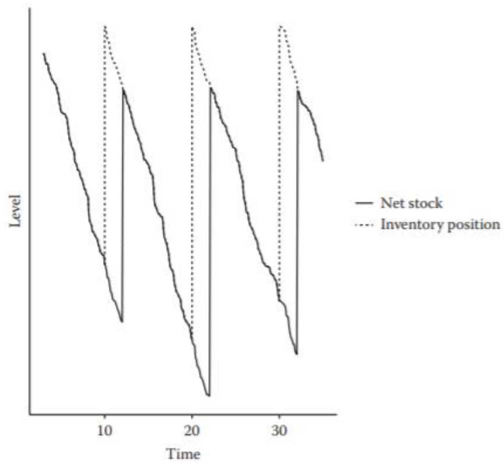


Figure 2.4 - Typical behaviour of a (R, S) system (Silver et al., 2017)

RGBV uses a (R, S) system, so 2.6 will be used to calculate the required order quantity for the results of the experiments.

2.3.4 (R,s,S) System

The (R, s, S) policy is a combination of the (s, S) and (R, S) policy. The (R,s, S) system is a periodic review system where every R units of time the inventory position is checked, if the inventory position is below reorder point s, enough is ordered to raise it to S. If the position is above s, nothing is done until the next review period.

This system is a combination of the (s, S) and the (R, S) system. Every R units of time the inventory position is checked. If the inventory position is below the reorder point s, we order enough to raise it to S. if the inventory position is above s, nothing is done until the next review period.

2.4 Inventory classification

Most companies make use of an inventory classification. The main purpose of classification of items is to simplify the task of task of inventory management, by setting control methods and service levels per class rather than for every stock keeping unit separately.

The most used technique for classifying inventory is the ABC analysis. The origin of the ABC analysis began with the inventor Vilfredo Pareto and his 80/20 principle. He discovered that 80 percent of the land in Italy was owned by 20 percent of the population (Pareto, 1935) . Later was discovered that his principle holds for many different areas, including inventory management. This principle formed the basis of the ABC analysis, where often 20 percent of the stock keeping units account for account for 80 percent of the annual dollar usage (Silver et al., 2017).

In most cases classification is based on SKU criteria such as demand value (price of an item multiplied by demand volume) or demand volume. Often a distribution by value analysis (DBV) is performed to classify the importance of Stock Keeping Units (SKUs). The figure below illustrates a typical Distribution by value observed in practice.

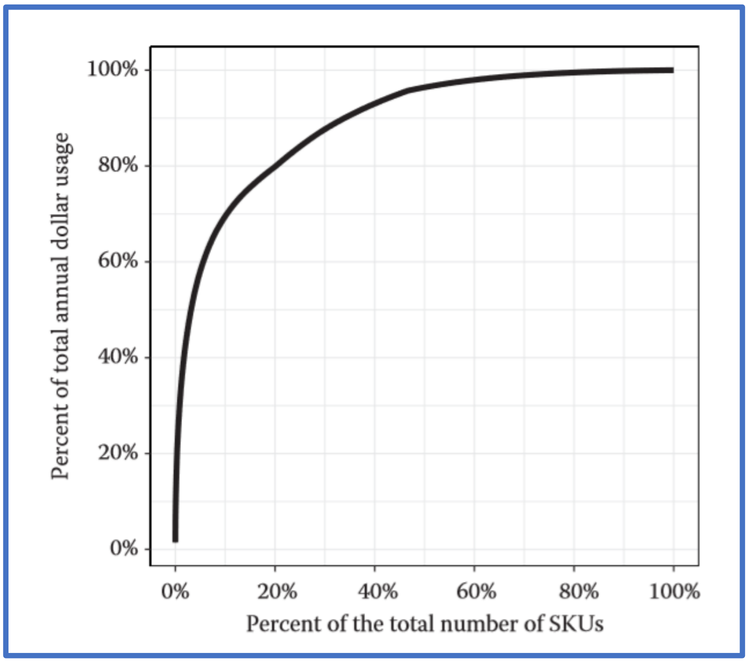


Figure 2.5 - Typical distribution by value of stock keeping units (Silver et al., 2017)

Almost all companies make use of three different categories (Silver et al., 2017):

- Class A items which are the first 5 to 10 percent of the SKUs, ranked by the distribution by value analysis. Although some companies rank the 20 percent of first SKUs as class A items. Usually these items account for 50 percent or more of the total dollar movement of the items under consideration.
- Class B items are of secondary importance. The most SKUs fall into this category. Around 50 percent of the total SKUs account the remaining 50 percent annual dollar usage.
- Class C items are the SKUs remaining that are a minor part of annual dollar usage.

When the items are classified, the standard approach in inventory management is to fix service levels per class Lee. Literature is not one-sided about which service-level belongs to which class. Some authors think A items are the most important for a firm in determining the profit and should therefore get the highest service level, to prevent backlogs (Armstrong, 1985). But other authors claim that stock outs are not worth the effort for C items and should therefore have the highest service level (Knod & Schonberger, 2001).

A lot of adaptions and extensions have been made to the ABC analysis. Such as dividing the SKUS in multiple classes, usually with a maximum of six classes (Graham, 1987). It is proven that dividing the inventory in more classes results in lower inventory costs (Teunter et al., 2010). Moreover the use of multiple criteria such as lead time, rate of obsolescence and certainty of supply are considered by a number of authors. (Chen, Li, Marc Kilgour, & Hipel, 2008).

Another method is classifying the items based on the ability to forecast an item, this method is called the XYZ analysis and is often used as an extension of the ABC analysis (Chopra & Meindl, 2016). Items with a constant demand get a X classification and items with an erratic demand a Z classification. If the XYZ analysis is combined with the ABC analysis items with a with a high value and constant demand are ranked as AX items and items with low value and erratic demand are ranked as CZ items.

(Zhang, Hopp, & Supatgiat, 2001) where the first to classify SKUs based on an inventory cost perspective. They were able to cut inventory investment while remaining the same service levels. Thereafter, (Teunter et al., 2010) develop a new cost criterion for ABC analysis which shows that it outperforms the traditional methods demand volume and demand value as well as the method of (Zhang et al., 2001). (Teunter et al., 2010) method can be an applied using the following steps:

1. Rank the SKUs in descending order of $\frac{h*Q}{b*D}$
2. Divide the SKUs int classes A,B and so on.
3. Fix the cycle service level for each class, where A should have the highest service level, followed by B, and so on.

In the formula in step 1, h is the holding cost of an item, b the shortage cost, Q the average order quantity of an item and D the demand per time unit.

(Teunter et al., 2010) prove that their method outperforms the all methods, including the demand volume, demand value and the cost criterion method of (Zhang et al., 2001). To calculate this method the holding costs, shortage costs, average order quantity and demand is needed. In this research a method is made up to calculate the shortage and holding costs. During the experiments the relationship between the costs and the service level will become clear. If the optimal service level mostly depends on holding and shortage costs, this classification method will be recommended to RGBV.

2.5 The Economic Order Quantity model

Most companies make use of the Economic Order Quantity (EOQ) model when making the decisions:

- When should an order be placed for a product?
- How large should each order be?

The formula for the Economic Order Quantity is (Winston, 2004):

$$Q^* = \sqrt{\frac{2DK}{h}} \tag{2.7}$$

$D = Annual\ demand\ (units)$
$K = Cost\ per\ order$
$h = Holding\ costs$

Ordering cost (K)
Many costs with placing an order do not depend on the size of the order, these costs are called the Ordering and setup costs. An example of ordering and setup costs is the paperwork and billing which are associated when placing an order, these are costs that are there no matter how big the order is.

Holding costs (h)
This is the cost of holding one unit of inventory for one period of time. So, if the time period equals one month the holding costs will be dollars or euros per unit per month. Holding cost include storage costs, insurance costs, taxes on inventory, the possibility of theft and obsolescence, and in some cases the possibility of spoilage. However, most of the time the biggest part of holding costs are the opportunity costs. This could be the interest the company could have if the inventory was not tied up in inventory. Or the profit it could have made by investing the capital instead of buying inventory from it.

With the EOQ formula, an order quantity is found which minimizes the sum of the holding and ordering costs. As you can see in the graph below the annual ordering cost declines as the lot size increases, which makes sense because when the lot size increases the number of times ordered decreases. On the other hand, as the lot size increases the annual holding costs increase, which also makes sense because an item will on average be longer in stock.

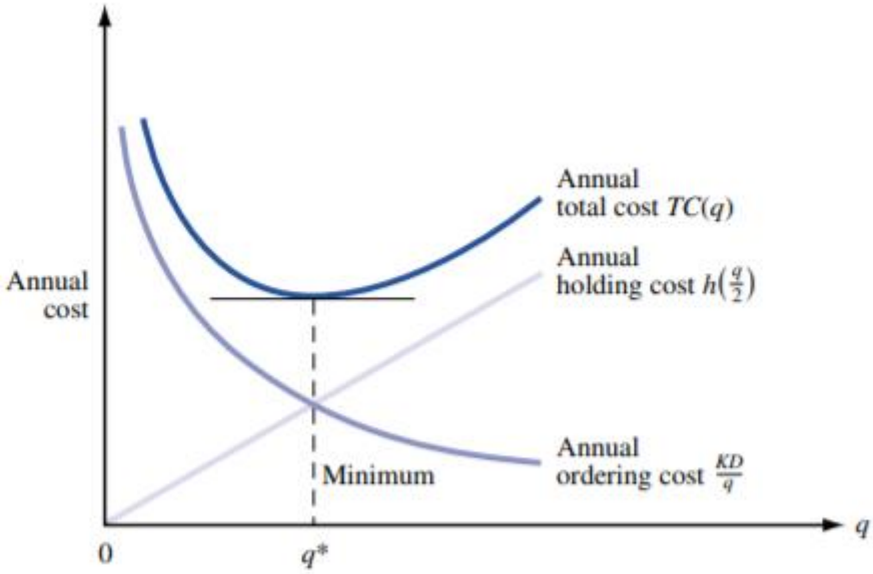


Figure 2.6 - Trade-off between Holding Cost and Ordering Cost (Winston, 2004)

The EOQ formula makes the following assumptions:

- *Constant Demand*
  In the EOQ model the demand is assumed occur at a known constant rate. This assumption implies that if there is an annual demand of 120 units, the demand per month would be 120/10=10 units.

- *Constant Lead Time*
  The lead time for each order is known. For instance, if the lead time is one month and an order is place today, the order will be delivered one month from now.

- *Repetitive Ordering*
  The orders are not one-time orders. The orders that are placed are repetitive, so the decision how much to order repeated in a regular fashion.

- *Ordering Costs*
  There are ordering costs each timer an order is placed, regardless of the quantity of the order.

- *Continuous ordering*
  The EOQ model assumes that an order may be placed at any point in time. Inventory models which allow orders to be placed at any point of time are called continuous review models. On the other hand, there are periodic review models, in these models an order can only be placed in a certain point of time. For instance, at the end of each month.

RGBV does not use the EOQ formula because the ordering costs cannot be clearly mapped. This is because part of the fixed costs has been included by the suppliers of RGBV, but RGBV has no insight in this calculation. However, during this research, the fixed costs incurred at RGBV were determined. For the calculation of these costs, see chapter 4.2.4.

2.6 Determination of shortage costs

Shortage costs are the costs resulting from a stock out, so when demand cannot be fully and immediately satisfied because of lack of stock. The value of shortage costs is important for several reasons. Firstly, in determining the total costs incurred for evaluating inventory replenishment policies. Secondly, in determining the total costs incurred for determining optimal parameters of an inventory policy. Thirdly, when comparing the cost of a stock out with the cost of eliminating that stock out by shipping products from elsewhere.

(Oral, Salvador, Reisman, & Dean, 1972) come up with a method to calculate the fixed costs per stock out occasion. They evaluate the shortage costs by the use of a decision tree which can be seen below.

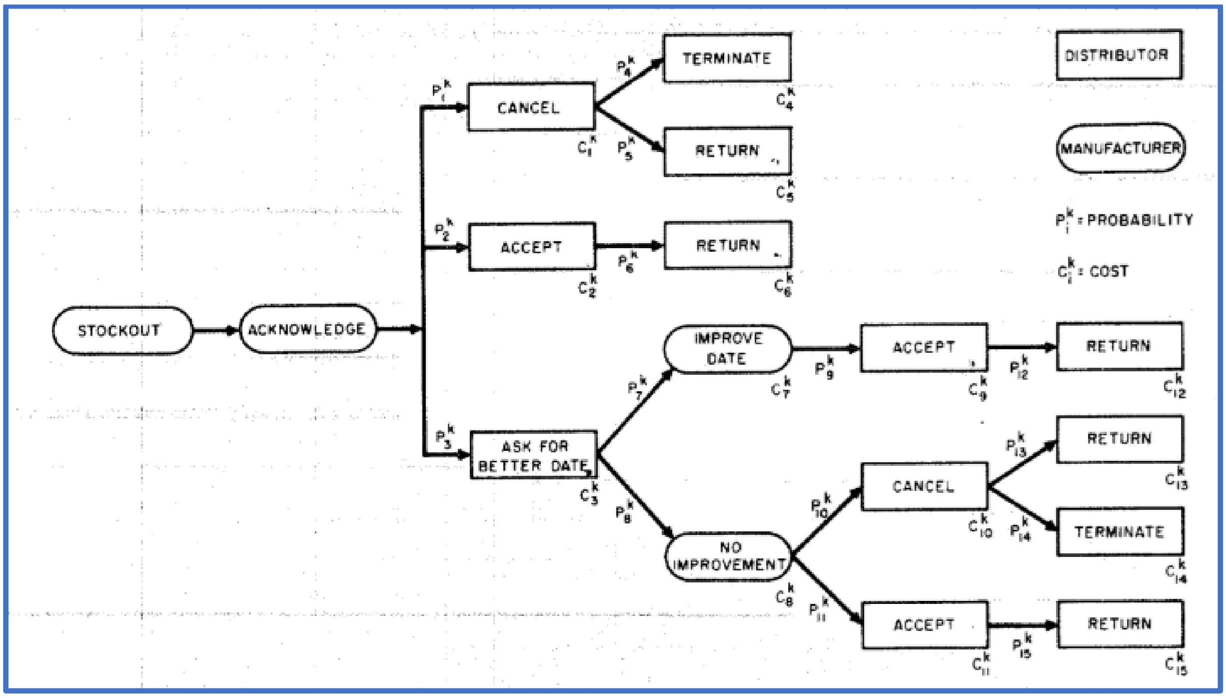


Figure 2.7 - All different courses of action which the manufacturer and distributor can take in case of stock out occurs

This figure shows all possible responses if a stock out occurs. Every response n has a cost of C_n^k and a probability of P_n^k of occurring. By summing all probabilities times costs a total expected stockout cost for item k is found. The authors acknowledge that the methodology described above cannot be repeated for all products within companies, because its very time consuming. Therefore, it was attempted to find a correlation between the unit shortage costs and the gross profit per item. The resulted in finding a correlation coefficient of 0,942, and a formula for the relationship between the shortage costs and gross profit.

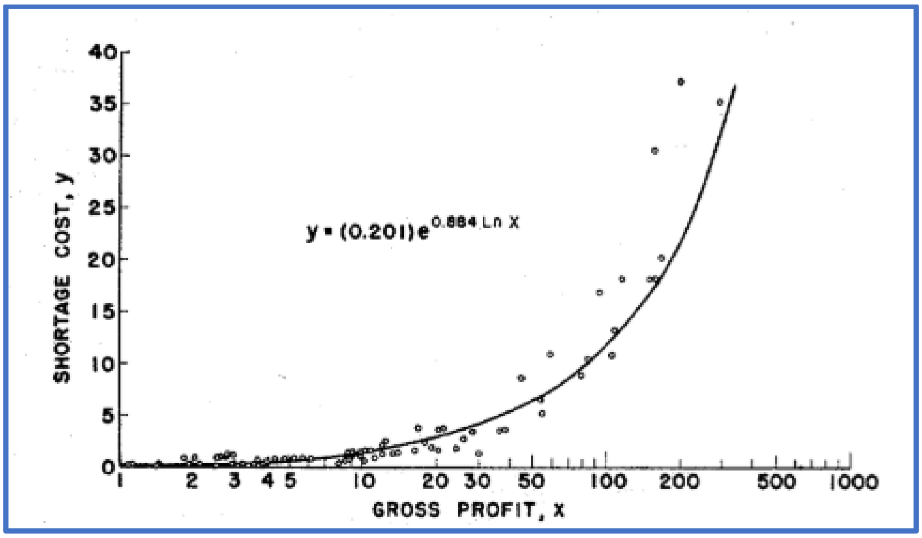


Figure 2.8 - Shortage costs versus gross profit margin

Formula for calculating the shortage costs per product:

$$y = 0{,}20 * \ e^{0{,}88+Ln(X)} \qquad (2.8)$$

$y = unit\ shortage\ costs$
$x = gross\ profit$

The formula of (Oral et al., 1972) is a sufficient way to calculate the shortage costs. However, there are assumptions on the basis of the formula. When using this formula, you have to assume that the correlation of the gross profit of the company's products is the same as the one correlation of the products tested by (Oral et al., 1972). You could also choose to make your own calculation with the method provided by (Oral et al., 1972), but that is very time consuming and cannot be done for a lot of products. In discussion with the stakeholders from the company, we have come up with another, more tailored, way of calculating the shortage costs, which can be seen in paragraph 4.2.

2.7 Simulation

Simulation will play an important role in this research, so it is important to understand what it means, what the pros and cons are, and what different types of simulations are available. When we have this information at our disposal, a conclusion can be drawn which simulation best fits this research. Then the foundation of the simulation, the conceptual model will be discussed. We conclude with a paragraph on how we can determine whether the model is suitable for use.

2.7.1 What is simulation?

Simulation is a very powerful and widely used management science technique for the analysis and study of complex systems (Winston, 2004). (Robinson, 2014) provides a more comprehensive definition of simulation: 'Simulation is experimentation with a simplified imitation (on a computer) of an operations system as it progresses through time, for the purpose of better understanding and/or improving that system'. A simulation is thus a tool which tries to predict the performance of system under a specific set of inputs. It is the responsibility of the modeller to vary the inputs and to run the model in order to determine the effect. The model user enters different scenario's in order to develop sufficient understanding on how to improve the real situation. Simulation is a tool which supports the decision maker in his decision making processes (Robinson, 2014).

2.7.2 Why do we use simulation?

Simulation makes it possible to analyse interventions using multiple scenarios. It is also possible to experiment, but this is very costly and time consuming. It would take weeks to months or even more to obtain a reflection on one experiment. A simulation can run many times faster than real time, some computers can run years of real time in just minutes in a simulation.

Next to simulation, there are other methods available which can be used: spreadsheet calculations, spreadsheet models or developing an algorithm. It is very hard to model variability in these methods, while simulations are able to model variability. Because of complexity and stochastic relations, not all real-world problems can be represented adequately by these alternatives for simulation, because these often require so many simplifying assumptions that the solutions are likely to be inadequate or inferior. The only alternative form of modelling and analysis available to the decision maker is simulation (Winston, 2004). Simulation requires few assumptions, although the desire to simplify models and a shortage of data mean some appropriate simplifications and assumptions are normally made (Robinson, 2014).

There are of course disadvantages to simulation, (Robinson, 2014) lists the costs of simulation as the most important one. The costs of modelling a simulation are often considerably, especially because this is often done by consultants that are hired by the company. Also, most simulations require a lot of data, which is often not immediately available and usable in a lot of companies. The first argument does not really play a role, given the nature of this research. The second argument does apply in this research, but given the many benefits there is chosen to make use of a simulation in this research.

2.7.3 Different kinds of simulation

In order to select the adequate simulation for this research it is important to know which kinds of simulation are available. The most used approaches for simulation are: discrete-event simulation, Monte Carlo simulation, system dynamics and agent based simulation (Robinson, 2014). These different types of simulation will be explained below.

Discrete event simulation

Discrete event simulation is used for modelling queuing systems. A queuing system is a system in which entities flow from one activity to another, and activities are separated by queues. The queues occur when entities arrive at a faster rate than they can be processed by the next activity. More circumstances fall under queue systems than one would initially expect. Queuing systems can be people, items but also information represented by entities moving through the system.

Monte Carlo simulation

Monte Carlo simulation is named after the famous casino in Monaco. As can be made up from the name, the aim of a Monte Carlo simulation is to model risk in an environment that is subject to chance. The word is conceived as a set of distributions representing variables that describe the sources of chance (Robinson, 2014). Figure 2.9 illustrates the idea. For the sources of chance (A, B, C) distributions are assumed, then random samples are drawn from these distributions which together generate the output of the simulation model. The Monte Carlo approach is used widely in complex environments, especially in financial services.

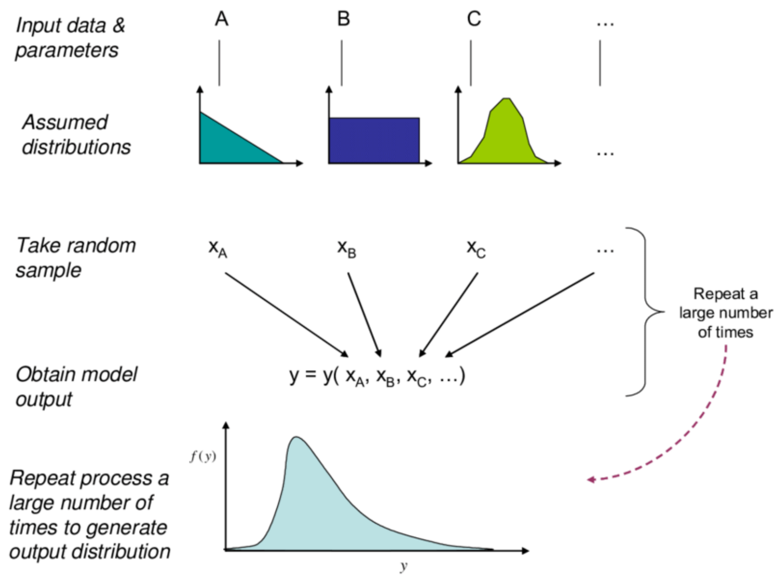


Figure 2.9 - Illustrating the concept of a Monte Carlo simulation (Bui & Henderson, 2019)

System dynamics

System dynamics is a continuous simulation approach that represents the world as a set of stocks and flows (Sterman, 2000). The stocks are accumulations of elements such as items, people or money, and the flows adjust the level of stock which flows adjust the level of stock. Because the in-flows and outflows change continuously, time must be modelled continuously. An example of this is a population model in which the birth rate is the inflow which increases the population and the death rate an outflow which decreases the population. System dynamics is used in a very broad range of applications (Robinson, 2014), particularly in researching strategic issues (Morecroft, 2007). A few examples of areas in which system dynamics is used is the modelling growth of high tech firms, fore-casting energy consumption and forecasting commodity prices.

Agent based simulation

Agent based simulation focusses on studying complex systems and their emergent behaviours (Heath & Hill, 2010). The idea is to model the systems from bottom up as a set of agents, with individual be-haviours which interact with each other over time. The aim is to notice patters, structures and behav-iours that appear. The structure of an agent-based simulation model can be described on the basis of the following three elements:

- *Agents*: with attributes and behaviours
- *Agent relationships*: defining who agents interact with and how
- *Agent environment*: The environment in, and with, which the agents interact

Monte Carlo simulation is most applicable for this research, because in this research the environment is subject of chance, as the demand and lead time are not known.

2.7.4 The conceptual model

Prior to making a computer model, a conceptual model must be made. _A conceptual model is a non-software specific description of the computer simulation model, describing the objectives, inputs, outputs, content, assumptions and simplifications of the model (Robinson, 2008). Developing a conceptual model consist of the following key activities: understanding the problem situation, determining the modelling and general project objectives, identifying the model inputs and outputs and identifying the model content, assumptions and simplifications. (Robinson, 2008) provides a figure with the outline of these key activities, which is displayed below.

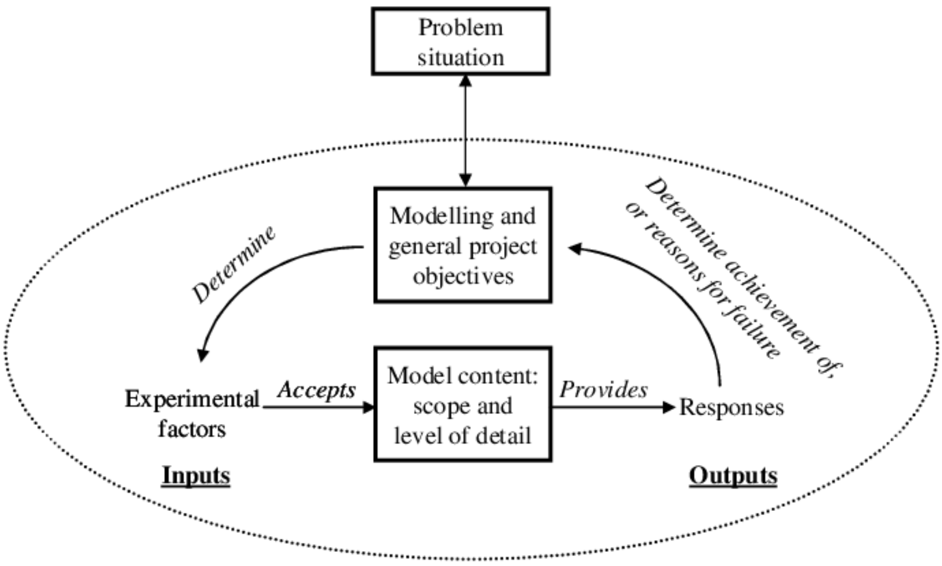


Figure 2.10 - A framework for conceptual modelling (Robinson, 2008)

The key requirement of a conceptual model are validity, credibility, feasibility and utility (Robinson, 2008). Validity is about the model creating an adequate representation of reality for the purpose on hand and credibility means that this is also believed by the client. Feasibility means that the model can be built within the restrictions of the available data and time. Utility means that the model should be easy to use, flexible and have a sufficient run speed.

2.7.5 Validation and verification

When the model has been built, it is important to check if it is suitable to use. This is done by model validation and model verification. Model validation controls if the model is sufficiently accurate for the purpose at hand (Carson, 1986), and model verification is the process of ensuring that the conceptual model has been transformed into the computer model with sufficient accuracy (Davis, 1992). It is sufficiently accurate because no model is ever 100 percent accurate, a model is not even meant to be completely accurate, but a simplified means of exploring and understanding reality (Pidd, 2009).Therefore in validation and verification the goal is to create enough confidence to use the model in decision-processes (Sterman, 2000).

2.8 Summary and conclusion

- Formula 2.2 should lead to a reduction of costs, given that RGBV makes use of a periodic review system and has both demand variability and lead time variability. Therefore, there will be experimented with this formula.
- RGBV uses a (R, S) system, so 2.6 will be used to calculate the required order quantity for the results of the experiments.
- Teunter et al., 2010 prove that their method outperforms all other methods, including the demand volume, demand value and the cost criterion method of (Zhang et al., 2001). During the experiments the relationship between the costs and the service level will become clear. If the optimal service level mostly depends on holding and shortage costs, this classification method will be recommended to RGBV.
- The EOQ formula cannot be used because RGBV does not have insights in the fixed costs made at the supplier.
- The formula of (Oral et al., 1972) is a sufficient way to calculate the shortage costs. However, this method is very time consuming, therefore this method will not be used. In discussion with the stakeholders from the company, we have come up with another, more tailored way of calculating the shortage costs, which can be seen in paragraph 4.2.
- Monte Carlo simulation is most applicable for this research, because in this research the environment is subject of chance, as the demand and lead time are not known.

3 Current situation analysis

In this chapter, the current situation of RGBV is described and analysed. The decisions made by the purchasing model formula will be mapped. Also, the current policy, classification method and formulas used will be given.

3.1 Current classification method

Currently RGBV uses a distribution by value analysis to classify the items. This classification can be seen in table 3.1.

Table 3.1 - RGBVs classification method

Class	**Description**
Class A	The A class items are the items which make the first 80% of the costs made on items in the last half year.
Class B	The B class items are the items which make the cumulative cost from 80% to 90 % in the last half year.
Class C	The C class items are the items which make up for the remaining costs of the last half year.
Class D	The D class items are the items to which no money has been spent in the last six months.

To visualize the distribution by value analysis of RGBV figure 3.1 has been made.

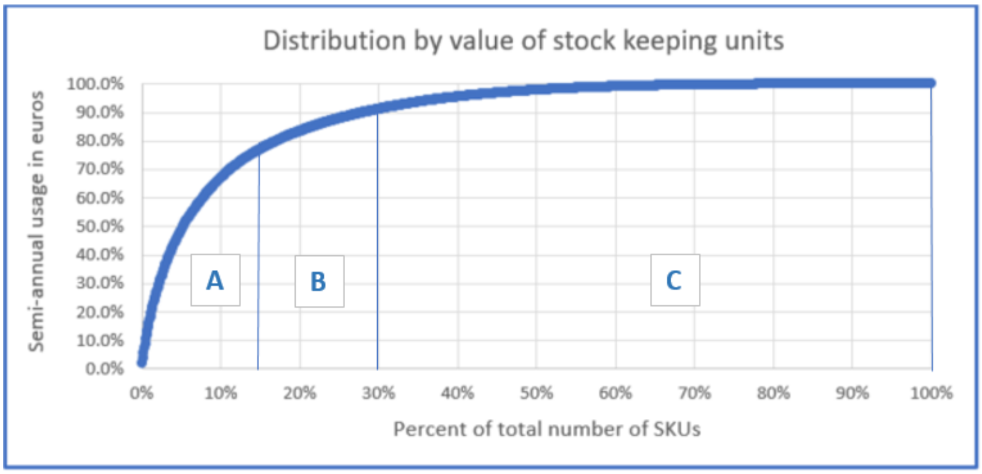


Figure 3.1 - Distribution by value of stock keeping units of RGBV

When the ABC classification has been performed, an XYZ classification is performed. This is done with the coefficient of variation. The coefficient of variation is calculated with the formula 3.1, which can be seen below.

$$\text{CV} = \frac{\mathit{Standard\ deviation\ last\ six\ months}}{\mathit{Mean\ last\ six\ monhts}} \tag{3.1}$$

$$\text{CV} = \mathit{coefficient\ of\ variation}$$

If the coefficient of variation is equal or smaller then 1, the item is classified with a “Low” variation. If the coefficient of variation is between 1 and 1,5 the item is classified with a “Medium” variation. If the coefficient of variation is higher than 1,5 the item is classified with a “High” variation.

3.2 The current purchasing process

RGBV makes use of an order up to level (R, S) policy, with a review period of 2 weeks (R=2). Every two weeks, three employees from the purchasing department go through around 1100 products. First, they deselect the products that have not been used since the last time they ordered. Then all three of the employees make a schedule individually and then compare the three schedules. This takes them 1 to 1,5 days per person. After making the schedule, they will discuss the differences and that is how the purchasing schedule is made. Comparing the schedules takes about 1 to 1,5 hours. They make use of a model which gives them an advice about how much they should order. After the collective scheduling, the items need to be purchased. This takes one employee of the department around one hour.

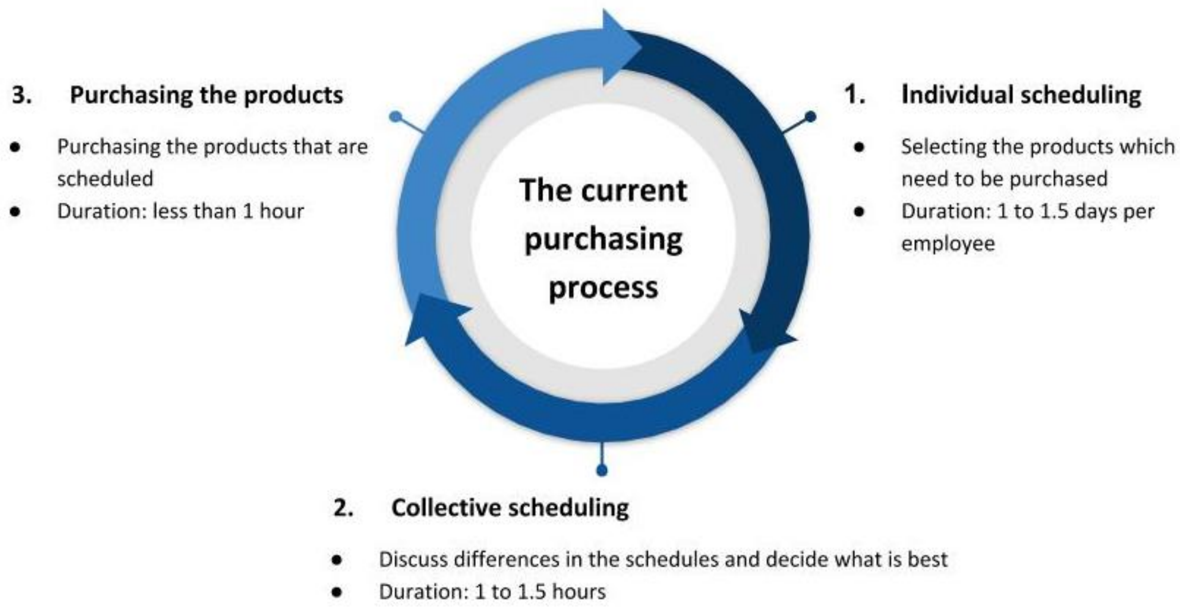


Figure 3.2 - The current inventory process.

It is to be noticed that the inventory position of the company is checked every week. So, if there is risk of a stock out or a stock out occurs, they will order then. But in general, this is done every two weeks for every product. This system is used because is easier to save shipping costs when items are ordered together.

3.3 The Purchasing model

When making a purchasing schedule the purchasing department makes use of a model which gives them an advice about how much they should order. In the model lead time is assumed deterministic and is given in weeks. Demand is stochastic and a forecast is made based on historical demand and allocations. The advice of the model is based on certain decisions and calculations. In this part the decisions that the model takes and the paths that lead to certain outcomes will be explained. The purchasing model makes use of the following important steps:

1. Safety stock adjusted
2. Purchase required
3. The adjusted purchase (end advice)

The steps and decisions that the purchasing model makes, can be seen in figure 3.3. In this figure the words in bold are the important steps that are determined by the model. These values depends on decisions that model asks. The yellow diamonds represent the asked questions. The possible answers to these questions are given above the black arrows. The following questions are asked:

- *Question box 1*: Is the item class D?
- *Question box 2*: Adjusted safety stock - (Inventory position - forecasted demand) < 0?
- *Question box 3*: Is the safety stock in weeks smaller than the minimum safety stock in weeks, bigger than the maximum safety stock in weeks, or in between the maximum and minimum safety stock in weeks?

The safety stock adjusted, purchase required, and the adjusted purchase will be explained in the next chapters.

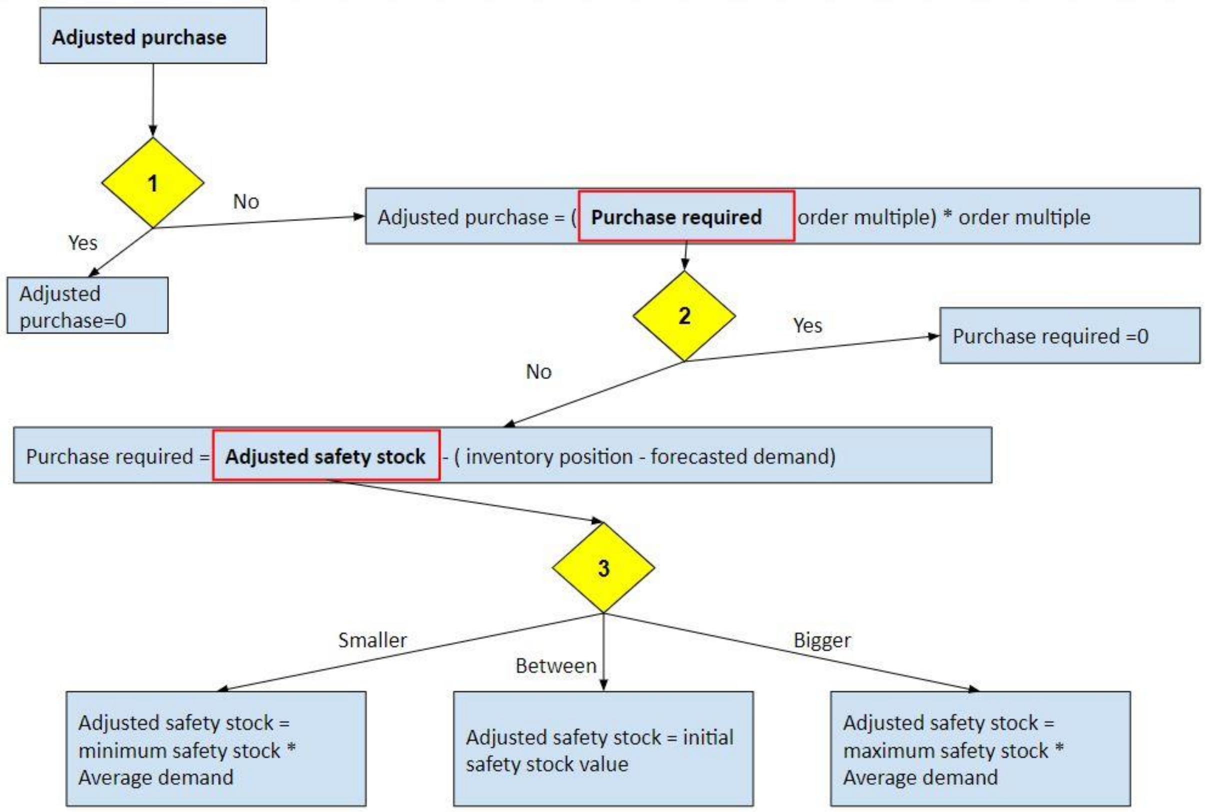


Figure 3.3 - Steps of the RGBV's purchasing model

3.3.1 Safety stock adjusted

The adjusted safety stock is an important part in the amount which should be purchased. Therefore, it is important to know how the model comes to the adjusted safety stock. In the model the following formula is used to calculate safety stock:

$$Safety\ stock = Z * \left(\sqrt{LT}\right) * \ \sigma_d \tag{3.2}$$

$Z = number\ of\ standard\ normal\ deviations\ (Z - score)$
$LT = lead\ time\ supplier\ in\ weeks$
$\sigma_d\ =\ standard\ deviation\ of\ demand\ of\ the\ last\ six\ months$

This is a commonly used formula to calculate the amount of safety stock needed. However, RGBV uses another formula which adjusts the level of safety stock required, in the purchasing model this formula is called: 'the adjusted safety stock'.

The adjusted safety stock tests if the safety stock in weeks is between the minimum and maximum safety stock in weeks. The safety stock in weeks is calculated with the following formula:

$$Safety\ stock\ in\ weeks = \frac{Safety\ stock}{last\ six\ months\ average\ weekly\ usage} \tag{3.3}$$

Depending on the safety stock in weeks value the adjusted safety stock can take three different paths:

If the value of 'safety stock in weeks' is between the minimum safety stock in weeks and maximum safety stock in weeks value, formula 2.4 is used and the level of safety stock does not get adjusted.
If the safety stock in weeks value is less than the minimum safety stock in weeks, then the formula 2.5 is used to calculate the required amount of safety stock.
If the safety stock in weeks value is more than the maximum safety stock in weeks, formula 2.6 is used to calculate the required amount of safety stock.

$$Safety\ stock\ adjusted \\ = minimum\ safety\ stock\ in\ weeks * last\ six\ monhts\ average\ weekly\ usage \tag{3.4}$$

$$Safety\ stock\ adjusted \\ = maximum\ safety\ stock\ in\ weeks * last\ six\ months\ average\ weekly\ usage \tag{3.5}$$

The minimum safety stock in weeks is 4 for every item. The maximum safety stock in weeks value depends on the classification of the item. Table 3.2 shows which maximum safety stock in weeks value belongs to which item.

Table 3.2 - Maximum safety stock in week parameter

Maximum Safety Stock Weeks				
		Variation		
		Low	Medium	High
Class	A	6	7	7
	B	6	7	8
	C	6	8	9

Unfortunately, there is no explanation given in the purchasing model about the parameters of the minimum and maximum safety stock weeks. When asking the purchasing department, they explained that the one who made this model has left Rotork, so there is no one who can explain where the values of these parameters come from. Probably the 50% rule is applied here for the maximum safety stock in weeks, which is then accounted for importance of the items (class of the items) and the variation in demand of the items. The lead time for most products in RGBV is 12 weeks. The 50% rule states that there should be enough safety stock to fulfil half of the orders during lead time. The lead time for most products within RGBV is 12 weeks.

As can be seen in figure 3.3, the adjusted safety stock can take three different paths. The initial safety stock value is adjusted in two out of three paths. We will now look at what percentage of time the initial safety stock value is adjusted. So, in what fraction of time the safety stock in weeks is not between the maximum and minimum safety stock value. This is done for the most recent advice that the purchasing model gave. The calculation is given below, with 928 the total number of items purchased and 272 the total number of items which safety stock level did not change cause of the adjusted safety stock.

$$Percentage\ of\ time\ the\ safety\ stock\ value\ is\ adjusted = \left(\frac{(928-272)}{928}\right) * 100\% = 70{,}1\ \%$$

More than 70% of times the safety stock gets adjusted because the value of the safety stock in weeks is not between the minimum safety stock in weeks and the maximum safety stock in weeks. This is a high percentage, especially because the background for this calculation is unknown. Also, the calculation is not really tailored to the situation, the adjusted safety stock model does not consider to which extent the safety stock in weeks differs with the minimum and maximum safety stocks in weeks. For instance, it does not matter if the safety stock in weeks is 3,9 or 1,0, the same formula for the safety stock adjusted will be made into practice.

Furthermore, this model sketches a wrong picture of the service level that the company is aiming to achieve. For the first formula, the service level is set at 95% for all products. This results in the company thinking that they have a service level of 95%. We already calculated which percentage of time the initial safety stock value is adjusted. The following calculation shows what percentage of time the adjusted safety stock is lower than the initial safety stock:

$$Service\ level\ lower\ than\ 95\%\ (\%) = \left(\frac{(928-272-53}{928}\right) * 100\% = 65{,}0\ \%$$

In this calculation 928 is the total number of items purchased, 272 the number of items which safety stock level did not change cause of the adjusted safety stock, and 53 the number of items which got a high safety stock level cause of the adjusted safety stock. As you can see in the calculation, for 65% of the items required safety stock gets adjusted in a lower required safety stock. This has a result on the service level that the company is aiming to achieve. The company thinks they are getting a service level of 95% for all items, but this is much lower for many items. As you can see in figure 3.4 the indicated service level is 0,95 = 95%, and the amount of safety stock which belongs to this service level is 1914 item. But this initial safety stock value is changed by the adjusted safety stock formula, which results in an adjusted safety stock of 1383 items.

Safety Stock									
Service Level	Standard Deviation (Last 6 Months)	Coefficient of Variation (Last 6 Months)	Service Factor	Lead Time Factor	Safety Stock	Safety Stock Weeks	Min Safety Stock Weeks	Max Safety Stock Weeks	Safety Stock Adjusted
0,95	335,90	1,70	1,64	3,46	1.914	9,7	4	7	1.383

Figure 3.4 - Example calculation of safety stock for a product

The service level which belongs to this level of safety stock is:

$$Service\ level = \frac{Safety\ stock\ adjusted}{\sqrt{LT} * \sigma_d} = \frac{1383}{3{,}46 * 335{,}90} = \varphi(1{,}18997\ ) = 88\% \qquad (2.9)$$

The formula used to calculate this service level is the formula that RGBV uses to calculate the initial safety stock value. The service level which corresponds with the z-score is looked up in the normal distribution table. This calculation is done for all items of RGBV, the results of this calculation are plotted in Figure 3.5. To see the table that belongs to figure 3.5 see appendix B.

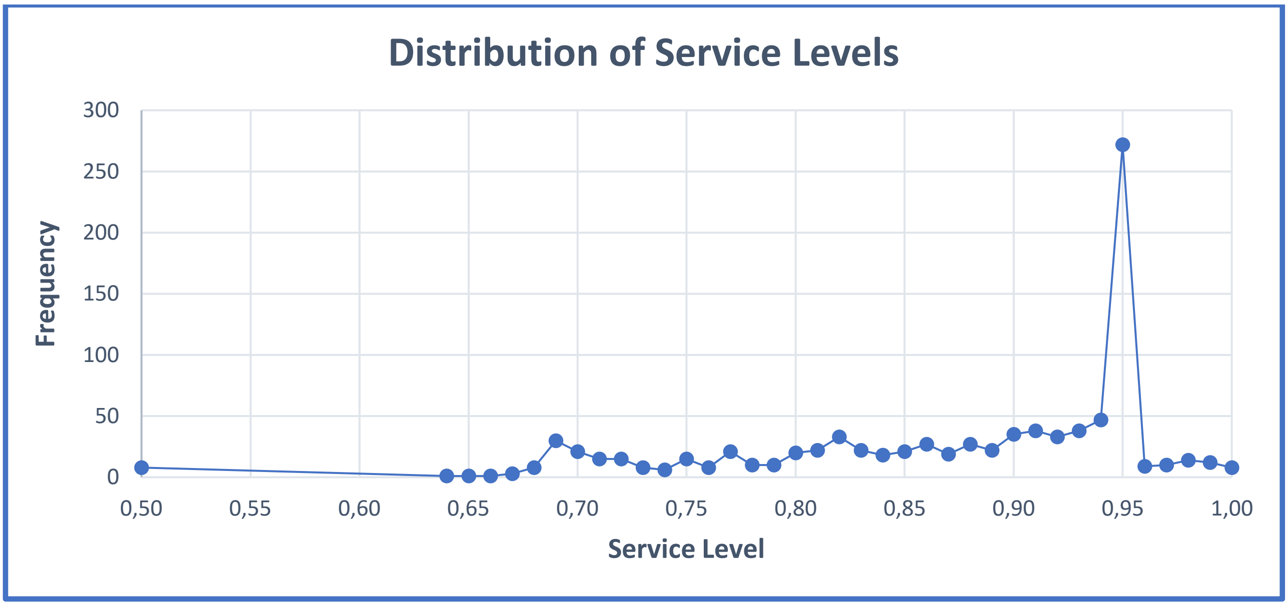


Figure 3.5 - Distribution of Service Levels of all products

Because this research is focussed on the class A items, the same analysis is done for the class A items. The results have been plotted in figure 2.11, and the corresponding table can be seen in appendix B. The actual average service level that RGBV has is 87%.

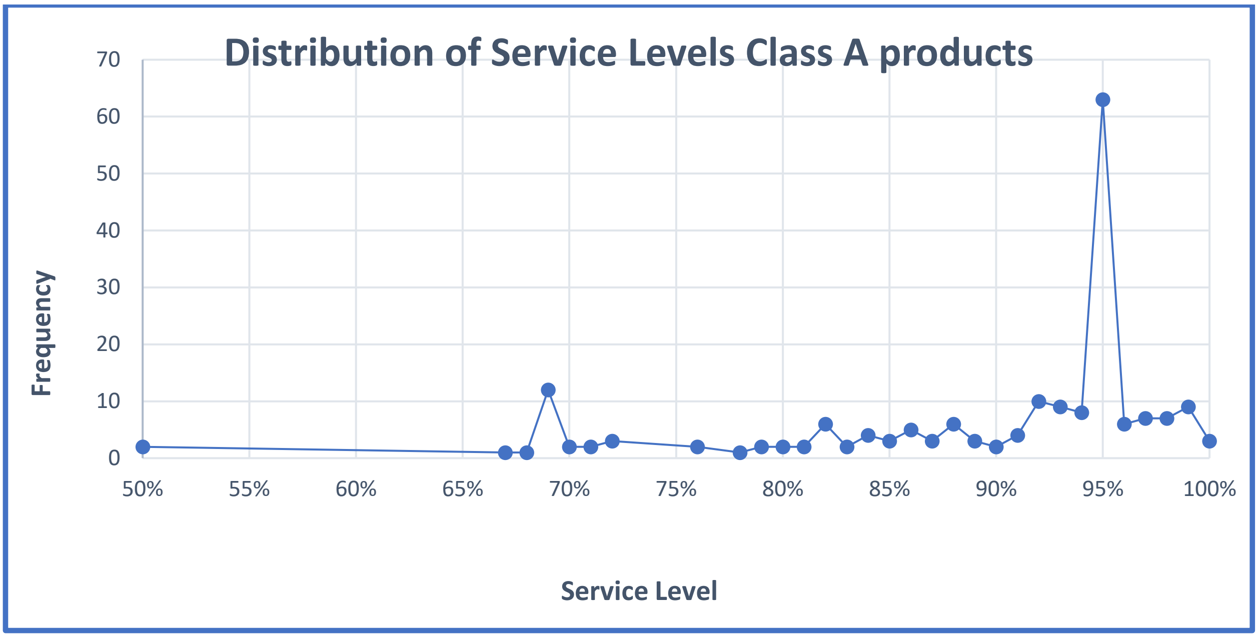


Figure 3.6 - Distribution of Service Levels of Class A products

It is made clear by the distribution of the service levels of the class A products, that not only the lower-class items deviate from the 95% service levels, but that this is also the case with the class A items. The purchasing department thought they were getting a 95% level for every item while many items have a lower service level. The average service level of the class A items is 92%.

3.3.2 Purchase required

As you can see in figure 3.3, the purchase required formula consists of two parts. First, it determines if equation 3.6 is smaller than zero:

$$\begin{aligned}&Purchase\ required\\&= adjusted\ safety\ stock - (Inventory\ position - \ forecasted\ demand)\end{aligned} \tag{3.6}$$

If the outcome of equation 3.6 is greater than zero nothing will be ordered. If the outcome of equation 3.6 is bigger than zero, the amount which value of purchase required is the outcome of equation 3.6. The purchase required depends on what is already in stock and what is already ordered for the coming weeks. Logically, if the adjusted safety stock goes up, the purchases required goes up as well.

3.3.1 Adjusted purchase

The adjusted purchase is then end advice that the model provides for the purchasing department. The value of the adjusted purchase is zero if the item in question is an old/obsolete item (class D item). This question is implemented to prevent items being bought that are not used anymore. The value for adjusted purchase is calculated by the following formula 3.7:

$$Adjusted\ purchase = \left(rounded\ up\ value\ of\ \left(\frac{purchase\ required}{order\ multiple}\right)\right) * order\ multiple \tag{3.7}$$

Most suppliers only deliver at a minimum order quantity and with an order multiple. The order multiples of the suppliers of RGBV range from range from one item to five thousand items. The adjusted purchase formula in the model takes this into account when giving an advice on how much to order.

3.4 Summary and conclusions

- RGBV classifies its items based on a combination of a distribution by value analysis and an XYZ classification.
- RGBV makes use of an (R, S) policy with a review period of 2 weeks.
- The purchasing model consists of the following important steps: safety stock adjusted, purchase required and the adjusted purchase. The adjusted safety stock changes the initial safety stock values in more than 70% of times. In 65% of times this results in a lower service level than 95%. The purchasing department was not aware of this.

4 The Model

In this chapter, the simulation model will be built. The following subjects will be discussed: the conceptual model, data for the model, the warmup period, the run length, the number of replications, validation and verification.

4.1 Conceptual model

In paragraph 2.7.4 is discussed which aspects should be included in a conceptual model. In this part the following subjects will be discussed: the goal of the simulation, the input and output variables, the scope of the simulation, and the assumptions and simplifications.

4.1.1 Goal of the simulation

The goal of the simulation is to simulate an alternative formula for the calculation of safety stock. The goal of the simulation is to test whether the selected safety stock formula is a better fit for RGBV. The current system will be simulated and then compared with the new system to find the best policy. Also, with the simulation will be found out if the optimal service level mostly depends on holding and shortage costs, because then the classification method of (Teunter et al., 2010) will be recommended to RGBV.

4.1.2 Input and output variables

The input and output variables are respectively the input and output of the simulation model. The input values consist of two types: the fixed and the variable input. The fixed input are the parameters you can use. These parameters will not be changed, for instance the cost of a product or the demand distribution of a product. The variable input are the variables which will be experimented with. The model input is how the goal of the simulation is to be achieved. The output of the simulation are the indicators used to determine whether a change in the experimental variable has a positive or negative effect (KPI's). The input and output variables are shown in the table 4.1.

Table 4.1 - Input and output variables

Input/ experimental factors	**Output- outcomes**
Service level	Handling costs
Different safety stock formula	Shipping costs
	Holding costs
	Shortage cost
	Ordering costs
	Total costs
	Order fill rate
	Product fill rate
	Average ending inventory
	Average inventory in transit

When constructing the simulation model, we should use the right input variables and output variables. The choice for the input and output variables result from conversations held with stakeholders from the company. The variable input and the output will be explained be, the fixed output is described in paragraph 5.2.

Input

- *Service level*

  Service level is the expected probability of not having a stock out in your replenishment cycle. The service level marks a trade-off between opportunity cost (holding costs) and the cost of operation (shortage costs). Reducing you service level will reduce your holding costs, because there is less safety stock in the warehouse, but will increase the probability of hitting a stock out, and therefore increase your total shortage costs within a replenishment cycle. It vital for the performance of organizations that they get their service levels right. In this simulation, we will experiment with service levels from 85 – 99 % to see which is optimal.

- *Safety stock formula*
  Safety stock is an important part of inventory and can be calculated with several formulas. The formula which is best according to literature will be compared with their current formula based on the output of the simulation model to see if it would benefit RGBV.

The output variables are chosen in a way that you can see the effect of the experimental variables. The following output variables have been chosen:

Output

- *Handling costs*
  Handling costs are the costs associated with getting the item in the right place, This KPI measures the impact of the experimental factors on the handling costs.

- *Shipping costs*
  The shipping costs measures the impact of the experimental variables on the costs of shipping an item from the supplier to RGBV.

- *Holding costs*
  This KPI measures the impact of input variables on the cost of holding inventory in stock. With this output variable, the impact of inventory management parameters on the cost of keeping an in stock can be measured.

- *Shortage costs*
  This output variable measures the impact of experimental variables on the cost of not immediately meeting demand from stock.

- Ordering costs
  This KPI measures the effect of an input variable on number of times that is ordered, and the costs related to this.

- *Total costs*
  This output variable measures the impact of the experimental variables on the total costs associated with inventory. This output variable is the sum of the other cost variables and therefore a very important KPI.

- *Order fill rate*
  This output variable measures what percentage of the orders is immediately fulfilled from inventory. The order fill rate is calculated by dividing the total number of orders immediately fulfilled from inventory on hand by the total number of orders.

- *Product fill rate level*

This output variable measures what percentage of the items is immediately fulfilled from the stock on hand. The product fill rate is calculated by dividing the number of products which are immediately fulfilled from inventory by the total number of products.

- *Average ending inventory*
  This output variable measures the impact of experimental input on the average inventory in the warehouse. This is only the inventory, which is physically in the warehouse, so the inventory on the boat is not considered.

- *Average inventory in transit*
  This KPI measures which inventory the impact of experimental variables on the average inventory in transit. Which is the lead time – 4 (this is the production time for most products in China) times the average of the column: average end inventory + orders in transit.

4.1.3 Scope of the model

In table 4.2 will be explained which to which extend each input variable will be experimented with, and the reason behind this.

Table 4.2 - Scope of the model

Part	Range	Reason
Service level	0.85 – 0.99	The general leadership of Rotork has restricted the individual establishments of Rotork to aim for a lower service level than 85%.
Safety stock formula	-	-

4.1.4 Limitations

Before constructing the model, we determine the limitations which limitations are applied in the simulation model. The limitations consist of assumptions and simplifications. The difference between an assumption and a simplification is that with assumptions the real situation is not known exactly and with a simplification the real situation is often known. Assumptions are therefore often made to fill up gaps in knowledge (Robinson, 2014). Simplifications are made to keep the model from becoming too complex, enable more rapid model development and use, and to improve transparency (Robinson, 2014). Below the assumptions and simplifications of the model are listed.

Assumptions:

1. Demand is assumed to have no serial correlation. This means that the demand in week t does not have influence on the demand in t + 1.
2. Lead time is assumed to have no serial correlation. This means that the lead time in week t does not have any influence in week t + 1.
3. Because of the lack of data, it is to be expected that some lead times of some items do not follow the normal distributions according to tests, still stakeholders within the company believe that the lead time of these items are normally distributed.
4. The mean of the lead times is compared with the lead time used in the purchasing model. Because of the lack of data, the lead time used in the purchasing model will be used in the simulation.

5. The standard deviation is expected to be higher or lower than the real standard deviation of the lead time, because the lack of data concerning the lead time performance of suppliers. Therefore, the minimum standard deviation of the lead time is set at one week and the maximum standard deviation of the lead time is set at two weeks.

Simplifications:

1. RGBV only order once every two weeks. This is almost always the case, but the inventory levels are checked every week, and if they foresee a big problem, there is ordered.
2. In the calculation of the shortage costs, the reputational cost for not meeting demand immediately from inventory is not considered.
3. The purchasing department does not change the advice that the purchasing model provides.

4.2 Data for the simulation model

As mentioned in 5.1.2 the input data consist of the experimental input and the fixed input, both are needed to run the simulation. The experimental input is already explained in paragraph 5.1.2. The fixed data will be collected in this paragraph.

4.2.1 Demand distribution

To make the simulation run properly, demand of the items must be generated randomly. This is done by making a distribution of the historical demand of the item. First a histogram is made to visualize the distribution of demand for the items, which can be seen on the right. An example of one of the histograms made can be seen in figure 5.1.

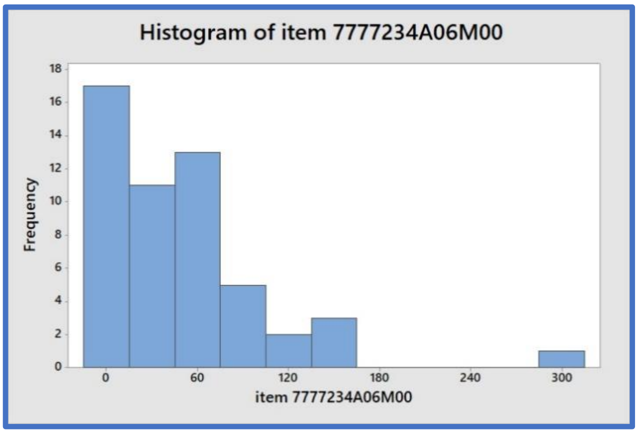


Figure 4.1 - Histogram of the demand of item 7777234A06M00

To determine if the data of the historical demand follow a specific distribution, the p-value is compared to the significance level. The significance level, often referred to as a or alpha indicates the risk that the data do not follow the distribution. If the p-value is smaller than alpha, which is 0.05 then the data do not follow that distribution. If the p-value is greater than a there cannot be concluded that the data do not follow that distribution.

The historical data of the demand is tested on the distributions most commonly used in simulation: normal, exponential, Weibull and log-normal. The red line in the middle of every graph in figure 4.2 is the distribution line. The blue lines are of the historical data of the demand of the product. If the distribution was a perfect fit the blue data points would be exactly on the middle red line. The other red lines are the boundaries of the 95% confidence interval. The distribution is a good fit if the roughly follow a straight line and the p-value is greater than 0.05. The AD value in the table next to the graph is short for the Anderson-Darling statistic and it measures how the data follow the distribution. The lower the AD value is the better the distribution fits the data. In figure 4.2 the data of the historical demand of the item 7777234A06M00 has been tested against the distributions, the identification of the distribution of the other items can be found in appendix B. The results of the analysis can be found in appendix C. Because the exponential, Weibull and log-normal cannot work with 0 values, the values for the weeks in which demand is 0 are changed to 1. If none of these distributions match the historical data of the item a discrete distribution is made based on the histogram of the product. An example of the probability plots made for each item can be seen below.

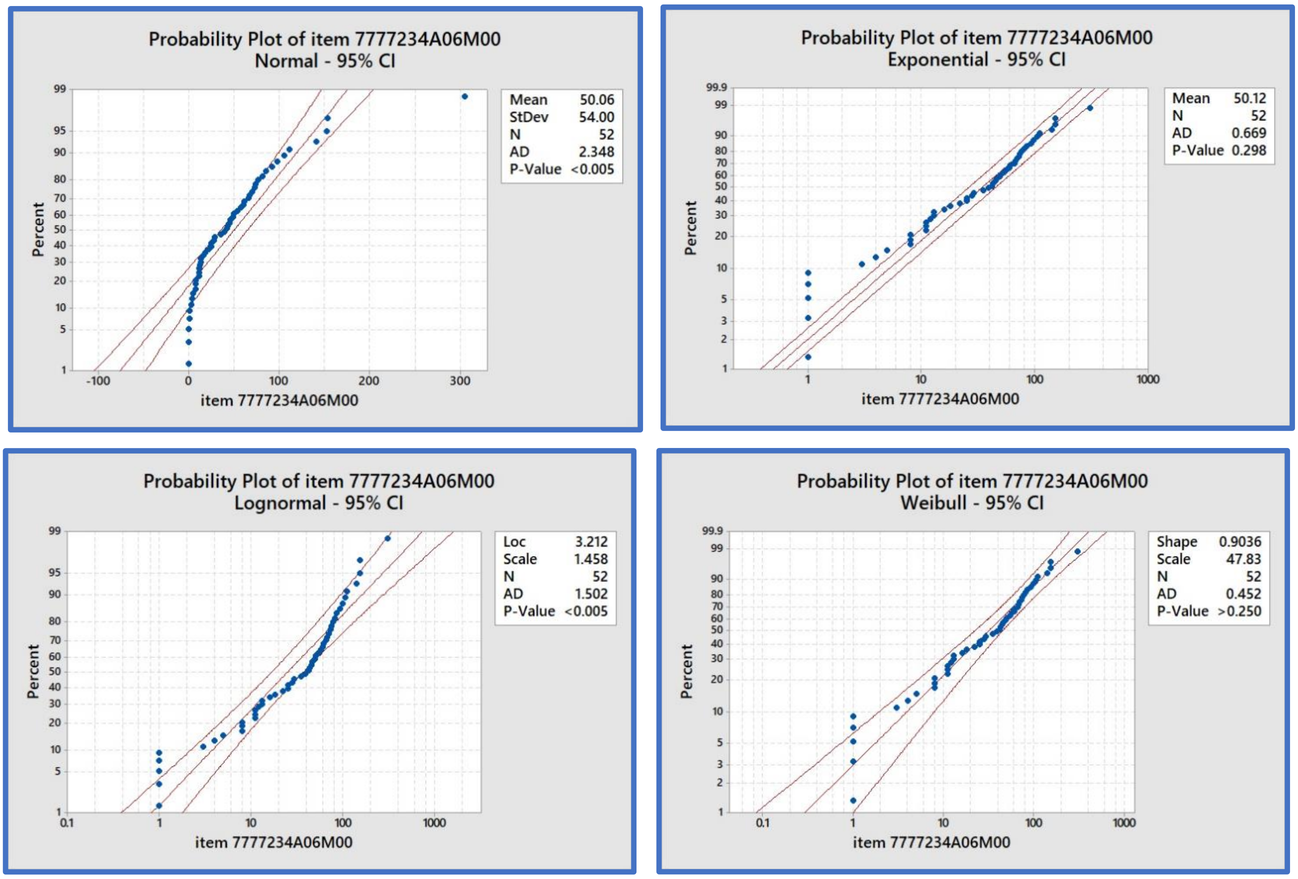


Figure 4.2 - Probability plots of the demand of item 7777234A06M00

4.2.2 Lead Time distribution

To be able to simulate the current inventory management process, the lead time distribution is needed.

To determine the distribution of the lead time an analysis of the delivery performance of the Chinese suppliers is done. The lead time is expected to be normally distributed, to see if this expectation is correct a probability plot of the normal distribution is made for the selected products. The data which is used to make these probability plots is all data which data from June 2018 till is now, which is all data available about the lead time performance of suppliers. An example of a probability plot can be seen in figure 4.3. For the probability plots of the lead time of all the items can be seen in Appendix D.

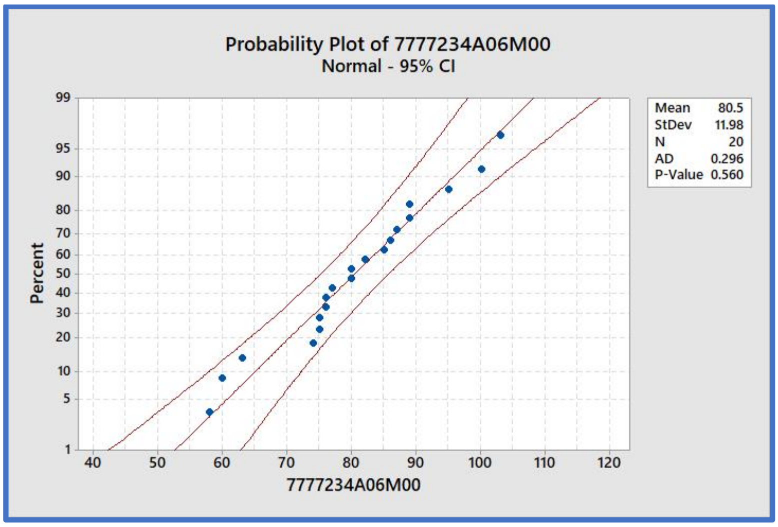


Figure 4.3 - Probability plot of the lead time of item 7777234A06M00

For almost all products we could not conclude that the data does not follow a normal distribution with a significance level of 5%. According to the probability plots made, just for four products it could be concluded that the lead time is not normally distributed. The reason for this could be the lack of data, because RGBV tracks the delivery performance of the suppliers for a relatively short time.

4.2.3 Average weekly demand and standard deviation

The average weekly demand and standard deviation of products is needed to calculate the order up to level point of the company and the safety stock levels of the base model. The average weekly demand and standard deviation of the items is calculated with data of historical demand of one year.

4.2.4 Inventory cost

In this chapter the costs associated with inventory management will be calculated. The following costs will be used as fixed input: Holding costs per item, shortage costs per item, shipping costs per item, handling costs per item and ordering costs per item. The holding, shortage, shipping, handling and total costs over one run length are output of the simulation model.

Holding costs

The holding costs are the sum of the opportunity cost and the occupancy costs. The opportunity costs represent the benefits that the company is missing out on. In this case, it means that every euro spend on inventory is a euro which will not yield interest. The occupancy costs are the costs which are associated with the space by items held in storage. Information about the average interest rate in 2019 can be found in table 4.3.

The occupancy costs are calculated by dividing the yearly cost of the warehouse by the number of pallets in the warehouse. To get the occupancy costs per week per item we divide this by 52 and the number of items that fit in one pallet. The costs of the warehouse, the number of pallets which fit in the warehouse can be found in table 4.3.

The opportunity cost is calculated with the following formula:

$$Opportunity\ cost = (price\ item + shipping\ cost + handling\ cost + occupancy\ cost) * interest\ rate$$

Table 4.3 - Information for the calculation of holding costs

Holding costs				
Occupancy costs			**Opportunity cost**	
Rent warehouse (year)	€	20,000.00	Average interest rate 2019	0.175
Number of pallets in the warehouse		940	Average interest rate per week	0.003365385
Cost per pallet (week)	€	0.409165		

Because the calculation of the holding costs requires some time, a calculation is made to give the holding costs as a percentage of the unit costs. The holding costs are divided by the unit costs and multiplied by 100%. The average holding costs as a percentage of the unit price is taken, this resulted in an outcome of 0.37%. The holding costs per week can now easily be calculated by multiplying the price of an item by 0.37%. This calculation can be seen in table 4.4.

Table 4.4 - Calculation holding costs as a percentage of the part costs

Part number	Unit cost		Holding cost		Holding cost / unit cost*100 %
GB10000	€	9.28	€	0.03325	0.36%
7777234A06M00	€	36.12	€	0.12983	0.36%
10DN00M050M00	€	20.91	€	0.08130	0.39%
44D0600C18001	€	9.87	€	0.03696	0.37%
44EZ200000000	€	16.40	€	0.06188	0.38%
50E0400000010	€	8.10	€	0.02837	0.35%
AB-00285-L-3	€	26.36	€	0.10075	0.38%
A0158716000A4	€	1.57	€	0.00537	0.34%
44BZ200000005	€	4.35	€	0.01625	0.37%
162C002600000	€	3.42	€	0.01209	0.35%
22F0Z10000001	€	15.77	€	0.06206	0.39%
270F000000000	€	3.11	€	0.01102	0.35%
PR-00099-3	€	7.17	€	0.02563	0.36%
AB-00133-L-1	€	13.46	€	0.04689	0.35%
44CZ200000000	€	6.73	€	0.02581	0.38%
AB-02749-1	€	5.62	€	0.02058	0.37%
21U4Z10000006	€	15.43	€	0.05993	0.39%
7777600D03911	€	93.64	€	0.33928	0.36%
22E2000K00002	€	26.33	€	0.11869	0.45%
24U1600327000	€	2.30	€	0.00838	0.36%
H0PS01212DPC0	€	1.16	€	0.00421	0.36%
H0SG03015DPC0	€	4.73	€	0.01877	0.40%
					0.37%

Shortage costs

The shortage costs are the costs that are associated with having a stock out. When a stock out occurs an emergency order will be placed, and this order will be brought by plane. The costs of an order per plane depends on the weight of the shipment. RGBV pays €3.50 per kilogram for an emergency flight.

The shortage costs of an item are calculated by multiplying the costs per kilogram and the weight of a product. The costs per kilogram when an emergency flight is needed can be found in table 4.5.

Table 4.5 - Information for the calculation of shortage costs

Shortage costs		
Airfreigt per kg	€	3.50

Shipping costs

The shipping costs are the costs of shipping an item. These costs consist of the transportation by boat and on the import rates of an item.

The shipping cost per pallet are calculated by dividing the total shipping costs of 2018 by the total pallets shipped in 2018. The shipping costs per item can be obtained by dividing the shipping costs per item by the number of items that fit on that pallet. Lastly the corresponding import rates of an item are multiplied with the shipping costs per item to get the total shipping costs of an item. In table 4.6 the information which is used to calculate the shipping costs is given.

Table 4.6 - Information for the calculation of shipping costs

Shipping costs		
Total cost shipping (2018)	€	212,251.23
Total pallets shipped (2018)		4062
Shipping costs per pallet	€	52.25

Handling costs

Handling costs are the cost associated with getting the item in the right place. In this case this means unloading the container in the right place, transporting the items from the bulk storage to the right storage, and getting the necessary paperwork done. Unloading the container and getting the paperwork done takes about 2 hours (120 minutes). The container consists of 30 pallets, so it takes on average 4 minutes to unload one pallet and do the paperwork. Driving a pallet from the bulk storage to the right storage place for an item takes about 1.2 minutes. This results in a total time of 5.2 minutes to handle one pallet. The employee which handles this process earns €35 per hour. This results in a total cost per pallet of €3.03. In table 4.4 the information which is used to calculate the handling costs is given.

Table 4.7 - Information for calculation of handling costs

Handling costs		
Unloading container + Paperwork (30 pallets)		120
Unloading Pallet + Paperwork pallet		4
Driving a pallet from bulk storage to right storage		1.2
Costs employee (hour)	€	35.00
Total costs per pallet	€	3.03

Ordering costs

Many costs with placing an order do not depend on the size of the order, these costs are called the Ordering and setup costs. An example of ordering and setup costs is the paperwork and billing which are associated when placing an order, these are costs that are there no matter how big the order is. Also, the time employees spend on how much they should order costs money. The combination of time an employee spends on determining how much to order and the paperwork forms the total ordering costs.

The purchasing employee looked in the system and saw that he did around 300 orders in four hours. The employee also earns €40 euro per hour, which means that the fixed ordering cost are:

$$\frac{4\ hours}{300\ orders} * €40 = €0.53$$

As mentioned in paragraph 3.2, three employees from the purchasing department go through all the products individually which takes them 1 to 1.5 days. The hourly wages are €40, and their workday is 7.5 hours per day, excluding the breaks. When the order they order on average around 300 products. This results in a fixed ordering cost of:

$$\frac{3 * (1 + 1{,}5) * 0{,}5 * 7{,}5 * 40}{300} + €0.53 = €4.28$$

Total costs

The total cost of inventory is a factor of many different costs. In this research, it will be the sum of the: holding costs, shortage costs, shipping costs and handling costs and ordering costs. The total cost will be the most important output variable of the simulation.

4.3 Implemented simulation model

In the following chapter the explanation of the implemented simulation model will be given. The following topics will be covered: the software used, second the way the items can be selected in the simulation model, the steps taken by the simulation model and the calculation of the output variables.

To make the simulation run, a code must be written. The programming langue in which this code is written is Visual Basic. The choice fell on this programming language because the author has experience with it, and because this way the code is easily executed in Excel, and Excel is widely used within RGBV.

4.3.2 Item selection

Figure 4.4 shows the product selection screen of the model. An item can be selected in the Combo box next to “item”. When the desired item is selected, the corresponding information of the item will appear automatically. The given information is linked with the simulation.

Item	7777234A06M00			
Item information				
Demand distribution		**Distribution parameters**		
Weibull	X	Shape	0.904	
		Scale	47.83	
Exponential		Mean		
Discreet				
Lead time distribution				
Normal	X	Mean	12	
		Standard deviation	2	
MOQ/order multiple	73			
Average weekly historical demand	50.06			
Standard deviation historical demand	54			
Inventory costs				
Handling costs (€)	0.0416			
Shipping costs (€)	0.7423			
Shortage costs (€)	18.9			
Holding costs (€)	0.1298			
Ordering costs (€)	4.28			

Figure 4.4 - Product selection screen of the model

4.3.3 Steps taken by the simulation

When the desired item is selected, the simulation can be used. This can be done by pressing the "Run Simulation" button, which is displayed in figure 5.5.

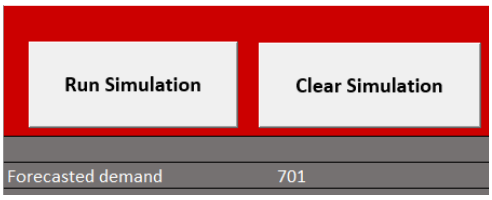


Figure 4.5 - Start simulation

Figure 4.6 shows the ordering process of the simulation and the steps that the model takes during the ordering process are given through 1-14 below.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Week	Begin inventory	Units received	Available units	Demand	Demand filled	End inventory	Stock out	End invt + orders in transit	End invt + orders in transit - safety stock	Place order	Quantity needed	Quantity ordered	Lead time	Arrive in week
1														
2														
3														
4														
5														

Figure 4.6 - The ordering process of the simulation

Steps 1 to 7 of the ordering process of the simulation:

1. *Begin inventory*
   The begin inventory in week t is the end inventory of week t-1. For instance, in week t -1 the end inventory for item 7777234A06M00 is 473, so the begin inventory in week t is also 473.
2. *Units received*
   Units received in week t are the units that have arrived in week t. For instance, in week t, 219 units have arrived.
3. *Available units*
   The available units in week t are the begin inventory in week t plus the units received in week t. So, for example for item 7777234A06M00, the available units in week t are 473 + 219 = 692.
4. *Demand*
   The Demand is drawn randomly from the distribution belonging to the item. The demand for item 7777234A06M00 in week t is 31 units.
5. *Demand filled*
   Demand filled is the minimum of available units and the demand. If the demand is higher than the inventory level of an item, they can only fulfil a part of the demand with the available units. Because the available units are bigger than the demand in week t, the demand which is fulfilled is the demand, which is 31 units.
6. *End inventory*
   The End inventory is available units minus the demand filled, so in week t the end inventory is 692 – 31 = 661.
7. *Stock out*
   The stock out is demand filled minus demand. In week t the demand which was filled was the same as the demand, so there was no stock out.

Steps 1,2,3,4 and 6 can be given as inventory balanced equations. With a balance equation, the left side of the equation must be same value as the right-hand side of the equation. The inventory balance equation can be given by the following formula:

$$Begin\ inventory_t + Units\ received_t - Demand_t = \ End\ inventory_{t+1}$$

$$With,$$
$$Begin\ inventory\ \geq 0$$
$$Units\ received\ \geq 0$$
$$Demand\ \geq 0$$
$$End\ inventory\ \geq 0$$

The inventory levels cannot be below zero because, in case of a stock out an emergency order is done, and the items are delivered by plane. To visualize the balance equation figure 4.7 is made which can be seen below.

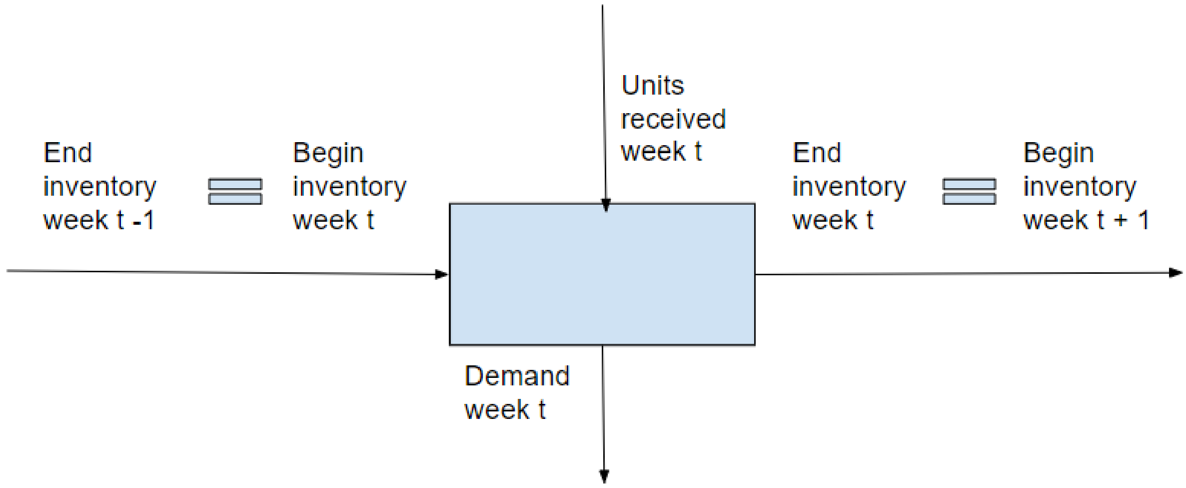


Figure 4.7 - Visualization of the inventory balance equation

Step 8 to 14 of the ordering process of the simulation:

8. *End inventory + orders in transit*
   End inventory + orders in transit in week t are the end inventory of week t plus the orders that were ordered before week t but have not arrived yet. As mentioned in step 7, the end inventory in week t is 661. In week t there are 292 items underway to RGBV, so end inventory + orders in transit for week t is: 661 + 292 = 953.
9. *End inventory + orders in transit – safety stock*
   End inventory + orders in transit – safety stock in week X is made to see whether to order, and if it is necessary to order how much should be ordered. The number of items that are kept in safety stock for the item 7777234A06M00 are 308 items, therefor the value of end inventory + orders in transit – safety stock in week t is: 953 – 308 = 645.
10. *Place order*
    The value in place order in week t can be either a "Yes" or a "No". If there was an order placed in week t - 1, the value of Place order in week X will always be "No". If there is no order placed in week t - 1, the model looks if the forecasted demand is higher than the end inventory + orders in transit – safety stock. If this is the case an order will be placed. There is no order placed in week t – 1. The forecasted demand is 701, which is higher than 645. So, an order will be placed in week t, and the value in "Place order" in week t will be "Yes".
11. *Quantity needed*
    If the value in Place order in week t is "Yes", the quantity needed in week t is calculated by subtracting the end inventory – orders in transit – safety stock of the forecasted demand. The forecasted demand is 701, and the end inventory + orders in transit – safety stock = 645, so the quantity which is needed is: 701 – 645 = 56.
12. *Quantity ordered*
    The quantity ordered is the quantity needed adjusted for the order multiple of the item. The order multiple of item 7777234A06M00 is 73, and the quantity needed in week t is 56. Because of the order multiple 73 units will be ordered in week t.
13. *Lead time*

The lead time is drawn randomly from the distribution belonging to the item. The lead time in week t is 13 weeks.

14. *Arrive in week*

    The week in which the order arrives is Week t + the lead time. The lead time in week t is 13 weeks, so the order will arrive in week t + 13.

4.3.4 Calculation of the output

In this part, will be explained how the output is calculated. Fist the costs per week will be explained then the output of the simulation. The costs per week are calculated with the following formulas:

- $Handling\ costs\ in\ week\ X = Cost\ of\ handling\ item\ X * Units\ received\ in\ week\ X$
- $Shipping\ costs\ in\ week\ X = Cost\ of\ shipping\ item\ X * Quantity\ ordered\ in\ week\ X$
- $Shortage\ costs\ in\ week\ X = Cost\ of\ shortage\ for\ item\ X * Stock\ out\ in\ week\ X$
- $Holding\ costs\ in\ week\ X = Cost\ of\ holding\ item\ X * End\ inventory\ in\ week\ X$
- $Ordering\ \ costs\ in\ week\ X\ = Cost\ of\ ordering$
- $Total\ \ costs\ in\ week\ X = Sum\ of\ all\ costs\ in\ week\ X$

The ordering costs in week X only occur if an order is placed in week X, if no order is placed in week X the ordering costs are 0. When the costs per week are calculated, the output variables can be calculated. All output variabels related to costs can be calculated by taking the sum of its associated costs. For instance, the output variabele handling costs is the sum of all handling costs per week. The other output variables are calculated by the follwing formulas:

- $Order\ fill\ rate = \frac{Number\ of\ orders\ immediatly\ fulfilled\ from\ inventory}{Total\ number\ of\ orders}$
- $Product\ fill\ rate = \frac{Number\ of\ items\ immediatly\ fulfilled\ from\ inventory}{Total\ demand\ in\ items}$
- $Average\ end\ inventory = \frac{Sum\ of\ all\ end\ inventory}{Run\ length}$
- $Average\ Inventory\ in\ transit = \frac{Sum\ of\ all\ inventory\ in\ transit}{Run\ length}$

As mentioned, this is the output for one replication, if multiple replications are performed, the average of the output of the replications is taken as the output of one experiment. The number of replications will be determined in the next chapter.

4.5 Warm up time, run length and replications

Before experimenting, it is important to know the time when you start keeping track of the statistics, how often the simulation should be running and for how long it should run. To determine this, it is important to know what type of output data we are dealing with. There are four types of output: Nonterminating & steady state, Non-Terminating & steady state cycles, Non-terminating & transient, terminating & transient. With non-terminating output data, the initial values of a simulation run should not be taken into account, with a terminating simulation they should be taken into account. The figure below displays the different kinds of output types.

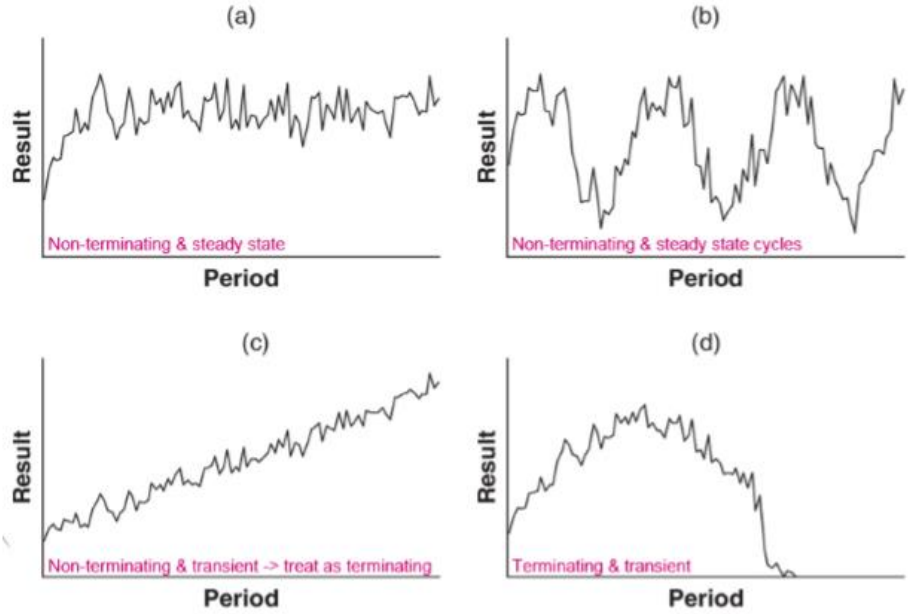


Figure 4.8 - Types of output for simulations

In figure 4.9 can be seen that we are dealing with a non-terminating & steady state output in this research. Because of this a warmup period for the model must be determined, this will be done in the next chapter.

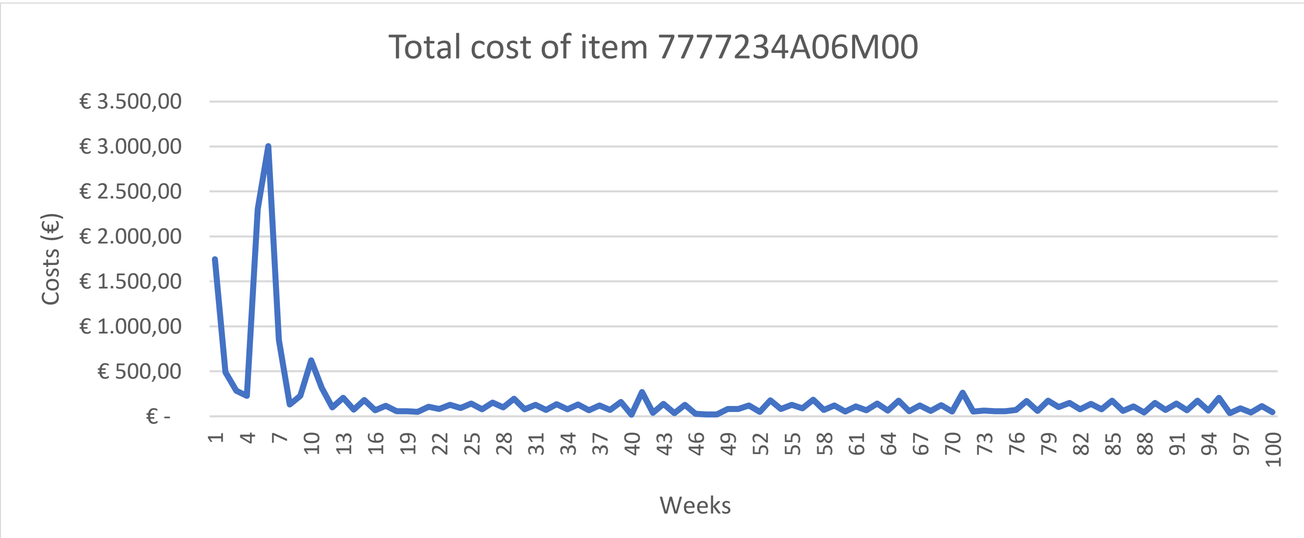


Figure 4.9 - Total cost of item 7777234A06M00 for 100 weeks

4.5.1 Warm up period

The warmup period indicates the time after which it is relevant to keep track of the results of the simulation. When starting the simulation, there are no products in stock. This gives high total costs for the first weeks because there are extremely high shortage costs, because no demand can be met. This will be the case until the first delivery arrives.

There are several ways to calculate the warm-up period, Time-Series Inspection method (Robinson, 2014) will be used in this study. With this method, the time series or a key output is plotted. The first time when the line in the graph looks consistent is the end of the warmup period. The problem with inspecting a time series or a single run is that the data can be very noisy and so it is difficult to spot any initialization bias. It is better, therefore, if a series or replications are run and the mean averages or those replications for each period are plotted on a time series (Robinson, 2014). That is why the average total cost per week of 10 replications is used, the result can be seen in figure 4.10. After 16 weeks, the outcome appears to be in a steady state, at this point the data does not seem consistently higher or lower than their 'normal' level. According to the time series method the warmup period can be set at 16 weeks. But to be sure and not make sure there is no doubt about the quality of the research, the warmup period is set at 20 weeks.

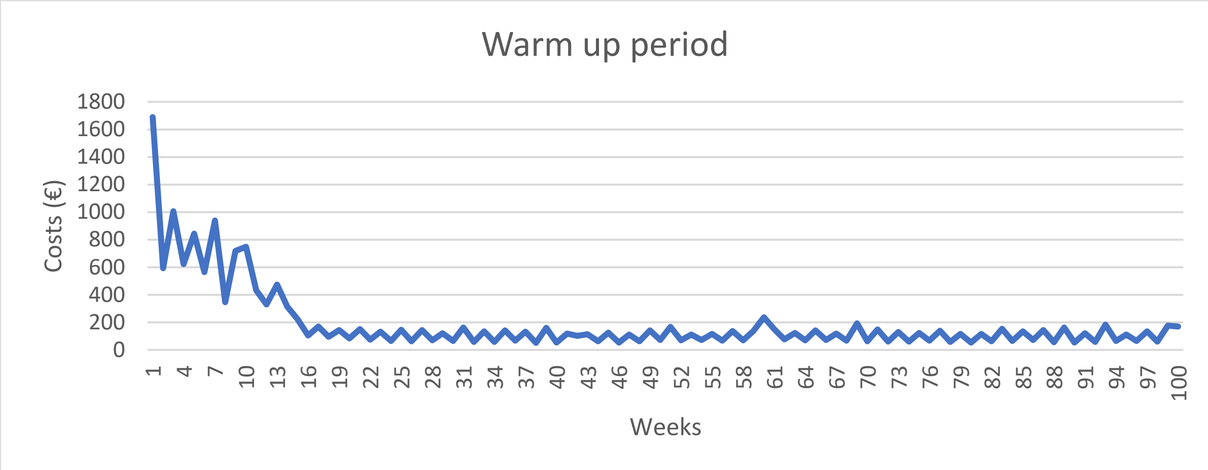


Figure 4.10 - Results from 10 replications of the total costs of item 7777234A06M00

4.5.2 Run Length and replications

The aim with both the run length and the number of replications is to ensure that enough output data is obtained from the simulation to estimate the model performance. The rule of thumb for the number of replications is that at least three to five replications should be performed (Law & McComas, 1990). Because in this simulation it takes relatively more time to perform multiple replications than to make the run length longer, we will make the run length so long that, according to the theory, 3 replications are justified.

There are different methods for calculating the number of replications required. These are: the rule of thumb (Law & McComas, 1990), the graphical method and the confidence interval method. Because the graphical method and confidence interval method use the output data from the model to draw a conclusion about the number of replications required, they are preferred to the rule of thumb (Robinson, 2014). The graphical approach is used in this research because it is a good method and less time consuming then the confidence interval method.

With this method the cumulative mean of the output data is plotted from a series of replications (Robinson, 2014). As more replications are performed the graph should become a flat line. The number of replications that is required to obtain that flat line, is the number of replications required to obtain enough output data to estimate the model performance. Performing more replications would only give marginal improvement, but will increase the process time of the simulation, and is therefore not optimal. The simulation was run 5 times with a run length of 1020 weeks. The cumulative mean of the mean total cost of a simulation was plotted. The result can be seen in the graph below. According to the graphical method the minimal number of replications is 3, see figure 4.11. Theoretically the number of replications required should be analysed for every experiment performed. In practice the number of replications analysis and then applied to all experiments.

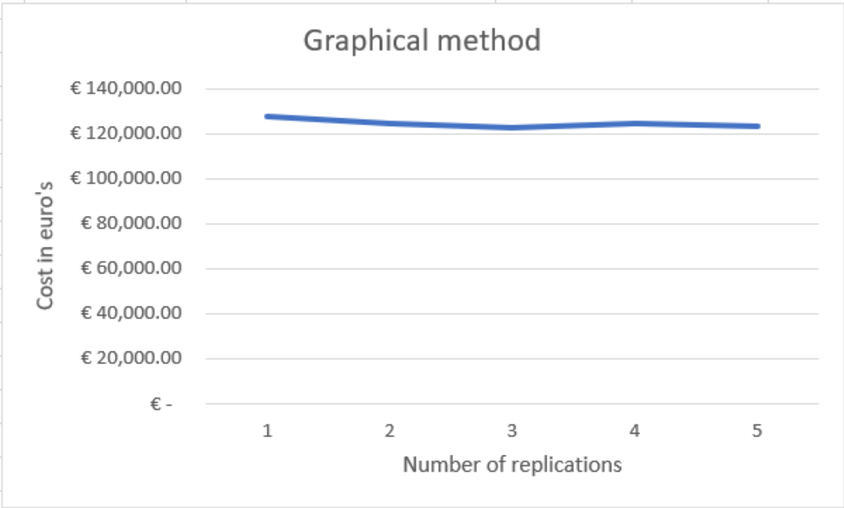


Figure 4.11 - Graphical method: plot of cumulative mean of total cost of item 7777234A06M00

4.4 Validation and verification

As mentioned in paragraph 3.3.5, model validation is determining if the model is a representative representation of the real situation and model verification is determining if the simulation model is a sufficient representation of the conceptual model.

4.4.1 Data validation

Data are a very important element when making a simulation model and a potential source of inaccuracy. That is why there has been consultation with management about the data used during this research. The assumptions and simplifications that were made were also made in consultation with the management. The used data can therefore be considered as valid.

4.4.2 White box validation and verification

In white-box validation, each component is viewed separately to see if it sufficiently matches reality, to achieve the goal of the simulation. The same is done for verification, only for the conceptual model. Although verification and white-box validation are conceptually different, they are often treated together. White-box validation and verification are both performed continuously throughout the model coding and they are both micro checks of the content (Robinson, 2014). Robinson lists three important methods of verification and white-box validation: Checking the code, visual checks and inspecting the output reports.

During coding, there is always looked critically to see whether the steps taken were logical. Also, an explanation has been given for every piece of code, so that the logic and purpose of the code is not forgotten. Every piece of code has also been written out in a worksheet so that the values that the model provided could be checked and the model is often been stopped at every step so that the next value that the model would produce could be predicted. During coding, it is regularly checked whether the simulation model produced logical output values.

4.4.3 Black box validation and verification

In black box validation, the overall behaviour of the model is considered. This can be done by comparing the simulation with the real system. For this reason, the simulation model is compared with the reality of the following components: Demand with Weibull distribution, demand with exponential distribution, demand with discrete distribution and lead time distribution.

The historical demand of the items below has been compared with the demand generated by the simulation. The average values of 3 replications for a run length of 1020 weeks have been taken. The same has been done for the standard deviation of the demand. The results can be seen in table 4.8.

Table 4.8 - Comparison real demand with demand generated by the simulation

Item	Demand distribution	Expected demand	Demand simulation	Difference	Expected standard deviation	Standard deviation simulation	Difference
7777234A06M00	Weibull	50.06	51.323407	-1.263407	54	57.98875	3.988748
AB-2749-1	Exponential	39.65	39.795389	-0.145389	37.7	39.48647	1.786471
10DN00M050M00	Discrete	66.35	67.249119	-0.899119	52.16	52.17035	0.010347

When we compare the values of the demand distribution, we can see an average deviation from the historical demand of 1.41% and an average deviation from the historical standard deviation of 4.04%. We conclude that the behaviour of the demand distribution is sufficient for the purpose at hand.

The average mean and standard deviation of 3 replications with a run length of 1040 weeks have been compared to the average historical lead time and standard deviation, the results can be seen in table 4.9.

Table 4.9 - Comparison real lead time with lead time generated by the simulation

Item	Lead time Distribution	Expected lead time	Lead time simulation	Difference	Expected standard deviation	Standard deviation simulation	Difference
7777234A06M00	Normal	12	11.798526	0.2014742	2	1.992699	0.007301

The expected lead time and the lead time generated by the simulation differ with 1.69% and the expected standard deviation and the standard deviation generated by the simulation differ with 0.37%. We conclude that the lead times generated by the simulation are sufficient for the simulation. Because all lead times are normally distributed, the historical lead time and the generated lead time is compared once.

The average historical end inventory of the item GB10000 is compared in table 4.10. The end inventory is taken from every month for a time of two years, with this data the average is calculated. The average historical end inventory is 1214. As you can see in the base model, the average end inventory of the model for the item GB10000 is 1298.

Table 4.10 - Comparison average historical end inventory and average end inventory from simulation.

Item	Average historical end invetory	Average end inventory from simulation	Difference	Difference (%)
GB10000	1214	1298	84	6.92%

The difference between the average historical end inventory and the average end inventory from the simulation can be explained by the fact that the decisions of the purchasing department cannot be included in the model. The purchasing department usually does not adhere to the model's recommended inventory levels. They usually use lower inventory levels than the model indicates. This explains the difference between the end inventory of the simulation and the real inventory.

When looking at appendix I, the service level that leads to the lowest cost of an item GB10000 is 92%. Based on experience, the purchasing department had kept lower inventory levels then the purchasing model advices. From this comparison can be concluded that the inventory levels which the purchasing department thinks are correct correspond to what the simulation indicates as the correct inventory level.

The goal of the simulation is to get insight in the impact of service level and safety stock formula, and to see which result in the lowest total cost. Based on the data validation, white box validation and black box validation we conclude that the simulation model is valid.

4.5 Sensitivity analysis

In sensitivity analysis the consequences of changes in model inputs are assessed, in his context model inputs are interpreted more generally than just experimental factors and include all model data (Robinson, 2014). The main approach in performing a sensitivity analysis is to vary the model inputs, and to run the simulation and record the outputs. If the gradient is steep then the output is sensitive to the input and if the gradient is shallow the output is insensitive to the input (Robinson, 2014).

4.5.1 Sensitivity analysis on lead times

It is not within the scope of this research to look for alternative suppliers, but it is still interesting to know for the model user, and the company to know what the impact of lead time is on the output of the model. Therefore a sensitivity analysis is performed for the items 7777234A06M00 and 7777600D03911. These items are chosen randomly. The impact of lead time on the total cost is plotted in graphs. In figure 4.12 the result can be seen for item 7777234A06M00 and in figure 4.13 that of item 7777600D03911. In both figures the gradient is steep, so it can be concluded that the total costs are sensitive to the input of the lead times. The impact of the lead time on all the output is given in Appendix F. Because the same shipping cost per item is used, the model gives the same shipping costs per item for all lead times. These shipping costs are a big part of the total cost of inventory. It is very hard to know the impact of the lead times on the shipping costs, because no alternatives are known. Still we came up with an approximation, just to give a bit of an estimate of the lead time on shipping costs:

$$Total\ cost\ 2 = Totol\ cost - shipping\ cost + \frac{Shipping\ cost}{(13 - Lead\ time)}$$

So, the total cost line in the graph is the impact of lead time on with the same shipping costs and the total cost 2 line is made with use of the formula which is given above. It is to be noted that lead time variability has not been taken account in performing this sensitivity analysis. Because in this research all lead times are normally distributed, this can result in negative lead times when experimenting with the lower lead times.

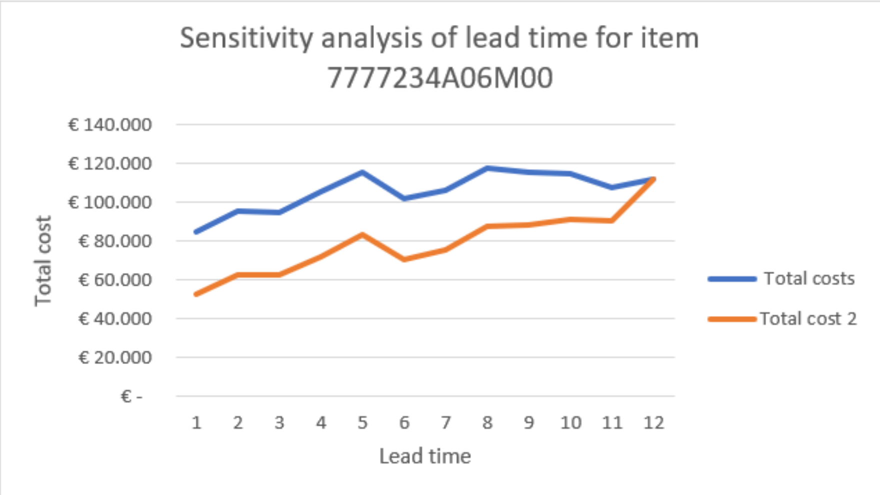


Figure 4.12 - Sensitivity analysis of the input lead time on the output total cost of item 7777234A06M00

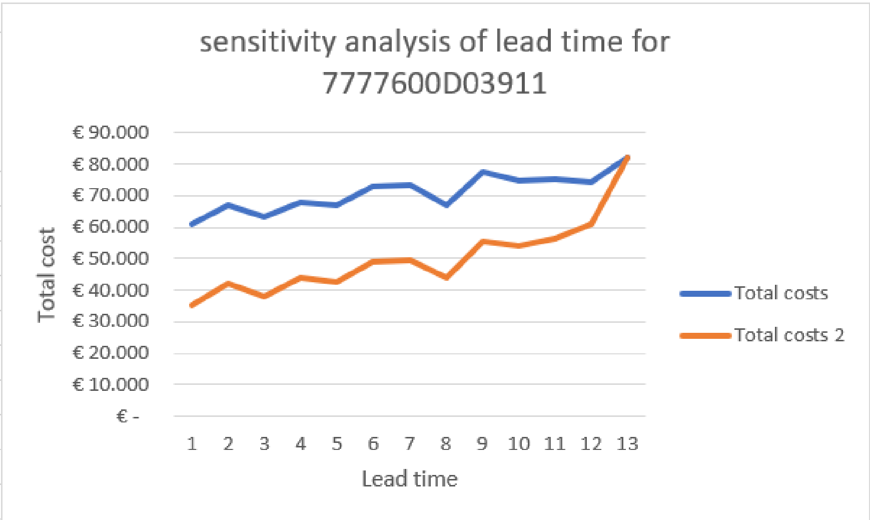


Figure 4.13 - Sensitivity analysis of the input lead time on the output total cost of item 7777600D03911

4.5.2 Sensitivity analysis on service level

A sensitivity analysis has been performed on the service levels has been performed, with the results shown in figure 4.14 and figure 4.15. The gradient is steep in both figures, so it can be concluded that the total costs are sensitive to the input of the lead times

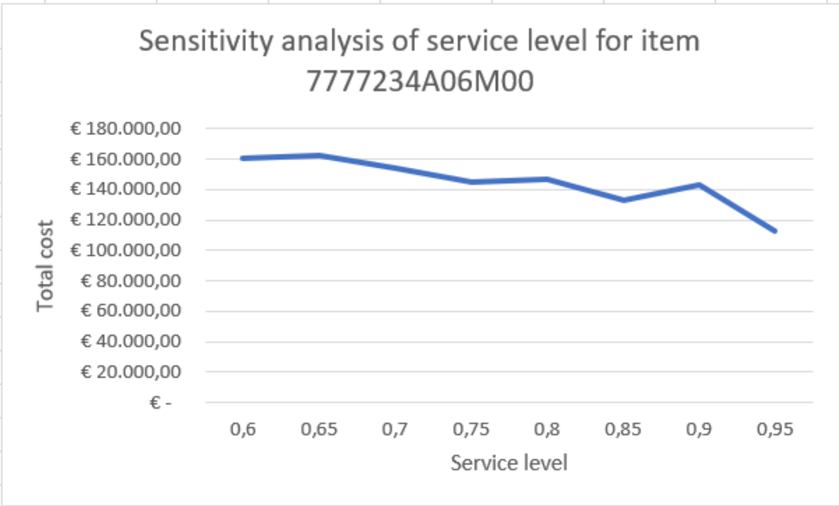


Figure 4.14 - Sensitivity analysis of the input service on the output total cost of item 7777234A06M00

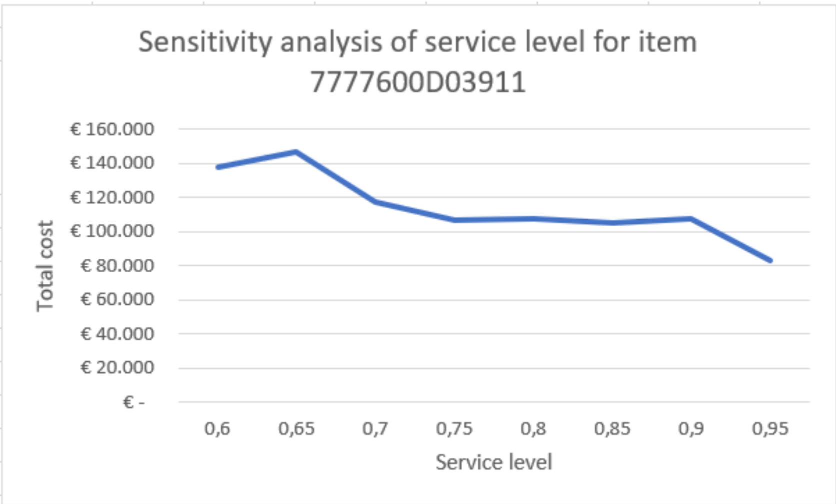


Figure 4.15 - Sensitivity analysis of the input service on the output total cost of item 7777600D03911

5 Interventions

In this chapter there will be experimented with the simulation model. First the base model is given, second an example of the output generated by the simulation model, third the results are given and last, the order up to level values for the interventions are given.

5.1 Base model

In the table 5.1 the output of the base model is given. The base model are the values which correspond to the current situation are given. The values are the averages of 3 replications, with a run length of 1015 weeks.

Table 5.1 - Base model

Item	Total Handling costs	Total Shipping costs	Total Shortage costs	Total Holding costs	Total Ordering cost	Sum Total costs	Order fill rate	Product fill rate	Average end inventory	Average inventory in transit
GB10000	€ 1,476	€ 26,548	€ 5,320	€ 42,783	€ 1,522	€ 77,649	98.7%	98.7%	1298	1476
7777234A06M00	€ 1,960	€ 35,240	€ 16,645	€ 57,707	€ 1,671	€ 113,222	98.1%	98.2%	449	524
10DN00M050M00	€ 3,628	€ 64,110	€ 29,661	€ 33,333	€ 2,047	€ 132,780	98.5%	98.9%	414	662
44D0600C18001	€ 150	€ 2,637	€ 3,607	€ 2,531	€ 1,556	€ 10,483	96.6%	96.2%	69	72
44EZ200000000	€ 760	€ 13,560	€ 10,705	€ 15,317	€ 1,007	€ 41,349	98.8%	98.4%	250	229
50E0400000010	€ 204	€ 3,656	€ -00	€ 20,822	€ 2,101	€ 26,784	100.0%	100.0%	741	445
AB-00285-L-3	€ 2,110	€ 37,422	€ 31,758	€ 26,018	€ 1,768	€ 99,076	97.3%	97.7%	261	388
A0158716000A4	€ 100	€ 1,664	€ 205	€ 8,154	€ 1,960	€ 12,084	99.6%	99.7%	1532	2026
44BZ200000005	€ 765	€ 13,573	€ 7,353	€ 11,978	€ 1,066	€ 34,734	98.3%	98.6%	744	950
162C002600000	€ 409	€ 7,320	€ 7,057	€ 9,084	€ 2,111	€ 25,982	97.1%	97.6%	758	958
22F0Z10000001	€ 1,381	€ 24,562	€ 15,533	€ 15,034	€ 1,625	€ 58,135	98.4%	98.4%	244	368
270F000000000	€ 71	€ 1,254	€ 328	€ 3,632	€ 1,017	€ 6,302	99.4%	99.4%	333	229
PR-99-3	€ 141	€ 251	€ 256	€ 4,094	€ 2,023	€ 6,764	99.5%	99.8%	161	208
AB-133-L-1	€ 258	€ 4,593	€ 3,576	€ 9,602	€ 2,107	€ 20,136	97.8%	98.2%	207	394
44CZ200000000	€ 1,977	€ 34,894	€ 20,436	€ 19,163	€ 1,840	€ 78,311	98.2%	98.6%	749	1129
AB-2749-1	€ 321	€ 5,735	€ 4,748	€ 6,346	€ 1,381	€ 18,532	97.9%	98.1%	311	350
21U4Z10000006	€ 506	€ 9,051	€ 5,475	€ 7,306	€ 740	€ 23,078	98.8%	98.5%	123	152
7777600D03911	€ 1,515	€ 27,201	€ 22,689	€ 34,668	€ 1,608	€ 87,681	97.5%	97.1%	103	153
22E2000K00002	€ 743	€ 13,130	€ 2,791	€ 5,594	€ 1,080	€ 23,338	98.4%	98.5%	48	45
24 U1600327000	€ 2,261	€ 3,967	€ 6,823	€ 3,805	€ 2,104	€ 18,960	96.2%	96.7%	458	716
H0PS01212DPC0	€ 412	€ 727	€ 256	€ 25,139	€ 572	€ 27,107	99.9%	99.9%	6025	2346
H0SG03015DPC0	€ 560	€ 10,016	€ 3,981	€ 6,761	€ 789	€ 22,107	98.6%	98.3%	363	393
Total	€ 21,709	€ 341,112	€ 199,204	€ 368,870	€ 33,698	€ 964,593	98.35%	98.43%	15641	14213

5.2 Output

Table 5.2 and figure 5.1 provide an example of how the output is represented. The table shows all outputs and the graph shows the total costs against a service level. This output is generated with the new safety stock formula. To see the output of all items see appendix J.

Table 5.2 - Output simulation of item 10DN00M050M00

Service level	Total Handling costs	Total Shipping costs	Total Shortage costs	Total Holding costs	Total Ordering cost	Sum Total costs	Order fill rate	Product fill rate	Average end inventory	Average inventory in transit
0.85	€ 3,547	€ 62,929	€ 102,403	€ 26,776	€ 2,023	€ 197,679	95.3%	96.1%	332	653
0.86	€ 3,614	€ 64,110	€ 69,724	€ 26,326	€ 2,027	€ 165,801	96.4%	97.4%	327	663
0.87	€ 3,580	€ 63,538	€ 60,734	€ 27,682	€ 2,034	€ 157,568	97.2%	97.7%	344	656
0.88	€ 3,630	€ 64,199	€ 72,023	€ 27,477	€ 2,053	€ 169,383	96.9%	97.3%	341	667
0.89	€ 3,560	€ 63,251	€ 53,678	€ 29,124	€ 2,030	€ 151,643	97.2%	97.9%	361	657
0.9	€ 3,599	€ 63,555	€ 68,561	€ 29,591	€ 2,053	€ 167,358	96.9%	97.4%	367	661
0.91	€ 3,621	€ 64,182	€ 35,763	€ 30,490	€ 2,056	€ 136,112	98.2%	98.6%	378	661
0.92	€ 3,635	€ 64,414	€ 38,939	€ 30,877	€ 2,042	€ 139,906	98.0%	98.5%	383	666
0.93	€ 3,573	€ 63,448	€ 21,181	€ 33,023	€ 2,044	€ 123,270	98.6%	99.2%	410	655
0.94	€ 3,656	€ 64,593	€ 39,331	€ 33,219	€ 2,046	€ 142,845	98.2%	98.5%	412	665
0.95	€ 3,570	€ 63,430	€ 20,227	€ 35,511	€ 2,047	€ 124,786	99.1%	99.2%	441	655
0.96	€ 3,591	€ 63,681	€ 23,598	€ 36,723	€ 2,060	€ 129,653	99.0%	99.1%	456	660
0.97	€ 3,695	€ 65,273	€ 21,521	€ 36,925	€ 2,034	€ 129,448	99.1%	99.2%	458	679
0.98	€ 3,692	€ 65,505	€ 11,760	€ 39,429	€ 2,052	€ 122,437	99.4%	99.6%	489	680
0.99	€ 3,653	€ 64,826	€ 7,461	€ 44,042	€ 2,054	€ 122,036	99.8%	99.7%	547	672

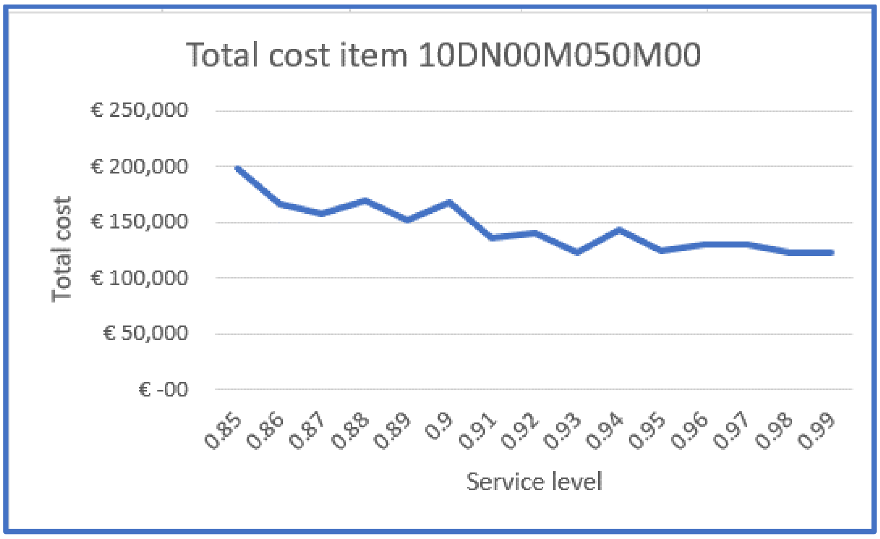


Figure 5.1 - Total cost plotted against service level

Because item 10DN00M050M00 is a very heavy item the shortage cost are a lot higher. This is because if a shortage occurs RGBV places an emergency order per plane. The costs of these ergency orders are paid per kilogram. Item 10DN00M050M00 is one of the heavier items of RGBV, which results in higher shortage costs.

5.3 Results

5.3.1 Cost related results

We define using the safety stock formula 2.2 as intervention 1. The service level used with intervention 1 is the same as the service level used in the base model. Intervention 2 makes use of the new safety stock formula, and using a service level between 85% and 99% which leads to the lowest total cost.

The most important results are shown in table 5.3. The first column gives the item, and the second column the costs associated with the base model. These are the costs that the company incurs in the current situation, for a period of 1020 weeks. The third column indicaties how much costs the company would incur with intervention 1. Column four gives the difference between the costs made in the current situation and the costs made with intervention 1. The sum of the difference is shown in bold at the bottom of the column.

Column 5 shows the amount of costs that the company would incur if they would use intervention 2. Column 6 indicates the difference between costs of intervention 2 and the costs incurrend in the current situation. The sum of this difference is shown in bold in the bottom of the column. To see the handling, shipping, shortage, holding and ordering costs of 1the interventions see appendix I

Table 5.3 - Results of the experimentation on total costs

Item	Total cost base model	Total cost model 95% service level	Base model - total costs intervention 1	Total cost model best service level	Base model - total cost intervention 2
GB10000	€ 77,649	€ 75,062	-€ 2,587	€ 69,838	-€ 7,810
7777234A06M00	€ 113,222	€ 123,594	€ 10,372	€ 109,387	-€ 3,835
10DN00M050M00	€ 132,780	€ 124,786	-€ 7,993	€ 122,036	-€ 10,743
44D0600C18001	€ 10,483	€ 9,139	-€ 1,344	€ 8,117	-€ 2,366
44EZ200000000	€ 41,349	€ 42,660	€ 1,311	€ 35,577	-€ 5,772
50E0400000010	€ 26,784	€ 29,234	€ 2,450	€ 25,216	-€ 1,567
AB-00285-L-3	€ 99,076	€ 88,259	-€ 10,817	€ 84,025	-€ 15,050
A0158716000A4	€ 12,084	€ 12,361	€ 277	€ 10,679	-€ 1,405
44BZ200000005	€ 34,734	€ 31,187	-€ 3,547	€ 31,187	-€ 3,547
162C002600000	€ 25,982	€ 24,502	-€ 1,479	€ 22,779	-€ 3,203
22F0Z10000001	€ 58,135	€ 55,257	-€ 2,878	€ 49,134	-€ 9,001
270F000000000	€ 6,302	€ 6,378	€ 76	€ 5,517	-€ 785
PR-99-3	€ 6,764	€ 7,227	€ 463	€ 6,424	-€ 341
AB-133-L-1	€ 20,136	€ 19,659	-€ 477	€ 18,830	-€ 1,305
44CZ200000000	€ 78,311	€ 69,206	-€ 9,105	€ 68,473	-€ 9,838
AB-2749-1	€ 18,532	€ 17,891	-€ 641	€ 16,867	-€ 1,665
21U4Z10000006	€ 23,078	€ 19,508	-€ 3,570	€ 18,939	-€ 4,139
7777600D03911	€ 87,681	€ 83,422	-€ 4,259	€ 79,225	-€ 8,456
22E2000K00002	€ 23,338	€ 23,242	-€ 96	€ 22,544	-€ 794
24 U1600327000	€ 18,960	€ 16,661	-€ 2,299	€ 16,371	-€ 2,589
H0PS01212DPC0	€ 27,107	€ 27,094	-€ 13	€ 22,999	-€ 4,108
H0SG03015DPC0	€ 22,107	€ 21,129	-€ 978	€ 19,741	-€ 2,366
			-€ 37,133		**-€ 100,686**

So, using the new safety stock formula would result in a reduction of costs of €37,133 for 22 items over a period of 1020 weeks. Because the items chosen are a mix of different types of class A items, we can estimate the total cost saving if this formula were used for all a class items. In total there are 195 class A items. So, the total cost saving for all class A items is given by the following calculation:

$$Total\ reduction\ of\ costs\ in\ 1020\ weeks = \frac{€37{,}133}{22} * 195 = €329{,}133$$

This results in a saving of the following amount of costs per year:

$$Total\ reduction\ of\ costs\ in\ per\ year = \frac{€329{,}133}{1020} * 52 = €16{,}779$$

As you can see in the calculation above the new safety stock formula would result in a cost reduction of €16,779 per year, and this is only for the class A items. If the the new safety stock formula would be used for all products it is very likely that this would result in lower costs as well. With intervention 2, a cost reduction of €100,686 could be made. This would be a cost reduction for all class A products of:

$$Total\ reduction\ of\ costs\ in\ 1020\ weeks = \frac{€100{,}686}{22} * 195 = €892{,}444$$

This results in a saving of the following amount of costs per year:

$$Total\ reduction\ of\ costs\ in\ per\ year = \frac{€892{,}444}{1020} * 52 = €45{,}497$$

It is likely that the total cost saving would be more, but it is not possible to estimate this because experiments have only been carried out with the A class items.

5.3.2 Non cost related results

In table 5.4 the non-cost related output for intervention 1 is given. Column 1 gives the selected items, column 2 the average order fill rate for an item over the run length, column 3 the average product fill rate. The average ending inventory is given in column 4 and the average inventory is given in column 5.

Table 5.4 - Non-cost-related output intervention 1

Item	Order fill rate	Product fill rate	Average end inventory	Average inventory in transit
GB10000	99,1%	99,2%	1253	1524
7777234A06M00	98,5%	97,7%	483	529
10DN00M050M00	99,1%	99,2%	441	655
44D0600C18001	97,7%	97,7%	70	72
44EZ200000000	98,0%	98,3%	239	242
50E0400000010	100,0%	100,0%	834	424
AB-00285-L-3	98,4%	98,7%	283	397
A0158716000A4	99,7%	99,8%	1584	2029
44BZ200000005	99,5%	99,6%	847	942
162C002600000	98,0%	98,3%	812	948
22F0Z10000001	98,9%	98,9%	275	372
270F000000000	99,6%	99,6%	353	225
PR-99-3	99,9%	99,9%	186	201
AB-133-L-1	98,8%	99,1%	231	405
44CZ200000000	99,4%	99,5%	936	1092
AB-2749-1	99,0%	98,7%	349	353
21U4Z10000006	99,5%	99,6%	138	148
7777600D03911	98,1%	98,2%	115	152
22E2000K00002	98,3%	98,6%	47	46
24 U1600327000	97,7%	97,9%	485	712
H0PS01212DPC0	100,0%	100,0%	6079	2383
H0SG03015DPC0	98,7%	98,8%	367	397
Total	98,90%	98,97%	16407	14248

The differences between the non-cost related output of the base model and intervention 1 will be discussed below. The first output that we will look at is the order fill rate. The order fill rate has increased by:

$$\frac{0.9897 - 0.9843}{0.9843} * 100\% = 0.55\ \% = increase\ order\ fill\ rate$$

Then we will look at the product fill rate. The order fill rate has increased by:

$$\frac{0.9890 - 0.9835}{0.9835} * 100\% = 0.60\% = increase\ product\ fill\ rate$$

The average end inventory has increased with:

$$\frac{16407 - 15641}{15641} * 100\% = 4{,}90\% = \ increase\ average\ end\ inventory$$

The average orders in transit have increased with:

$$\frac{14248 - 14213}{14213} * 100\% = 0.25\% = \ increase\ average\ inventory\ in\ transit$$

The average inventory position has increased with:

$$\frac{(16407 + 14213) - (15641 + 14213)}{(15641 + 14213)} * 100\% = 2.57\% = increase\ average\ inventory\ position$$

The increase in the order en product fill rate can be explained by the fact that the new safety stock formula takes lead time varibility into account. Because the formula takes this into account, the chance that a stock out occurs decreases and therefore the product availability increases. The increase in inventory kept can be explained by the fact that extra safety stock is kept.

Table 5.5 - Non-cost-related output intervention 2

Item	Service level	Order fill rate	Product fill rate	Average end inventory	Average inventory in transit
GB10000	0.92	98.3%	98.3%	1028	1455
7777234A06M00	0.91	97.9%	98.2%	409	539
10DN00M050M00	0.99	99.8%	99.7%	547	672
44D0600C18001	0.99	99.7%	99.7%	100	69
44EZ200000000	0.96	99.3%	99.3%	256	236
50E0400000010	0.85	100.0%	100.0%	685	442
AB-00285-L-3	0.99	99.6%	99.7%	362	408
A0158716000A4	0.85	98.4%	98.9%	1144	2056
44BZ200000005	0.95	99.5%	99.6%	847	942
162C002600000	0.96	98.4%	99.0%	827	968
22F0Z10000001	0.99	100.0%	100.0%	346	374
270F000000000	0.85	99.0%	99.3%	264	219
PR-99-3	0.88	99.6%	99.8%	150	201
AB-133-L-1	0.92	98.9%	99.2%	223	390
44CZ200000000	0.99	99.9%	100.0%	1205	1087
AB-2749-1	0.98	99.5%	99.6%	409	351
21U4Z10000006	0.93	99.4%	99.6%	137	140
7777600D03911	0.97	99.0%	99.1%	120	159
22E2000K00002	0.98	99.3%	99.4%	57	44
24 U1600327000	0.99	98.7%	98.6%	631	711
H0PS01212DPC0	0.86	99.9%	100.0%	5077	2479
H0SG03015DPC0	0.99	99.9%	100.0%	459	390
Total	0.94	99.27%	99.41%	15283	14332

As you can see in table 5.5, for some items it is better to have a lower service level and for some items a high service level is better. The reason of this is the difference in holding and shortage costs of the items. A more extensive explanation of this is given in chapter 5.3.3.

The differences between the non-cost related output of the base model and intervention 2 will be calculated below. The first output that we will look at is the order fill rate.

The order fill rate has increased by:

$$\frac{0.9927 - 0.9835}{0.9835} * 100\% = 0.94\% = increase\ order\ fill\ rate$$

Then we will look at the product fill rate. The order fill rate has increased by:

$$\frac{0.9941 - 0.9843}{0.9843} * 100\% = 1{,}00\ \% = increase\ product\ fill\ rate$$

The average end inventory has decreased with:

$$\frac{15283 - 15641}{15641} * 100\% = 2{,}3\% = \ decrease\ average\ end\ inventory$$

The average orders in transit have decreased with:

$$\frac{14332 - 14213}{14213} * 100\% = 0.83\% = \ increase\ average\ inventory\ in\ transit$$

The average inventory position has decreased with:

$$\frac{(15283 + 14332) - (15641 + 14213)}{(15641 + 14213)} * 100\% = 0.8\%$$
$$= \ decrease\ average\ inventory\ position$$

The increase in product availability can be explained by the fact that the extra safety stock is kept, because the new safety stock formula takes lead time variability into account. The decrease of average inventory position is because of the different service levels. Because the service level selected, on average less inventory is kept.

5.3.3 Order up to level point

The order up to level points are calculated with formula 2.6. The order quantity required can then be calculated by taking the order up to level and subtracting the inventory position of an item. This is the amount that they then need to order every two weeks.

Table 5.6 - Order up to level points intervention 1

Item	Average demand	Review period	Lead time	Lead time variability	Demand variability	Safety stock	Order up to level point S
GB10000	144,2	2	11	1	162,6	919	2793
7777234A06M00	50,06	2	12	2	54	319	1020
10DN00M050M00	66,35	2	11	1	52,16	305	1168
44D0600C18001	7,596	2	10	1	11,17	60	151
44EZ200000000	23,75	2	11	1	29,23	165	473
50E0400000010	63,71	2	13	2	46,92	299	1254
AB-00285-L-3	34,52	2	12	2	34,03	203	686
A0158716000A4	206,4	2	11	1	139,3	833	3516
44BZ200000005	92,94	2	11	2	81,67	472	1680
162C002600000	134,4	2	8	1	122	610	1954
22F0Z10000001	32,17	2	13	2	24,11	154	636
270F000000000	25,56	2	10	2	30,06	163	470
PR-99-3	19,67	2	12	2	19,77	118	394
AB-133-L-1	33,56	2	13	2	23,92	153	657
44CZ200000000	123,2	2	10	2	94,17	531	2010
AB-2749-1	39,65	2	10	2	37,7	208	684
21U4Z10000006	12,35	2	13	2	11,95	75	260
7777600D03911	12,96	2	13	2	11,66	73	268
22E2000K00002	4,827	2	10	1	6,138	33	91
24 U1600327000	72,94	2	11	1	60,15	350	1298
H0PS01212DPC0	442,5	2	10	1	476,2	2582	7892
H0SG03015DPC0	39,73	2	11	1	35,29	204	720

In the last column the order up to level point S is given. This is the amount to which the inventory level should be raise every review interval. The other columns are given to give the reader more insight into where the order up to level point comes from. For instance, item GB10000 has a high order up to level point. This can be explained by the other columns, item GB10000 also has a high safety stock level and a high average demand.

Table 5.7 -Order up to level points intervention 2

Item	Service level	Average demand	Review period	Lead time	Lead time variability	Demand variability	Safety stock	Order up to level point S
GB10000	0.92	144.2	2	11	1	162.6	785	2659
7777234A06M00	0.91	50.06	2	12	2	54	260	961
10DN00M050M00	0.99	66.35	2	11	1	52.16	432	1294
44D0600C18001	0.99	7.596	2	10	1	11.17	85	176
44EZ200000000	0.96	23.75	2	11	1	29.23	175	484
50E0400000010	0.85	63.71	2	13	2	46.92	188	1144
AB-00285-L-3	0.99	34.52	2	12	2	34.03	287	770
A0158716000A4	0.85	206.4	2	11	1	139.3	525	3208
44BZ200000005	0.95	92.94	2	11	2	81.67	472	1680
162C002600000	0.96	134.4	2	8	1	122	649	1993
22F0Z10000001	0.99	32.17	2	13	2	24.11	217	700
270F000000000	0.85	25.56	2	10	2	30.06	103	409
PR-99-3	0.88	19.67	2	12	2	19.77	84	360
AB-133-L-1	0.92	33.56	2	13	2	23.92	131	634
44CZ200000000	0.99	123.2	2	10	2	94.17	752	2230
AB-2749-1	0.98	39.65	2	10	2	37.7	259	735
21U4Z10000006	0.93	12.35	2	13	2	11.95	67	252
7777600D03911	0.97	12.96	2	13	2	11.66	84	278
22E2000K00002	0.98	4.827	2	10	1	6.138	42	100
24 U1600327000	0.99	72.94	2	11	1	60.15	495	1443
H0PS01212DPC0	0.86	442.5	2	10	1	476.2	1696	7006
H0SG03015DPC0	0.99	39.73	2	11	1	35.29	288	805

In the last column the order up to level point S is given. This is the amount to which the inventory level should be raise every review interval. In the second column the service level which results in the lowest total cost of inventory is given. The other columns are given to give the reader more insight into where the order up to level point comes from.

5.3.3 Influence service level on partial costs

The experiments showed that the handling, shipping and ordering costs remain fairly constant with different service levels. However, the service level has a major impact on holding and shortage costs. To illustrate this, the costs of inventory for the items 10DN00M050M00 and AB-133-L-1 are plotted in figure 5.4 and 5.5. It can be concluded that optimal service level mostly depends on holding and shortage costs. This is in line with the inventory classification of (Teunter et al., 2010), where the shortage and holding costs are vital factors for the determination of the service level.

Also, it was noticed that heavy items have lower costs with a high service level. This is because when there is a shortage, the products are urgently transported by plane, and the costs made by these emergency planes are per kilogram. As a result, the stock out costs for heavier products are a lot higher than the costs for lighter products, while the holding costs are not necessarily higher for heavier products because they mainly depend on the price of the item. It appears from the experiments that, for heavy products, it is therefore better to use a high service level.

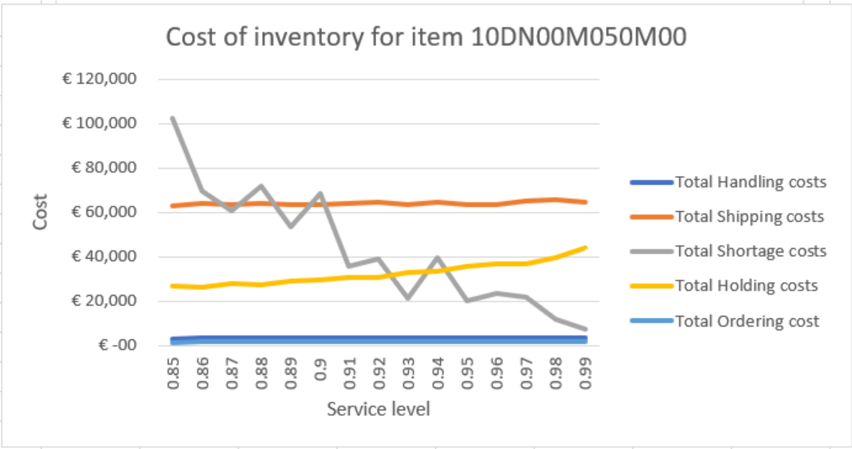


Figure 5.4 - Cost of inventory for item 10DN00M050M00

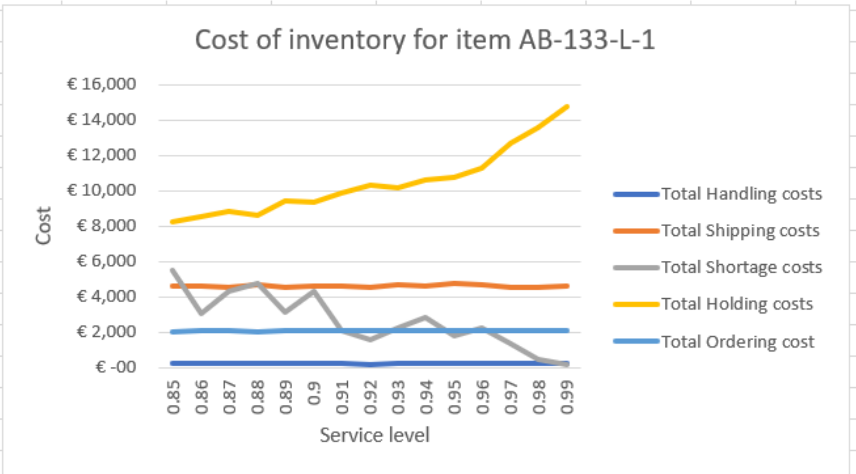


Figure 5.5 - Cost of inventory for item AB-133-L-1

6 Conclusions and recommendations

In this chapter, the conclusions and recommendations of the research will be presented. Besides that, a critical discussion will be made about this thesis. The conclusion will give an answer to the main question of the research:

How can RGBV reduce the total cost of inventory by improving the inventory management of safety stock of the A class product range?

Based on the results an answer to the research question can be given. The research proves that the inventory costs can be reduced by making use of an new safety stock formula which takes lead time into account. The research also shows that the classification of items based on costs will lower the total costs of inventory. If the new safety stock formula and new classification method would be used, the company would get the cost reduction of intervention 2, which is €45,497 per year. This is only the cost reduction of the class A items, if these methods would be used for all items the cost reduction would be much higher. The details of the interventions are given in chapter 6.1.

6.1 Conclusion

The following conclusions can be drawn based on the simulation model:

Intervention 1

- Over the run length (1020 weeks) of the model, the sum of the costs of 22 items will decrease by €37,133. The handling costs increase with €40, the shipping costs increase with €1065, the shortage costs decrease with €65,013, the holding costs increase with €26,719 and the ordering costs increase with €57.
- Intervention 1 will lead to a cost reduction of approximately €16,779 per year, if it were implemented for all A class items. If the intervention for would be used for all items, the cost reduction would be much higher.
- Product availability increases. The order fill rate increases by 0.55% and the product fill rate by 0.60%.
- On average more stock is kept. The average inventory stored in the warehouse will increase by 4.90% and the average inventory in transit to RGBV will increase by 0.25%. The inventory position of RGBV will increase by 2.57%.

Intervention 2

- Over the run length of the model, the costs for 22 products will decrease by €100,686. The handling costs increase with €127, the shipping costs increase with €2309, the shortage costs decrease with €136,813, the holding costs increase with €33,791 and the ordering costs decrease with €100.
- Intervention 2 will lead to a cost reduction of approximately €45,497 per year, if it were implemented for all A class items. If the intervention for would be used for all items, the cost reduction would be a lot higher.
- Product availability increases. The order fill rate increases by 0.94% and the product fill rate by 1.00%.
- On average less tock is kept. The average inventory stored in the warehouse will decrease with 2.3% and the average inventory in transit tor RGBV will increase by 0.83%. The inventory position of RGBV will decrease by 0.83%.

- If the service level is changed, the total costs change, in particular due to the changes in shortage and holding costs. The handling, shipping and ordering costs remain fairly constant.

So both interventions will lead to a cost reduction, although the cost reduction of intervention 2 is much higher. It is to be noticed that these cost reductions are only the cost reductions for using these methods for the class A items. If these interventions were used on all items, the cost reduction would be much higher. With both interventions the product availability increases, although the product availability of intervention 2 increases more. This means that with both interventions more demand is filled immediately from stock on hand. With intervention 1 on average more stock is kept, this is because on average more safety stock is kept. With intervention 2 less stock is kept, this is due to the fact that the service levels of the items vary more, resulting in lower total average safety stock level. It is noticed that if the service level is changed, the total costs change, mostly due the changes of the shortage and holding costs.

6.2 Recommendations

To reduce the total costs of inventory we give the following recommendations:

- Changing the current safety stock calculation in safety stock formula 2.2. The experiments prove that the new safety stock formula outperforms the current safety stock formula.
- Changing the current classification method in the classification method of (Teunter et al., 2010). (Teunter et al., 2010) proves that it outperforms the other classification methods. Also, RGBV now acquire methods to calculate inventory management costs, so it is feasible to use this method. If this classification method is used, they will approximately save the costs of intervention 2.
- Make use of performance indicators. For instance, the order fill rate and product fill rate are not used. These are very important indicators in how well a company is performing. Also, they can provide insight in the impact of inventory management related decisions.
- Conduct a research regarding the forecasting methods of RGBV. For instance, RGBV does not yet know if demand of their items depends on the season.

6.3 Discussion

In this section, a discussion will be made about the potential shortcomings of this research.

6.3.1 Impact of purchasing department

The decisions that the purchasing department takes are not included in this research. This is not possible because they make decisions based on experience and gut feeling, and that cannot be modelled. However, it is a simplification that has major consequences for the inventory levels of the items. This is because the purchasing department does not follow the majority of the end advices of the purchasing model regarding the safety stock and advice what to order exactly. This means that the values of the base model will not exactly match reality.

6.3.1 Validation

It is very important to validate a simulation model with real world data. However, due to the lack of data regarding the output of the model, this was very difficult. The model could not be validated based on total costs, order fill rate, or product fill rate. This is because RGBV does not keep track of this data. They do not keep track of when they were out of stock. They also do not keep track of any costs related to inventory management because RGBV did not yet have any methods for calculating inventory management costs.

6.4 Contribution to practice

The main goal of this research was to reduce the costs of inventory by improving inventory management. In this research, the current situation has been analysed and the decisions made by the model and formulas used by the model have clearly mapped in this thesis. In addition, RGBV did not yet have a method for calculating costs related to inventory management. There were no methods available to calculate the handling, shipping, shortage, holding and ordering costs. During this research, methods have been developed to calculate these costs. In addition to these contributions, both interventions also save significant costs and both interventions improve the product availability of the products. With these interventions a new safety stock level is calculated as well as a new order up to level point. The company can use this order up to level point when deciding how much should be ordered.

Bibliography

Heerkens, H., & van Winden, A. (2012). *Geen Probleem*.

Armstrong, D. J. (1985). Sharpening inventory managment.

Axsäter, S. (2015). *Inventory Control*.

Bernard, T. (2015). *Introduction to managment Science*.

Bui, E., & Henderson, B. (2019). *Determining Uncertainty in Sediment & Nutrient Transport Models for Ecological Risk Assessment*.

Carson, J. (1986). Convincing Users of Model's Validity is Challenging Aspect of Modeler's Job.

Chen, Y., Li, K. W., Marc Kilgour, D., & Hipel, K. W. (2008). A case-based distance model for multiple criteria ABC analysis. *Computers & Operations Research*, *35*, 776–796. https://doi.org/10.1016/j.cor.2006.03.024

Chopra, S., & Meindl, P. (2016). *Supply Chain managment*.

Davis, P. (1992). Generalizing Concepts of Verification, Validation and Accreditation for Military Simulation.

Graham, G. (1987). *Distibution inventory managment for the 1990s*.

Heath, B. L., & Hill, R. R. (2010). Some insights in the Emergence of Agent-Based Modelling.

Heerkens, H., & van Winden, A. (2012). *Geen Probleem*.

King, P. (2011). *Crack the code, understanding safety stock and mastering its equations*. Retrieved from http://web.mit.edu/2.810/www/files/readings/King_SafetyStock.pdf

Knod, E., & Schonberger, R. (2001). *Operations Managment: Meeting Customer Demands*.

Law, A., & McComas, M. (1990). *Secrets of successful simulation studies*.

Morecroft, J. (2007). *strategic modelling and business dynamics a feedback systems approach*.

Oral, M., Salvador, M., Reisman, A., & Dean, B. (1972). On the evaluation of shortage costs for inventory control of finished goods.

Pareto, V. (1935). *The mind and society*.

Pidd, M. (2009). *Moddeling in Managment Science*.

Robinson, S. (2008). *Conceptual Modelling for Simulation Part 2*.

Robinson, S. (2014). Simulation.

Silver, E., Pyke, D., & Thomas, D. (2017). *Inventory and Production Managment in Supply Chains* (Fourth Edi).

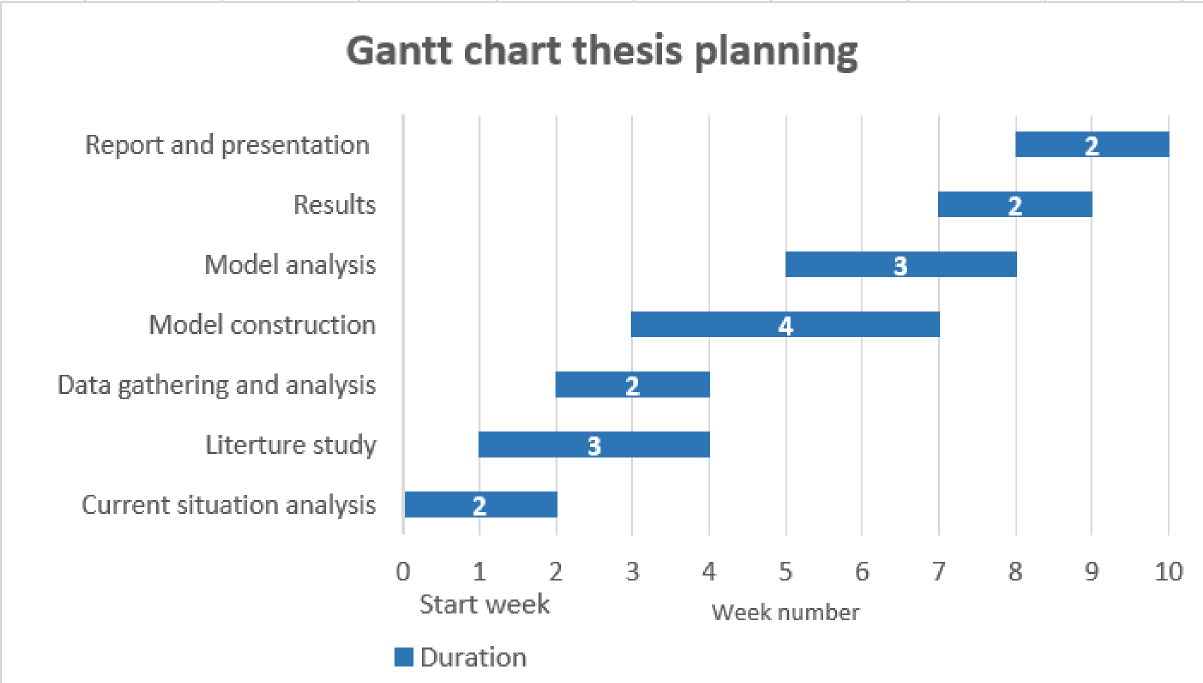
Sterman, J. (2000). Business Dynamics: Systems Thinking and Modeling for a Complex World.

Teunter, R., Babai, Z., & Syntetos, A. (2010). ABC Classification: Service Levels and Inventory Costs.

Winston, W. (2004). *Operations Research*.

Zhang, R. Q., Hopp, W. J., & Supatgiat, C. (2001). *Spreadsheet Implementable Inventory Control for a Distribution Center*. *Journal of Heuristics* (Vol. 7). Retrieved from http://webuser.bus.umich.edu/whopp/reprints/Spreadsheet Implementable Inventory Control for a Distribution Center.pdf

Appendix A – Gantt chart thesis planning



Appendix B – Distribution tables of actual service levels

Appendix B1- Distribution table service level all items

Service level	Frequency	Service level	Frequency
0.5	8	0.82	33
0.64	1	0.83	22
0.65	1	0.84	18
0.66	1	0.85	21
0.67	3	0.86	27
0.68	8	0.87	19
0.69	30	0.88	27
0.7	21	0.89	22
0.71	15	0.9	35
0.72	15	0.91	38
0.73	8	0.92	33
0.74	6	0.93	38
0.75	15	0.94	47
0.76	8	0.95	272
0.77	21	0.96	9
0.78	10	0.97	10
0.79	10	0.98	14
0.8	20	0.99	12
0.81	22	1	8

Appendix B2 – Distribution table service levels of class A items

Service level	Frequency	Service level	Frequency
0.5	2	0.86	5
0.67	1	0.87	3
0.68	1	0.88	6
0.69	12	0.89	3
0.7	2	0.9	2
0.71	2	0.91	4
0.72	3	0.92	10
0.76	2	0.93	9
0.78	1	0.94	8
0.79	2	0.95	63
0.8	2	0.96	6
0.81	2	0.97	7
0.82	6	0.98	7
0.83	2	0.99	9
0.84	4	1	3
0.85	3		

Appendix C: Items selected by the company

Part Number	Part Description	Type of item
GB10000	232-05 L Alu F05/F07 Ø25 K6.35	Built Gearbox
7777234A06M00	232-14 L Alu F10/F12 Ø60 KEY 18C	Built Gearbox
10DN00M050M00	Body 1250N F12 / F16 GG25	Component
44D0600C18001	Qdr. 1250 L Ø60.0F7 K18 Prep. for insert	Component
44EZ200000000	Qdr. 1950 L vert.pilot GGG40	Component
50E0400000010	Worm 1950 L M=4.0 Bearing Ø30 ARCOR	Component
AB-00285-L-3	BODY 2000 LH BLANK GGG40 ASSEMBLY	Component
A0158716000A4	W-nut M16 AISI303/304	Component
44BZ200000005	Qdr. 550 LH PILOTBORE Ø32 GGG40	Component
162C002600000	%Shaft 550/880 L=260 std. RVS	Component
22F0Z10000001	Cvrpl. 6800 standard (W) GGG40	Component
270F000000000	Pos.-ind.6800 Alu. W-uitvoering	Component
PR-00099-3	Carrier PR6 BS EN10083 GR. + DIN6325 PIN	Component
AB-00133-L-1	Worm 6800 L M=4 T CONDITION ARCOR	Component
44CZ200000000	Qdr. 880 L-vert. pilot GGG40	Component
AB-02749-1	E-fl. F10 550/880/1250 "GGG40"	Component
21U4Z10000006	Cvrpl. ILGD1500 mach GG25 "Square"	Component
7777600D03911	ILG/D 600 R F07F10F12 NO RELIEF/RAL9005	Built Gearbox
22E2000K00002	Cvrpl. 1950ILG/S F16/F25 China GGG40	Component
24U1600327000	Insert 150-serie []27.0H8 = TTV	Spare
H0PS01212DPC0	Handwiel PS125-12	Spare
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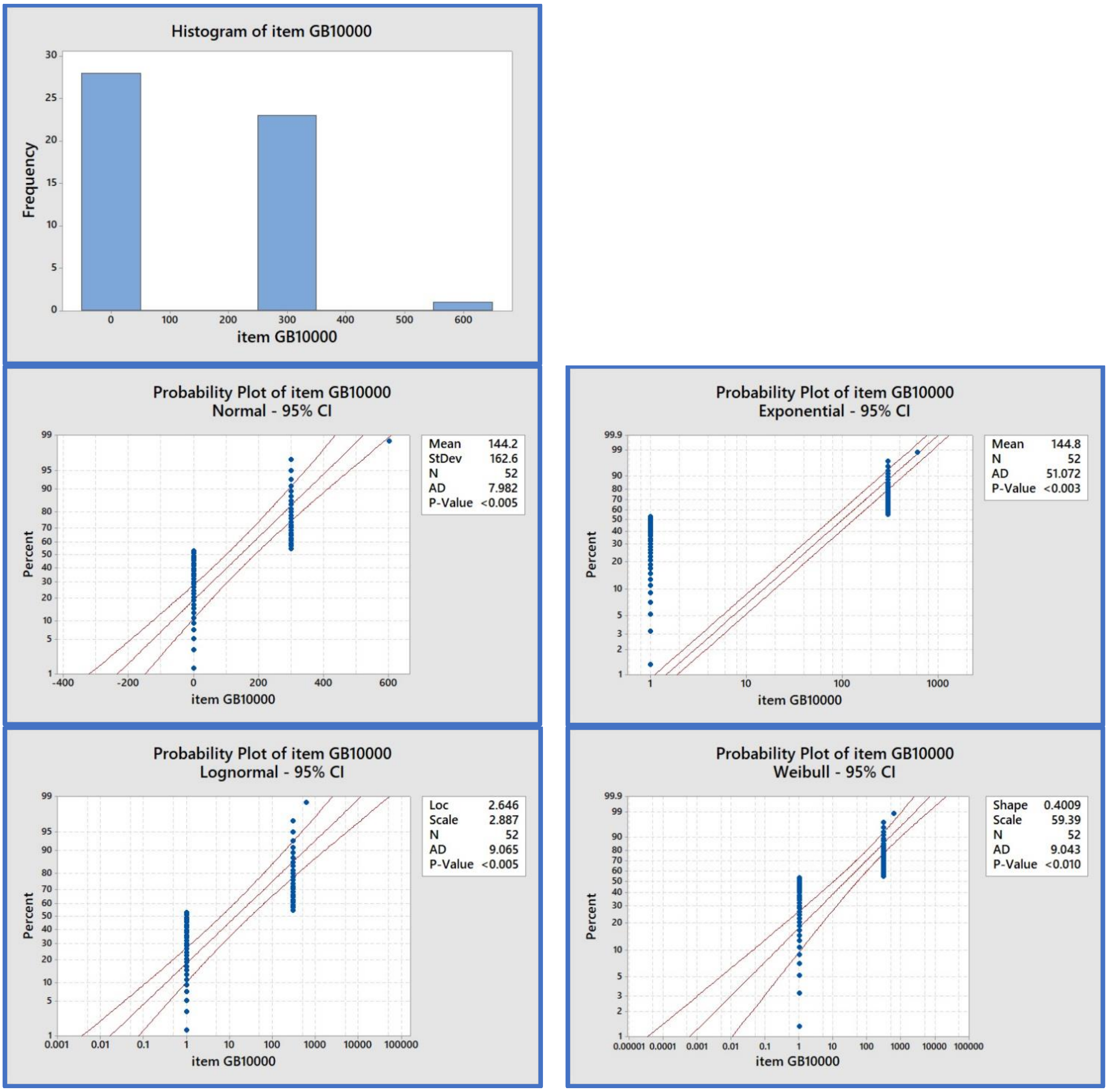
Appendix D – Demand distribution analysis

<u>Item GB100000</u>



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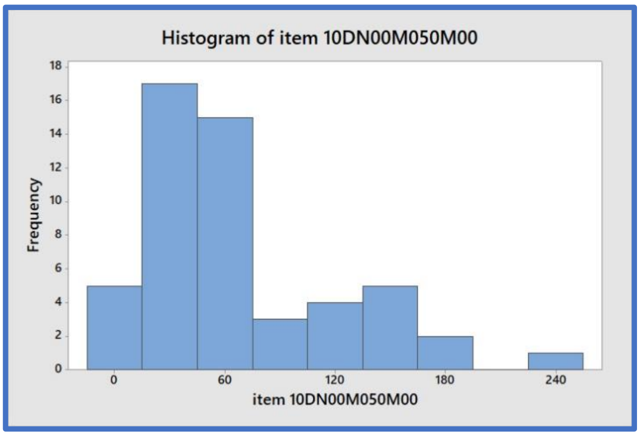

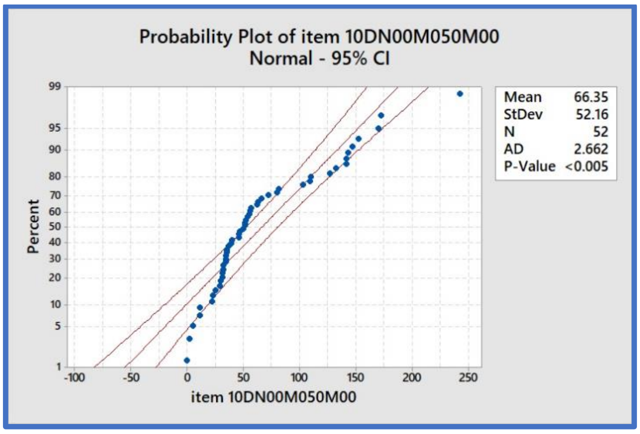

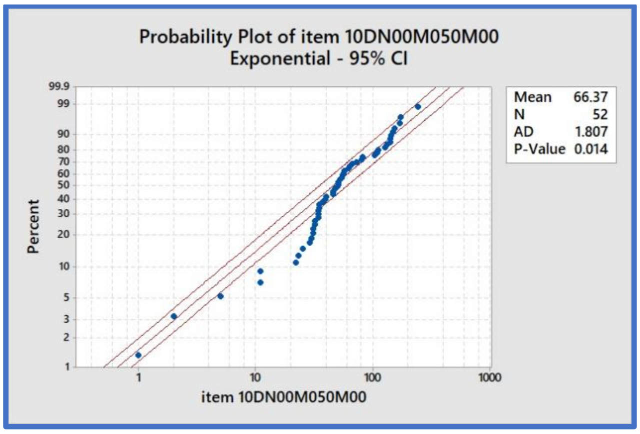

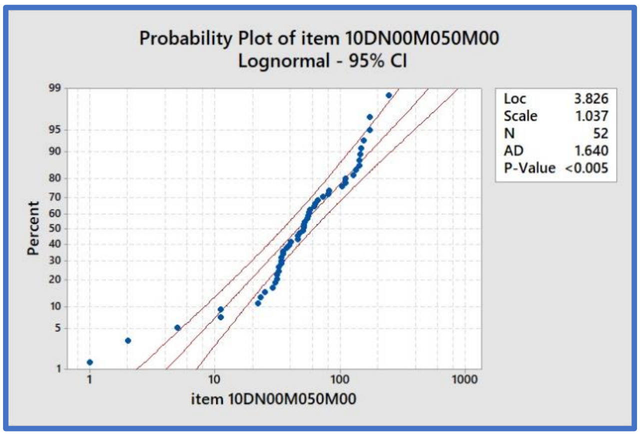

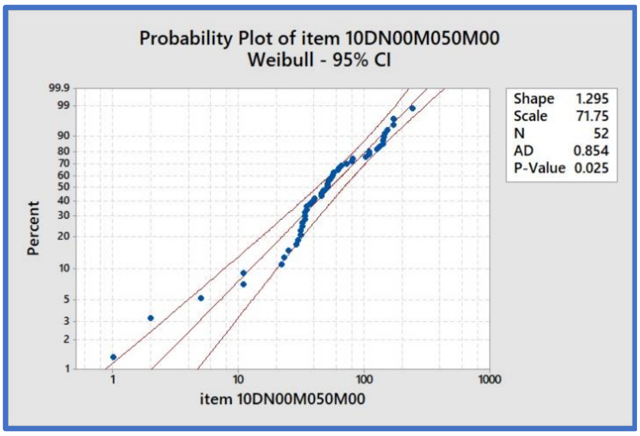

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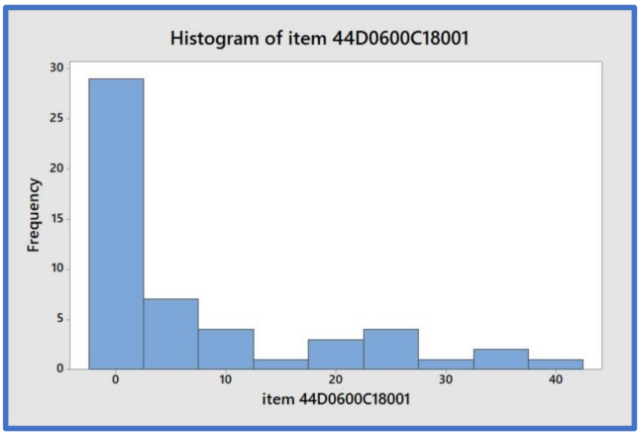

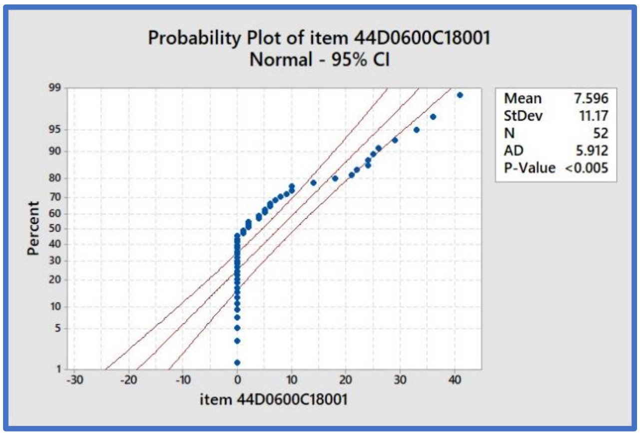

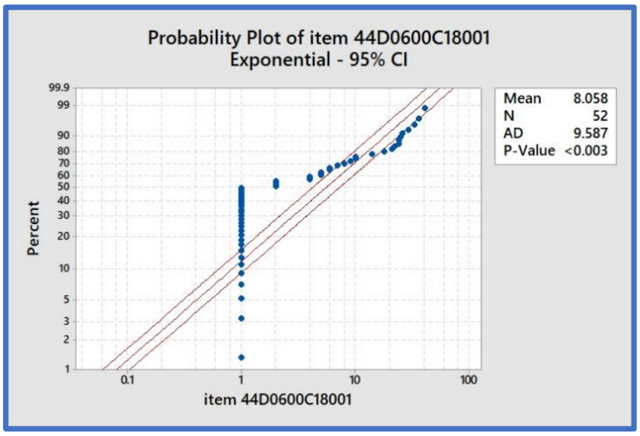

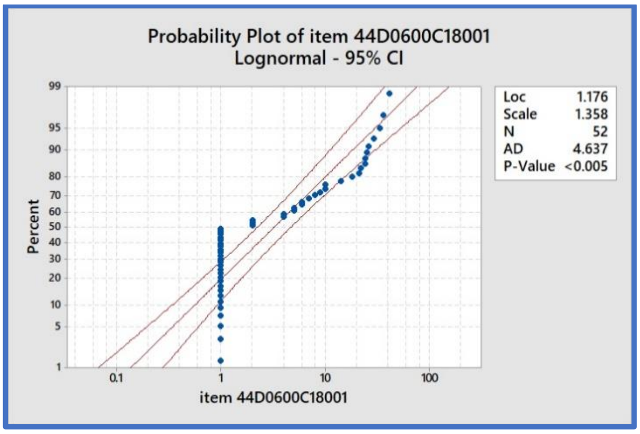

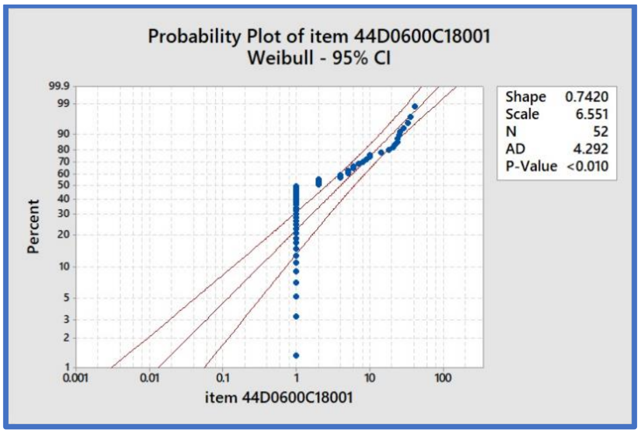

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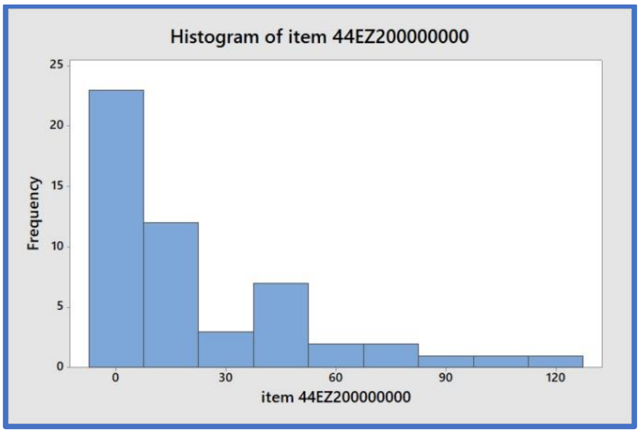

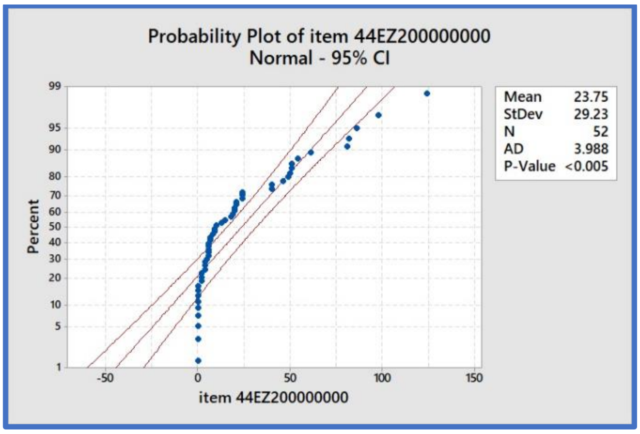

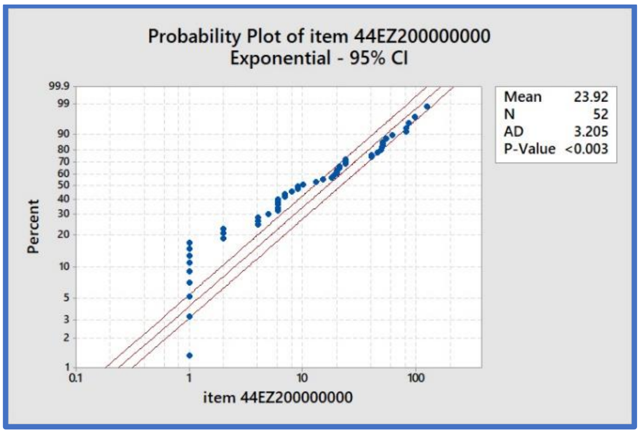

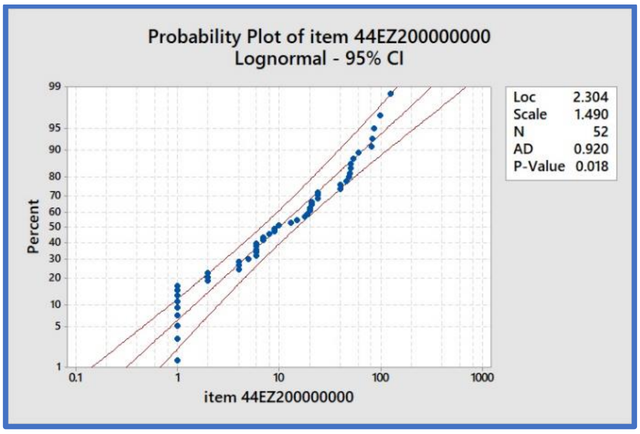

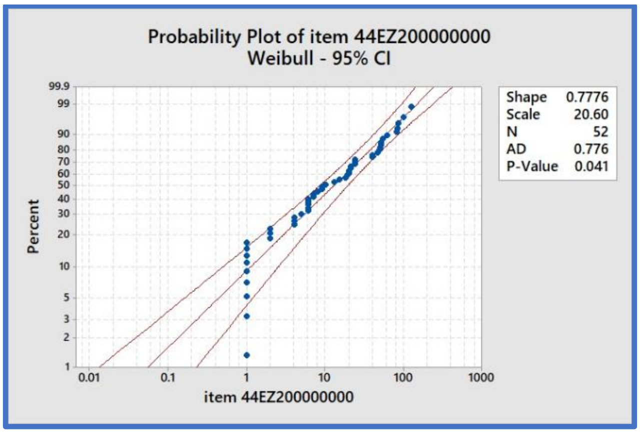

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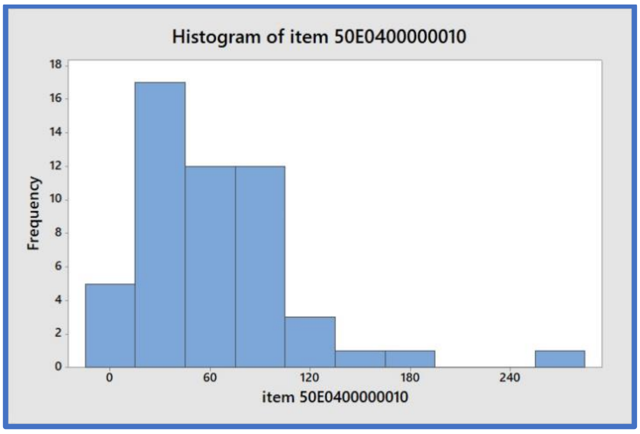

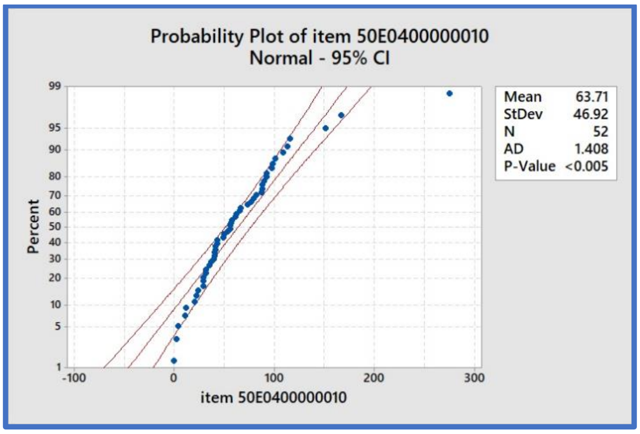

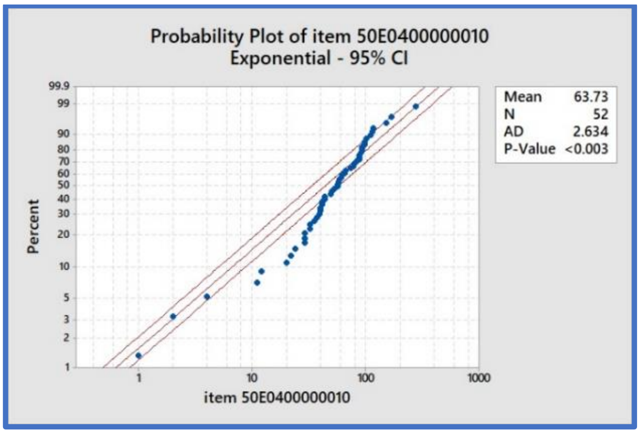

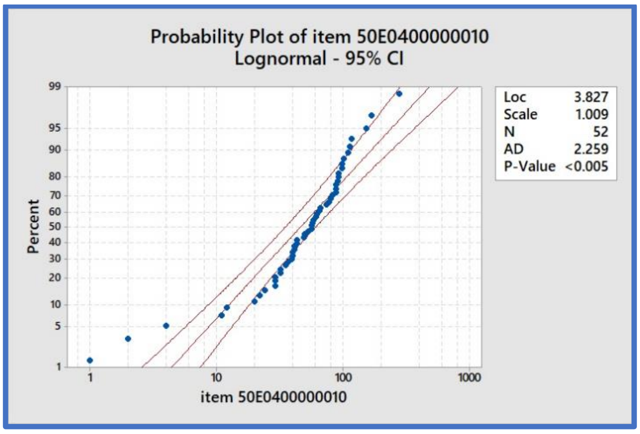

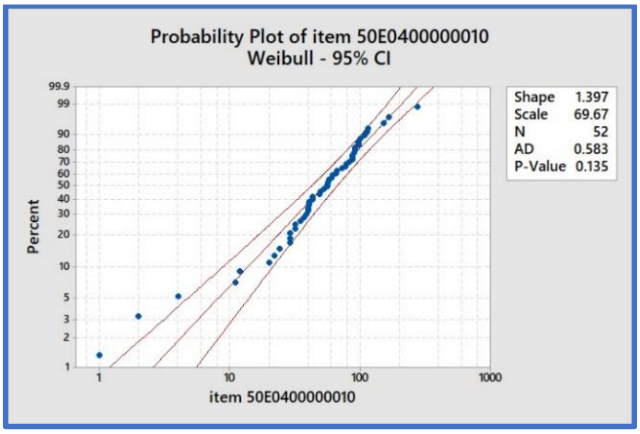

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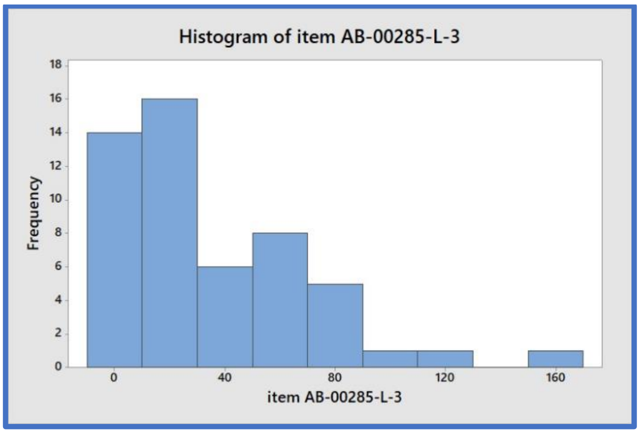

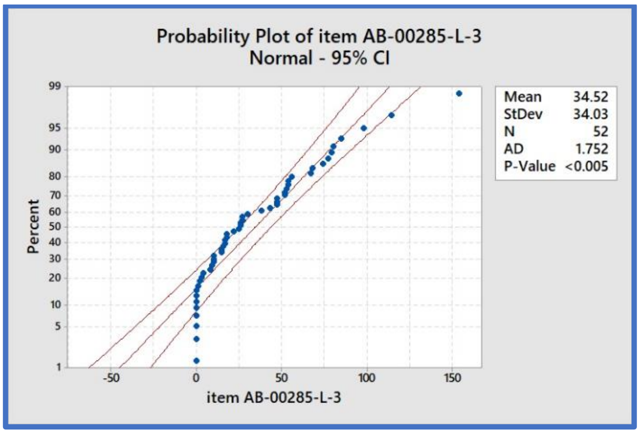

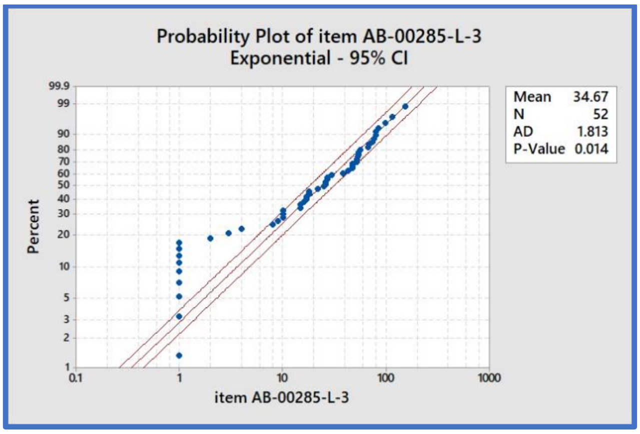

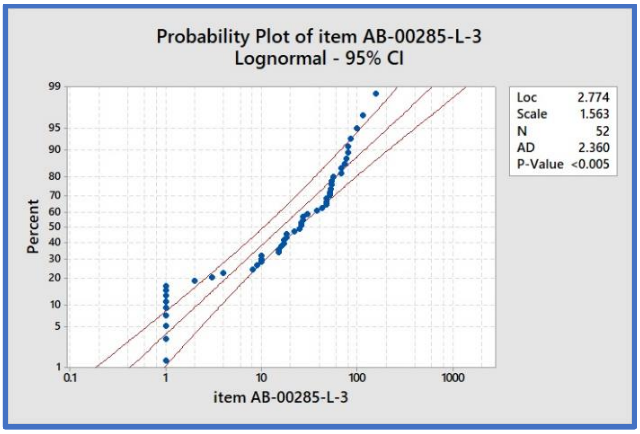

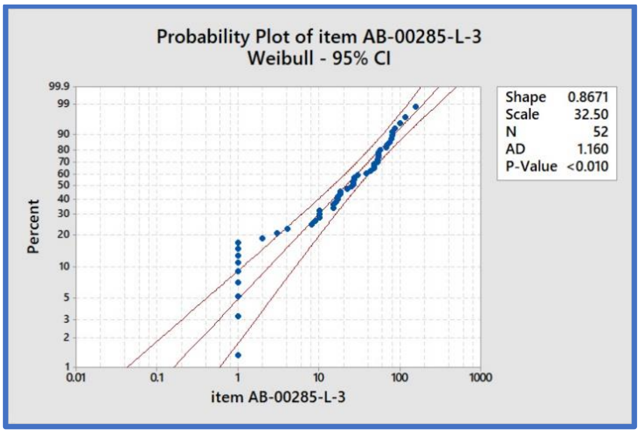

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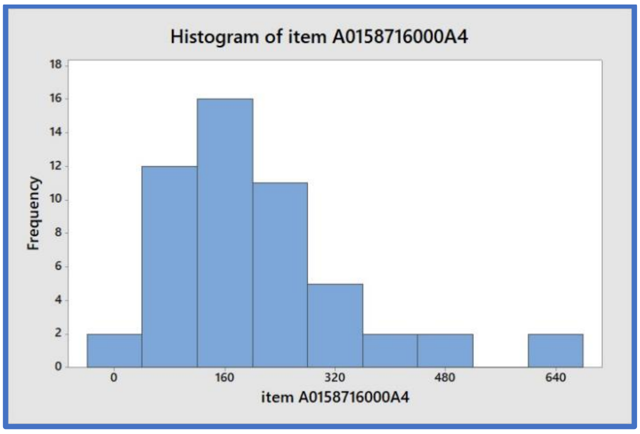

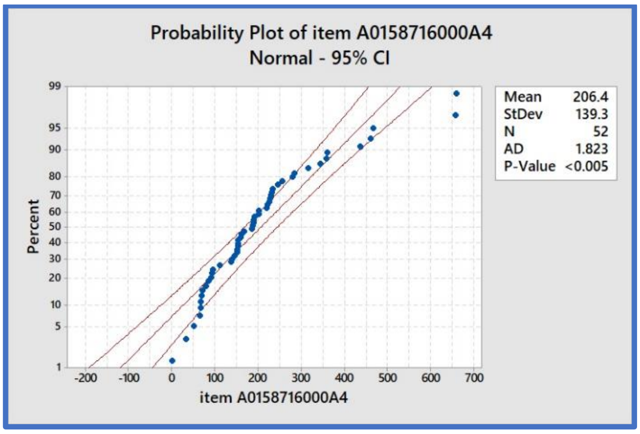

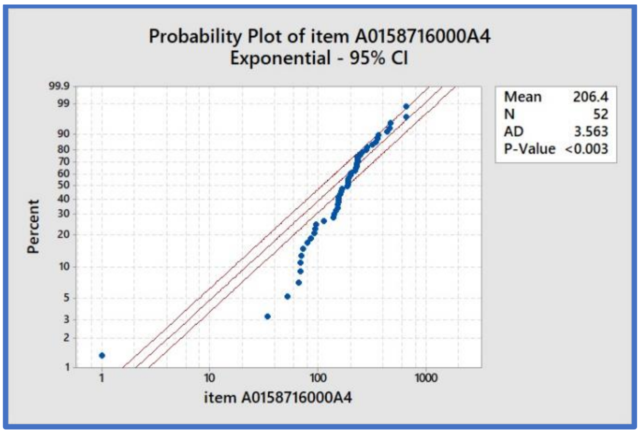

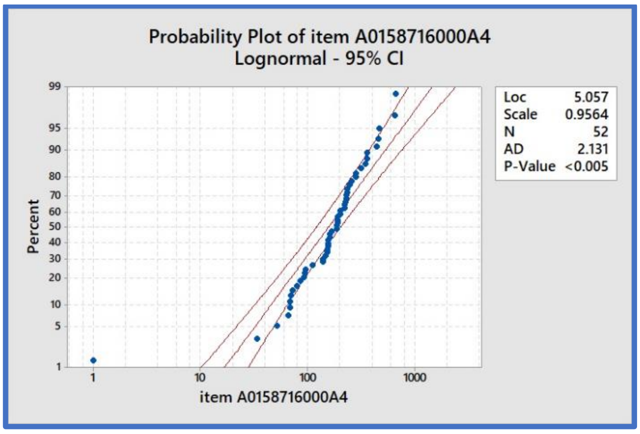

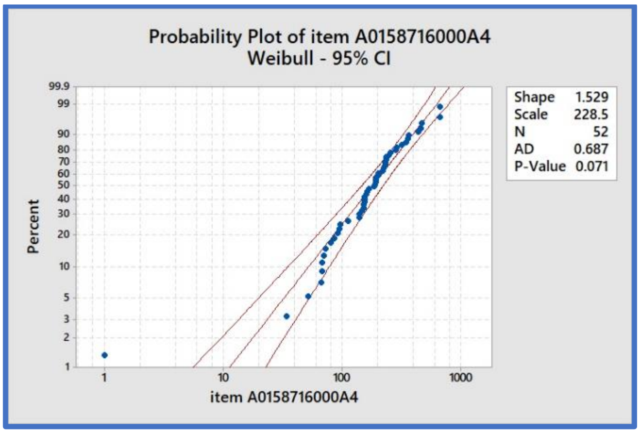

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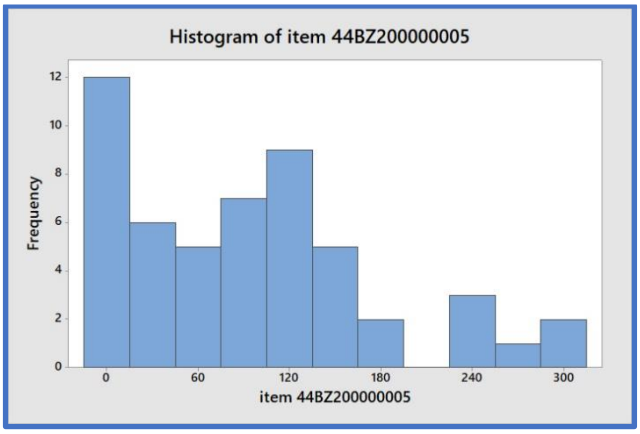

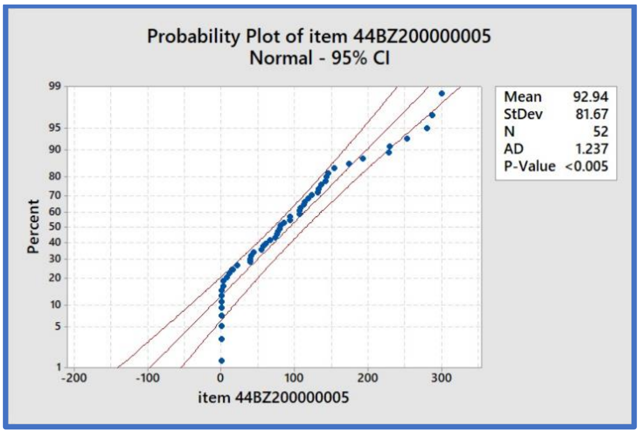

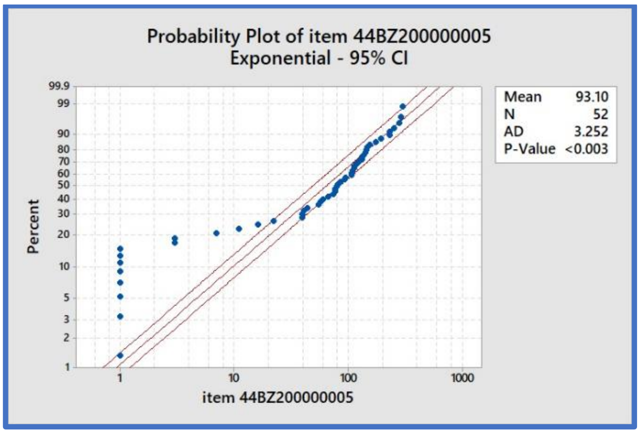

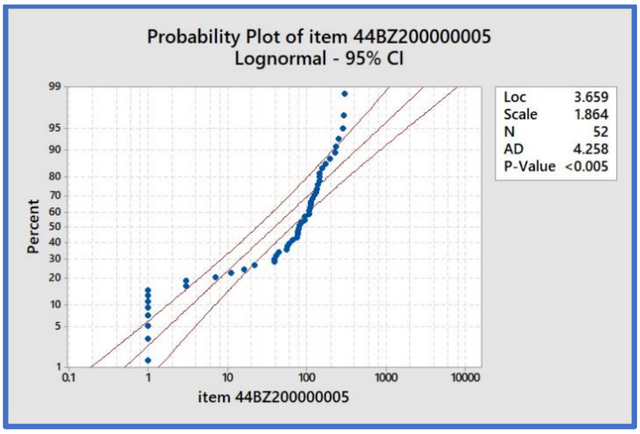

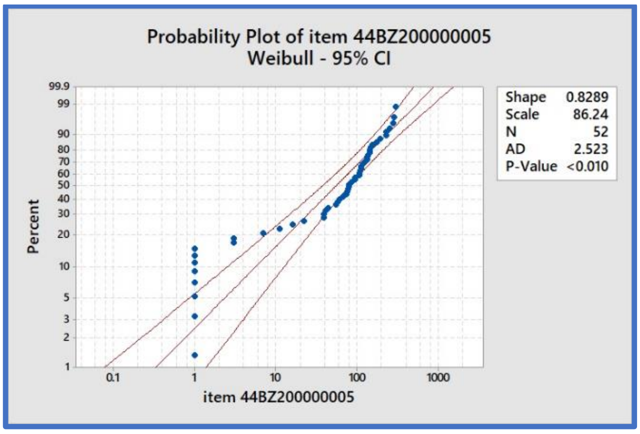

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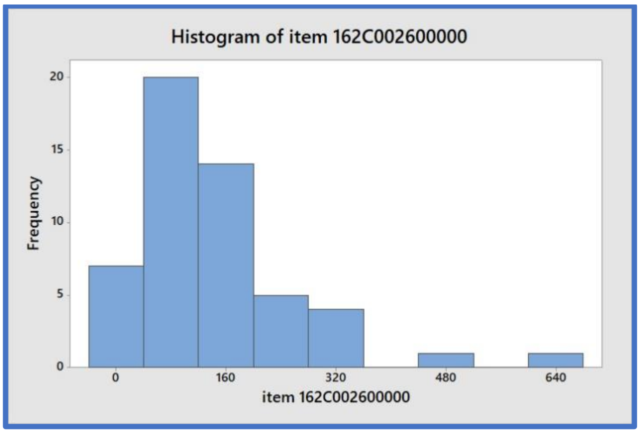

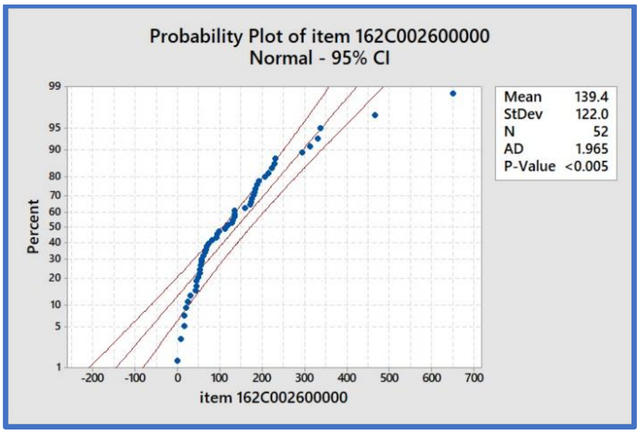

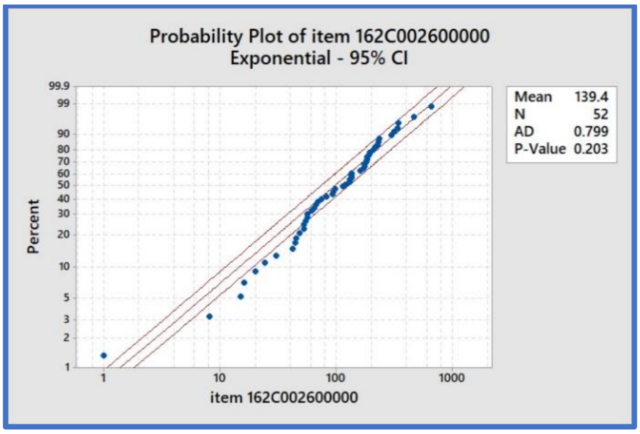

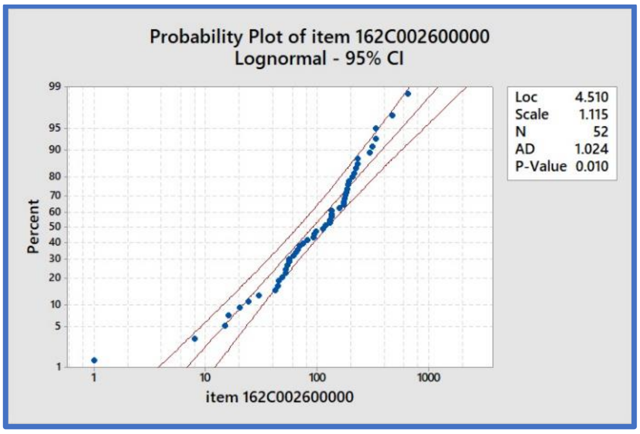

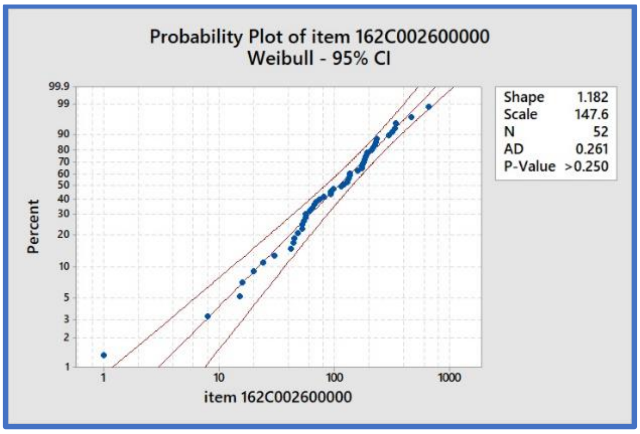

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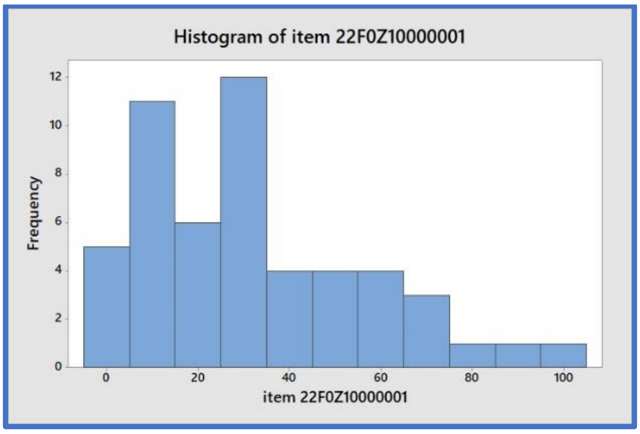

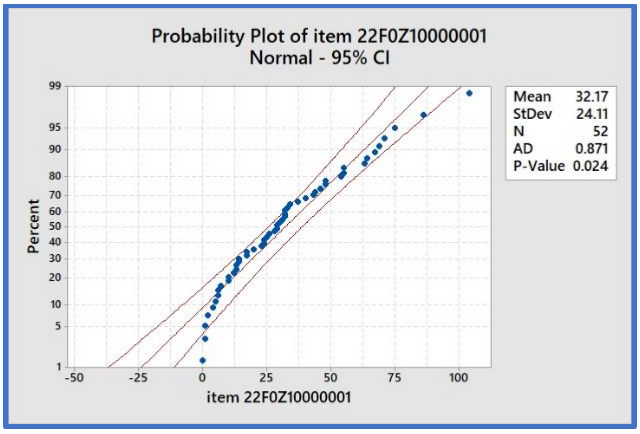

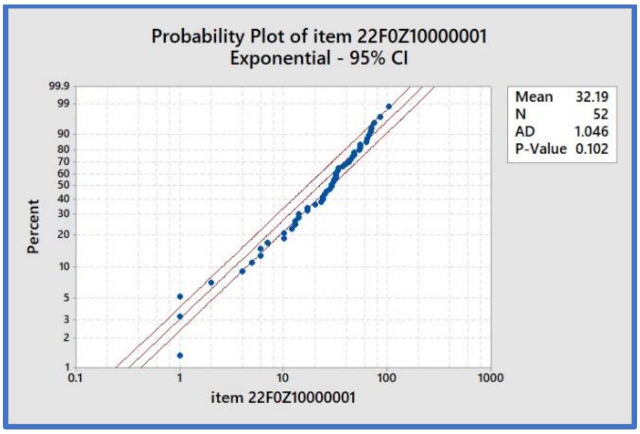

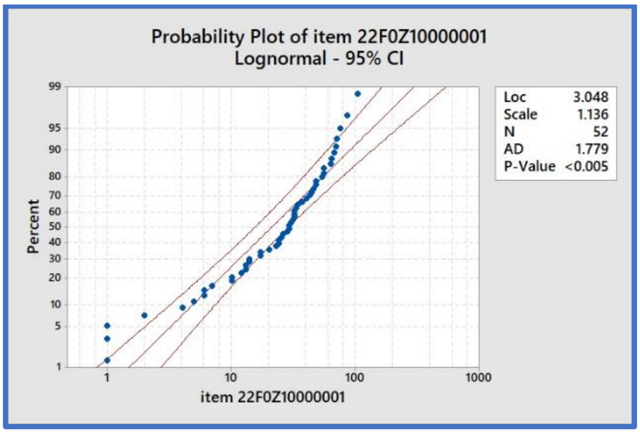

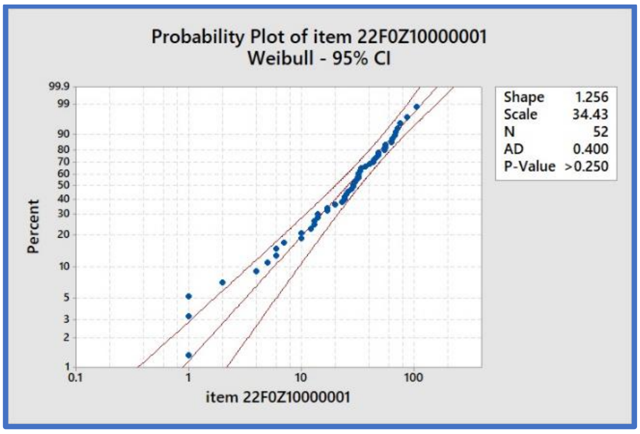

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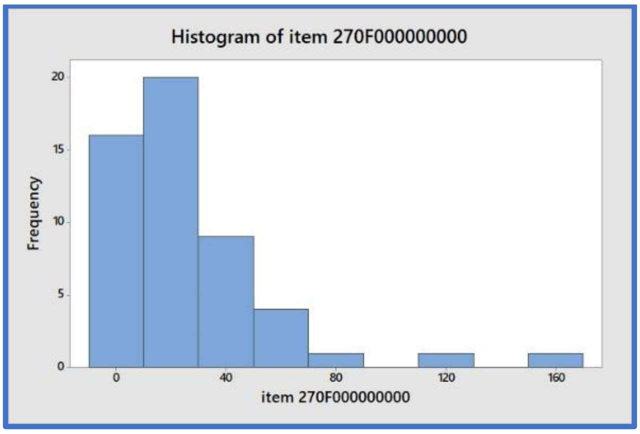

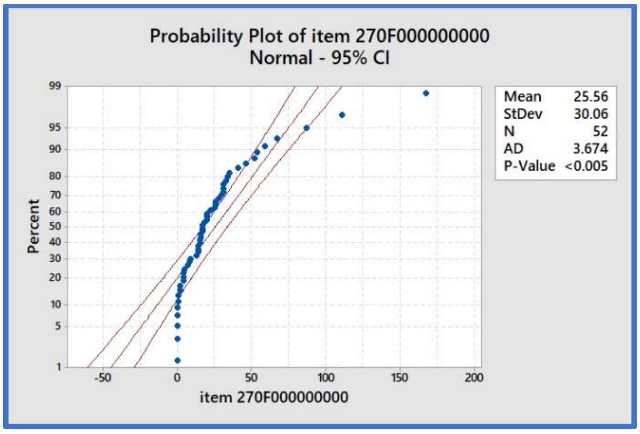

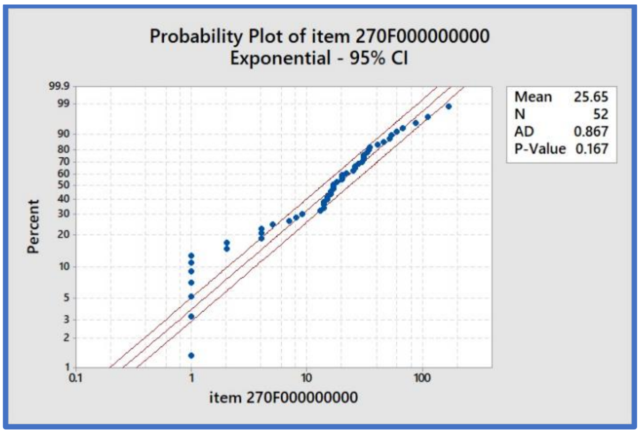

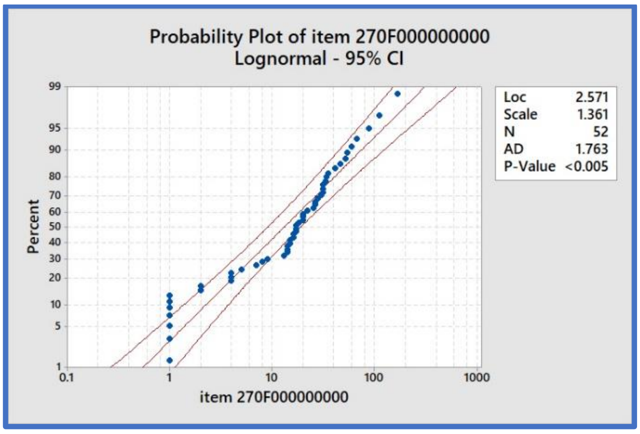

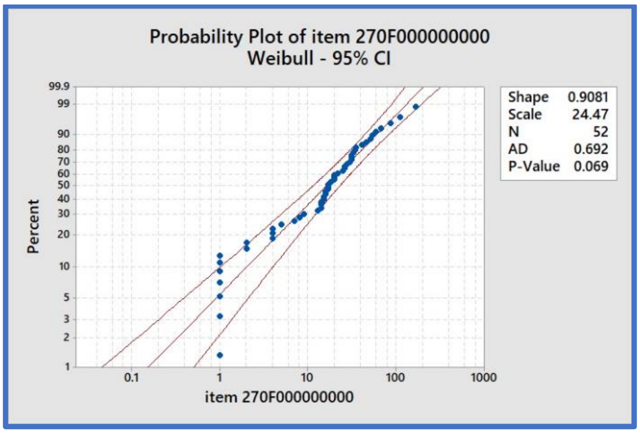

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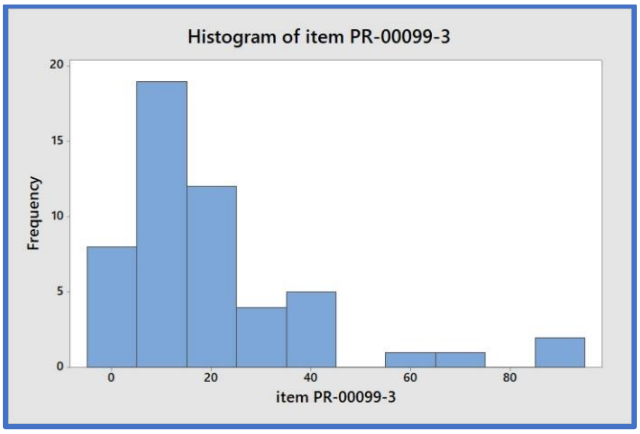

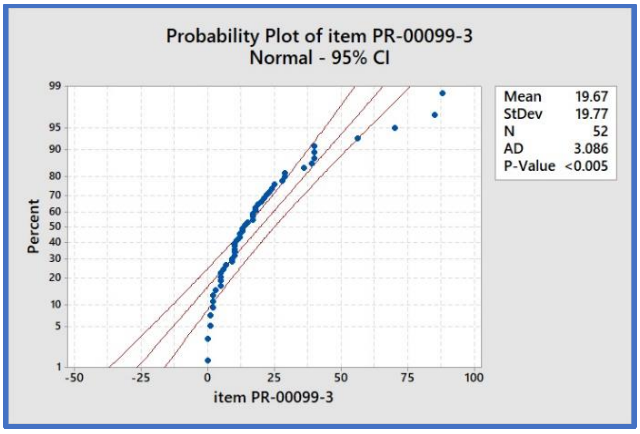

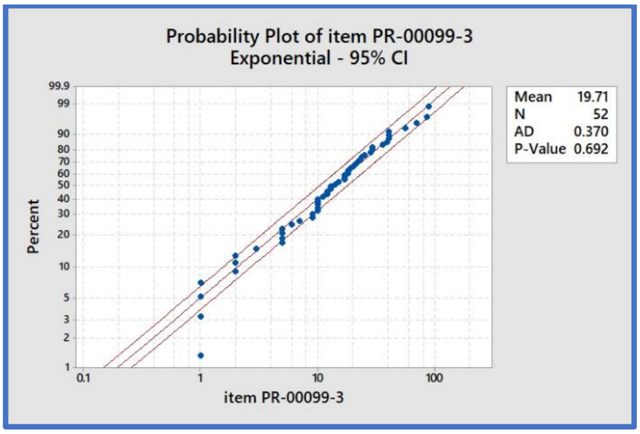

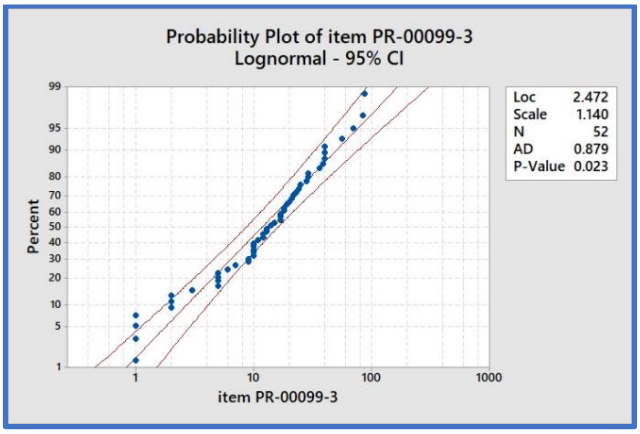

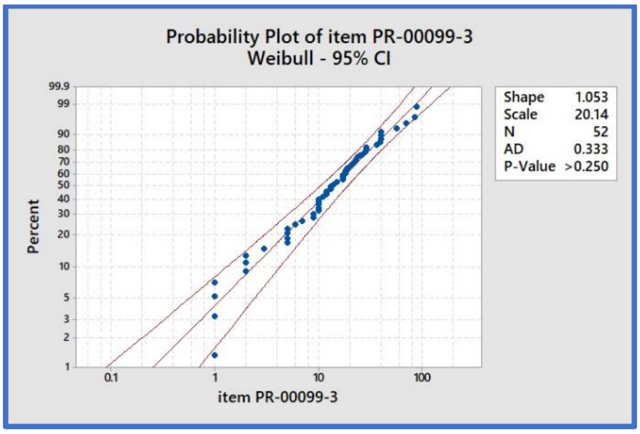

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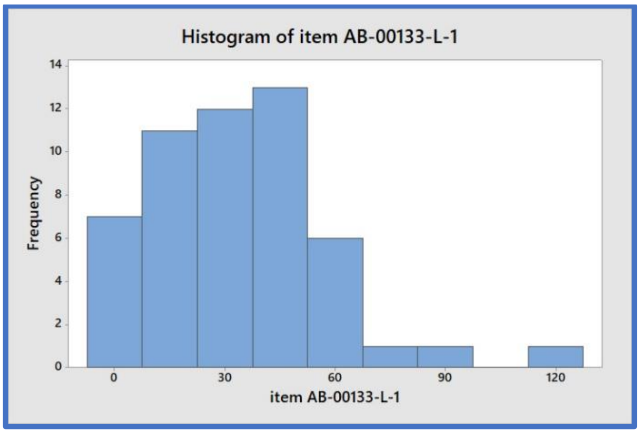

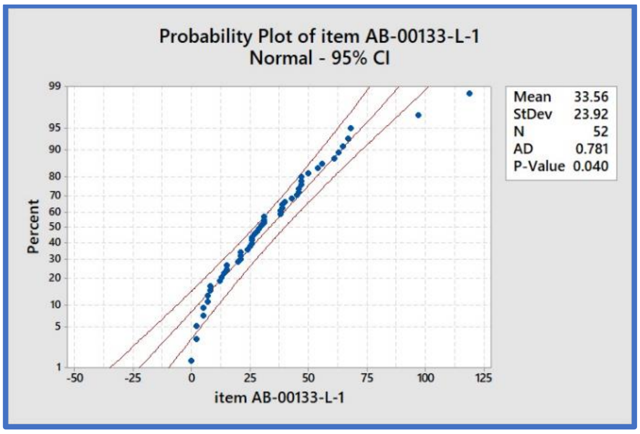

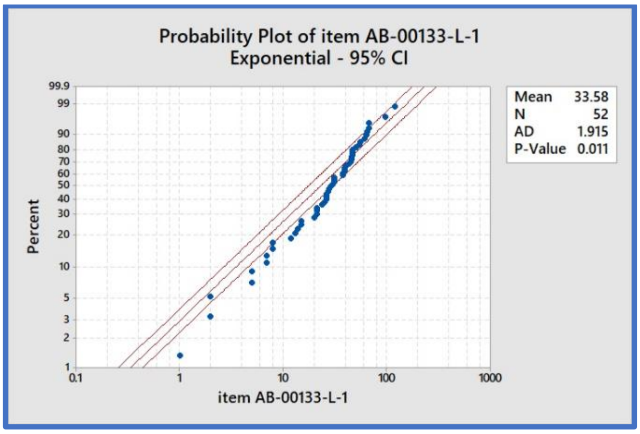

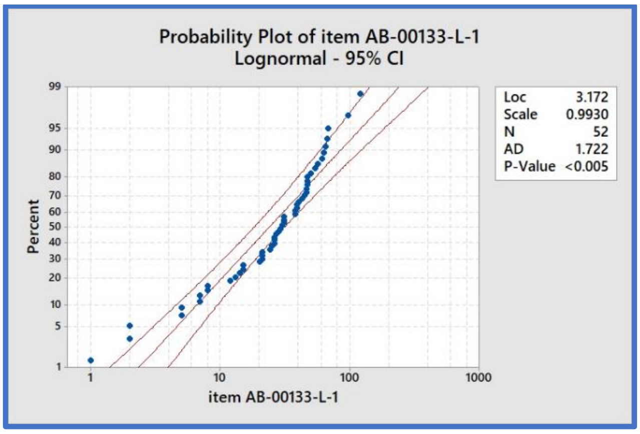

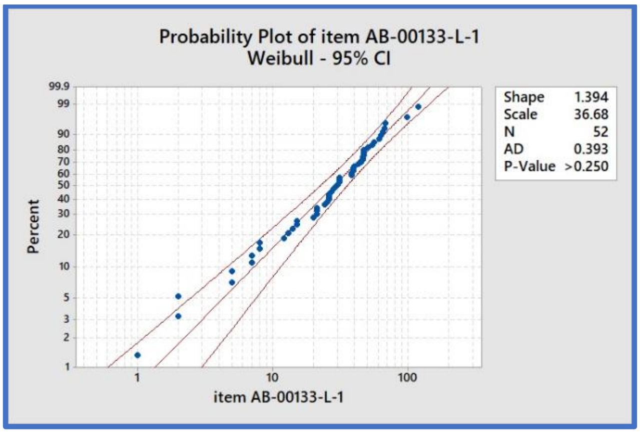

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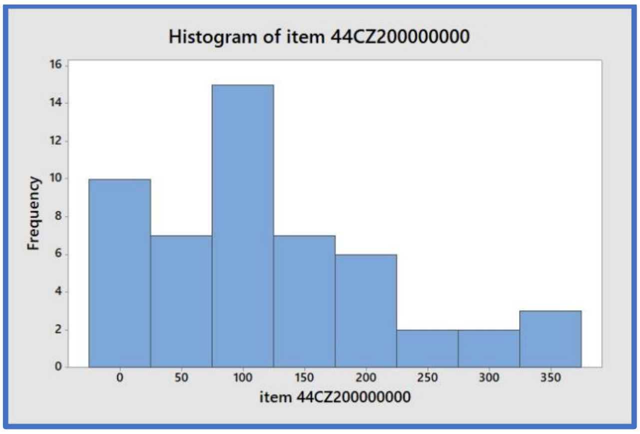

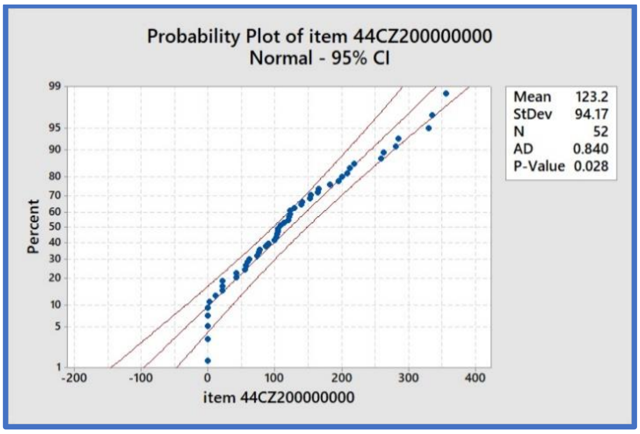

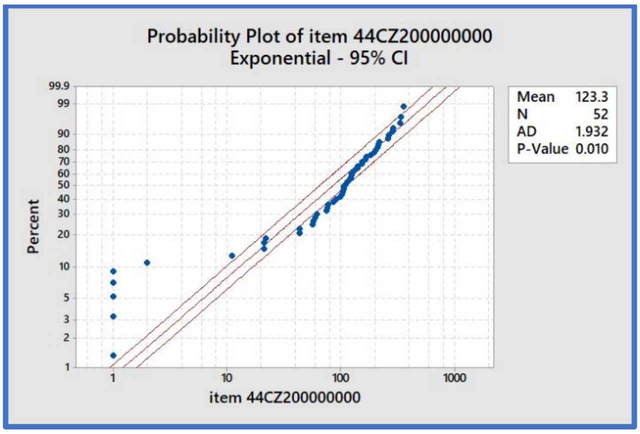

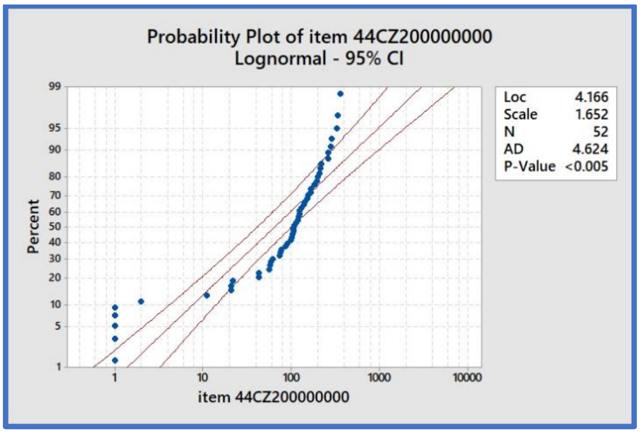

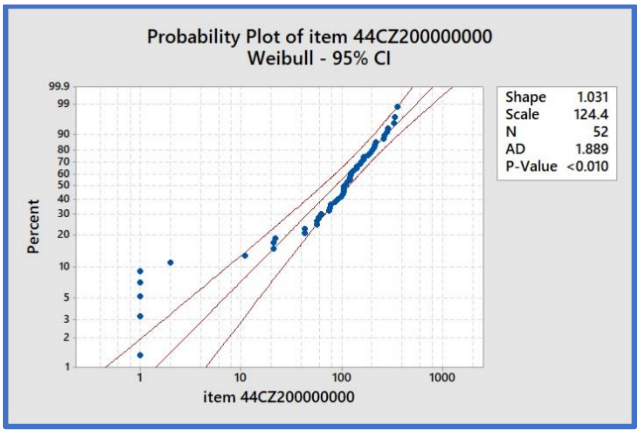

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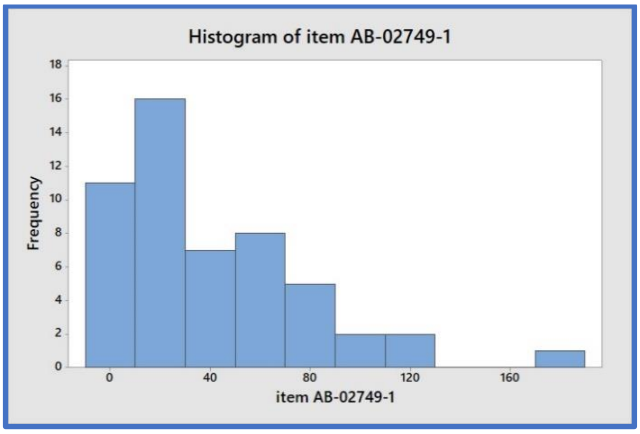

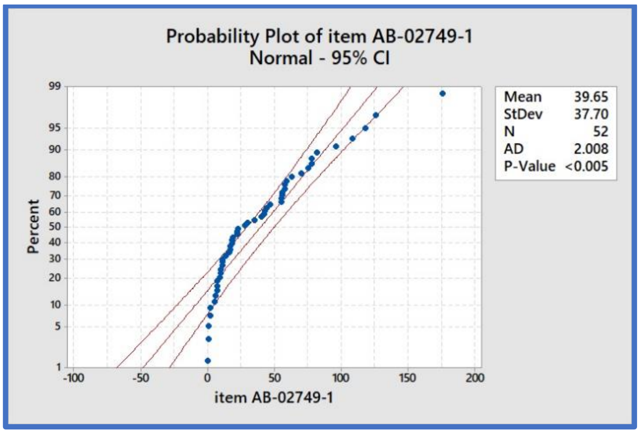

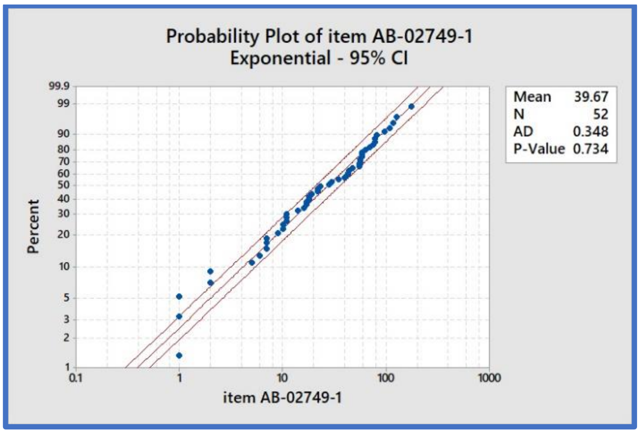

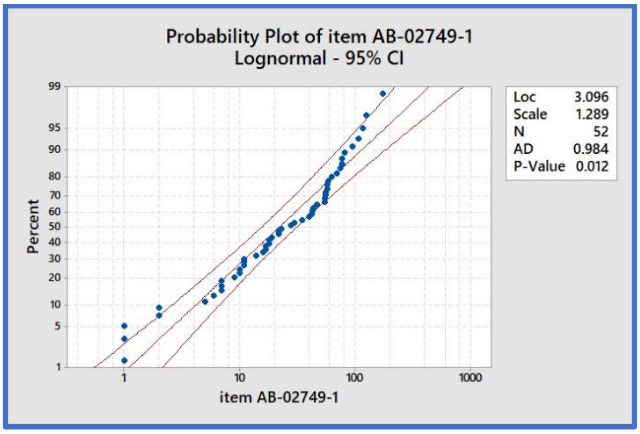

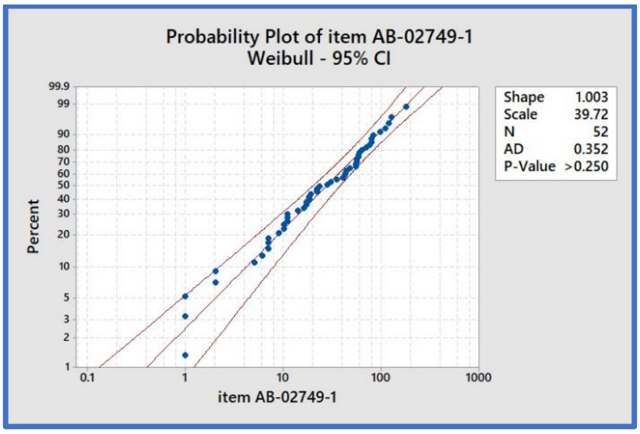

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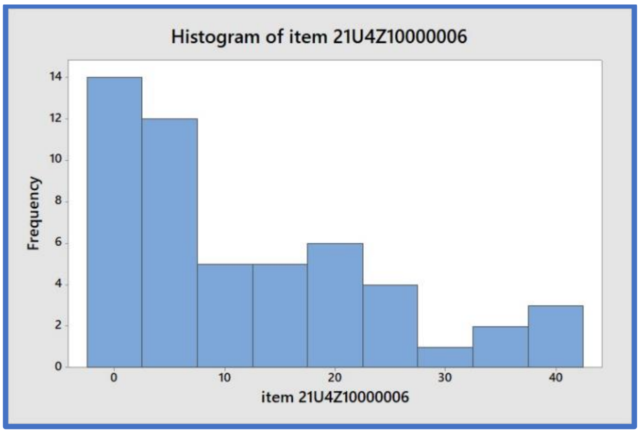
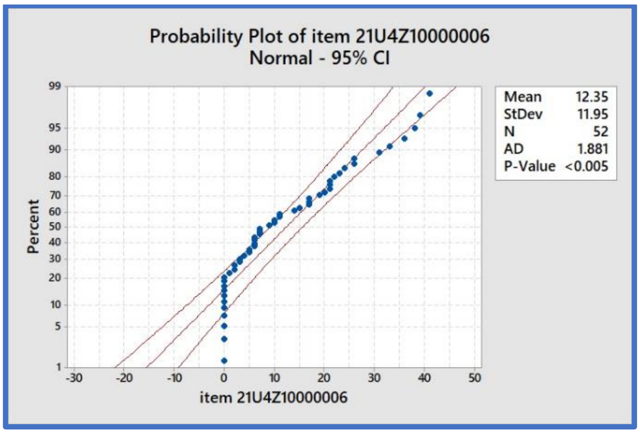
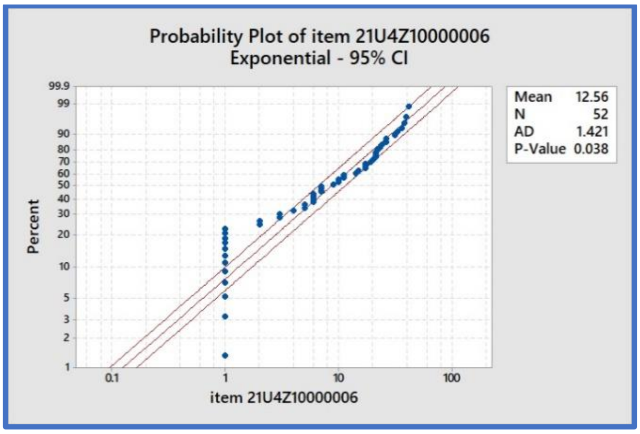
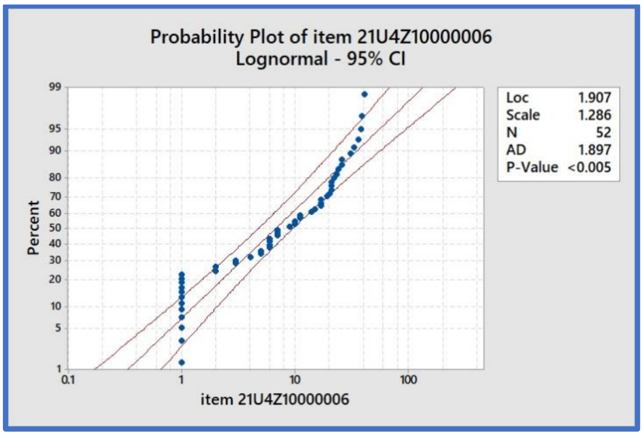
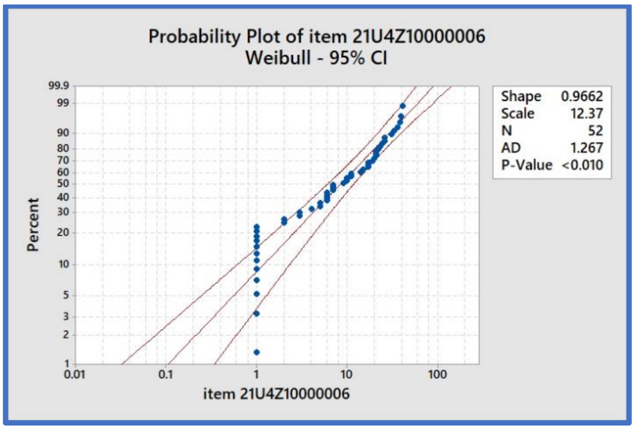


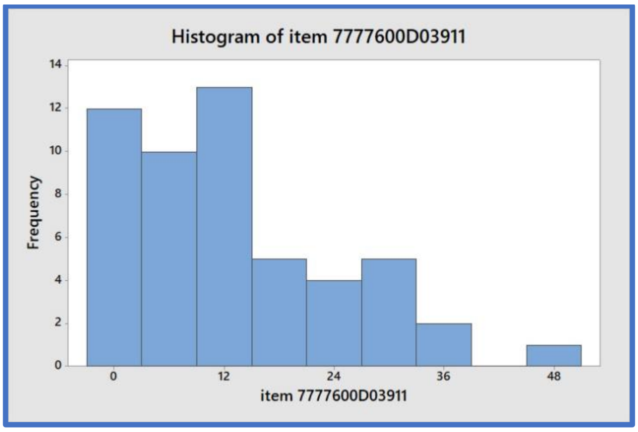


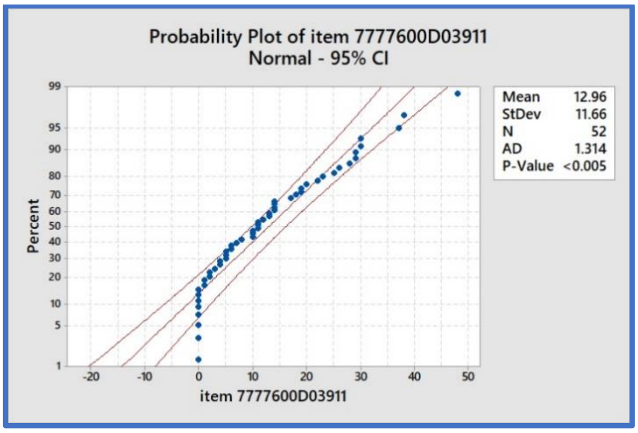


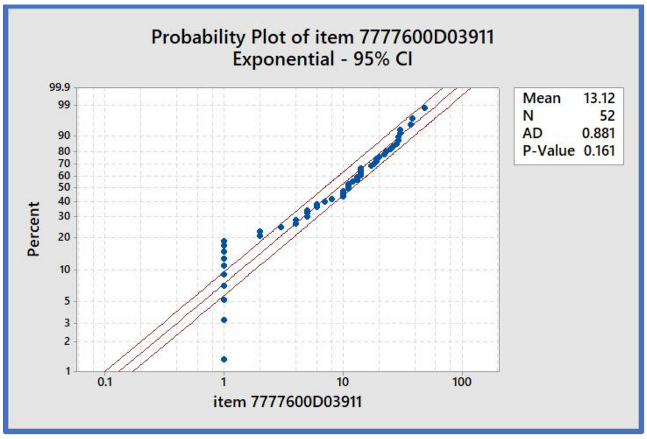


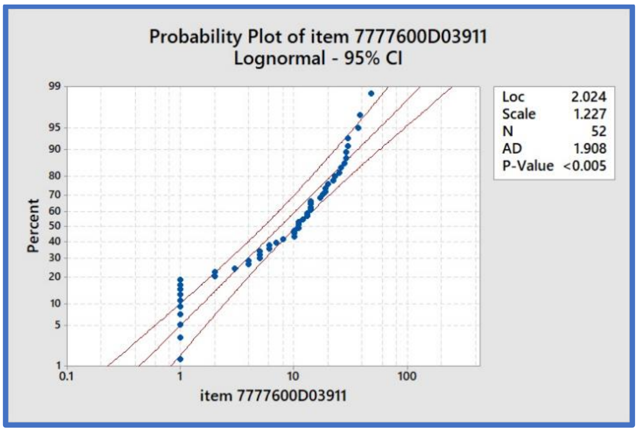


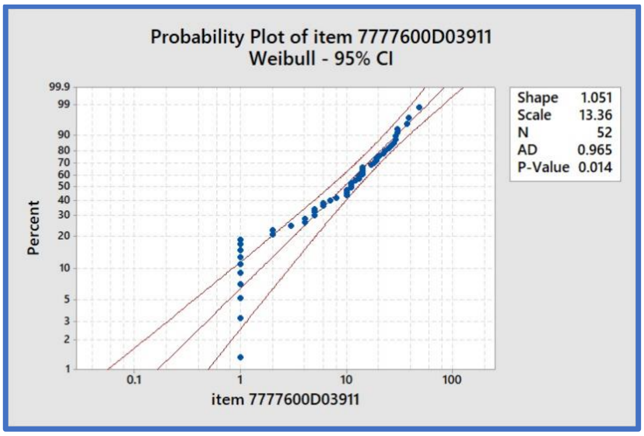
Item 7777600D03911



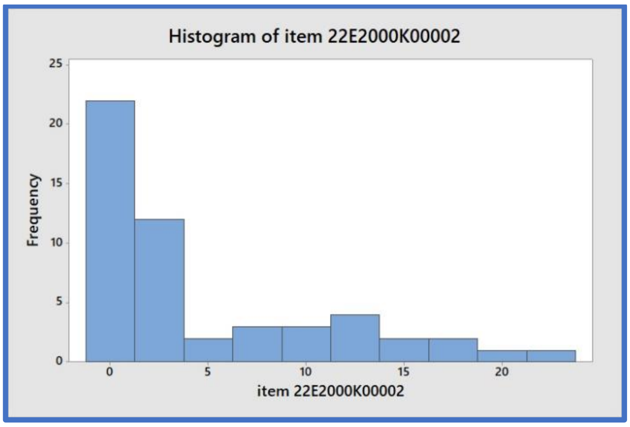


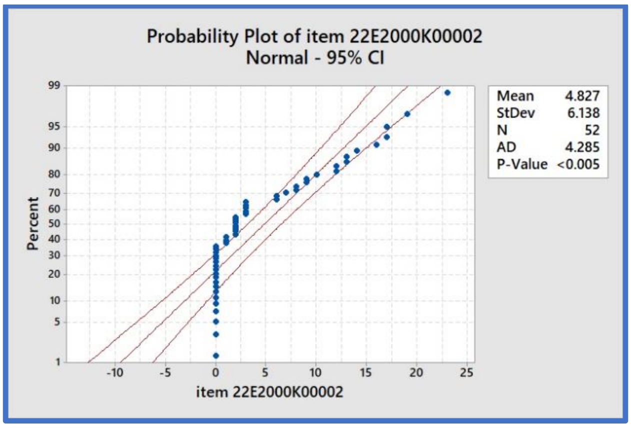


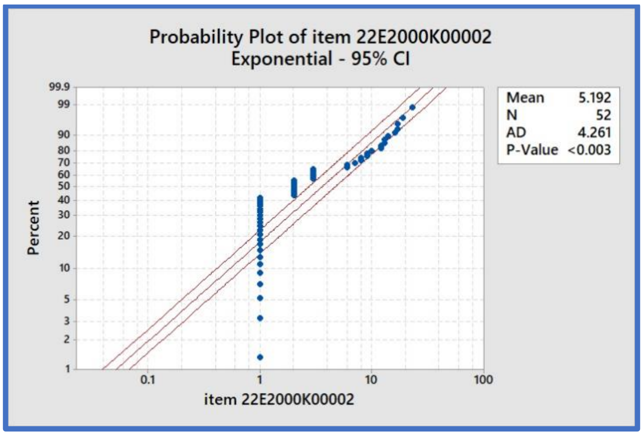


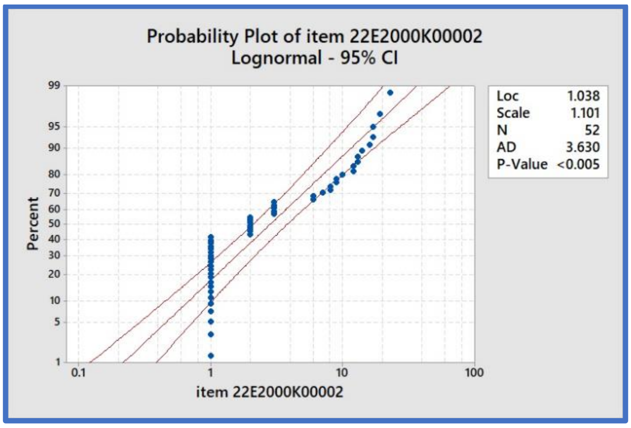


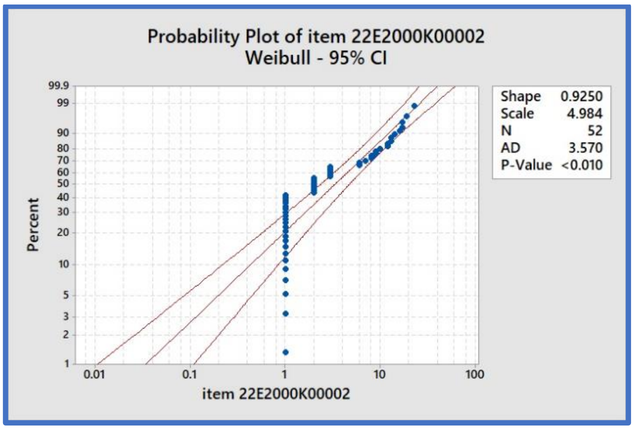
Item 22E2000K00002



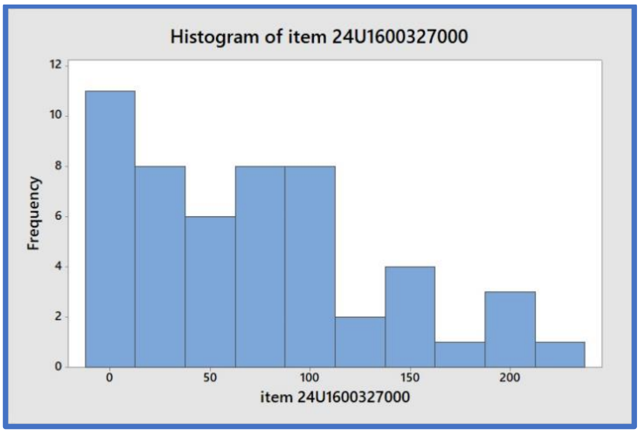


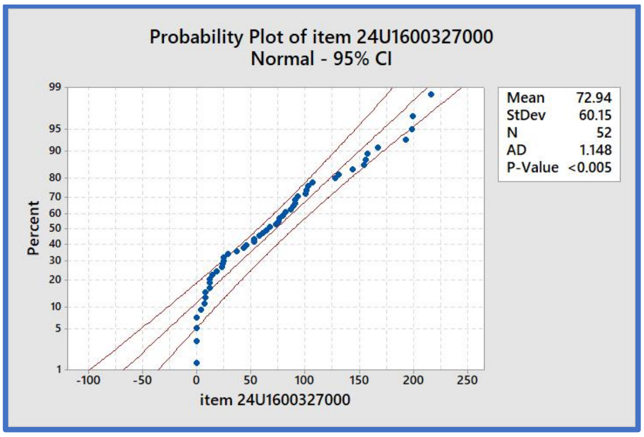


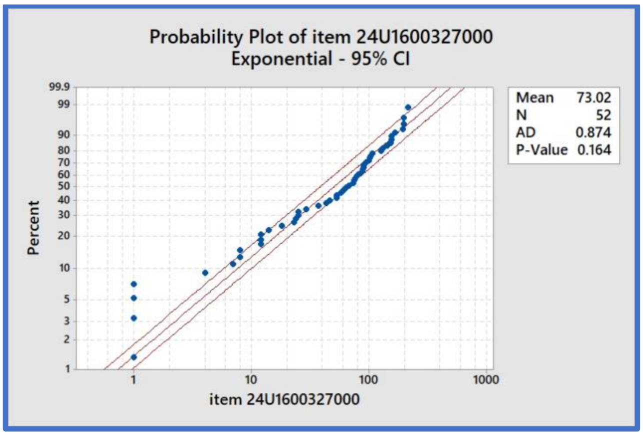


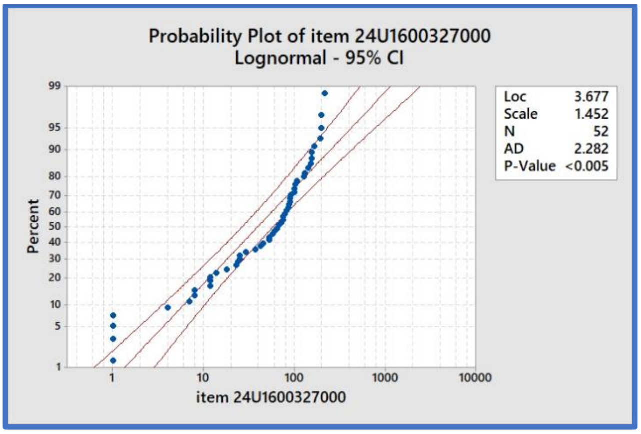


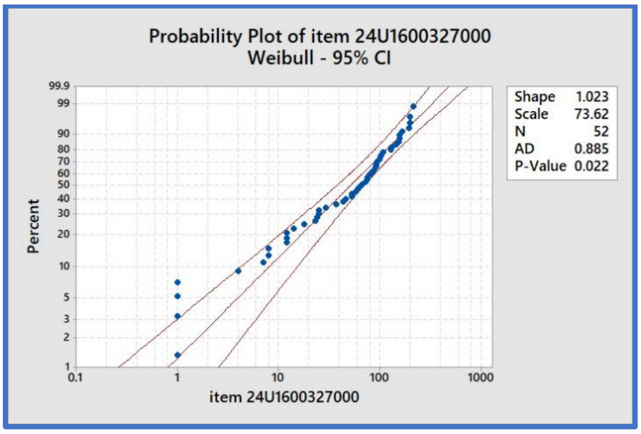
Item 24U1600327000



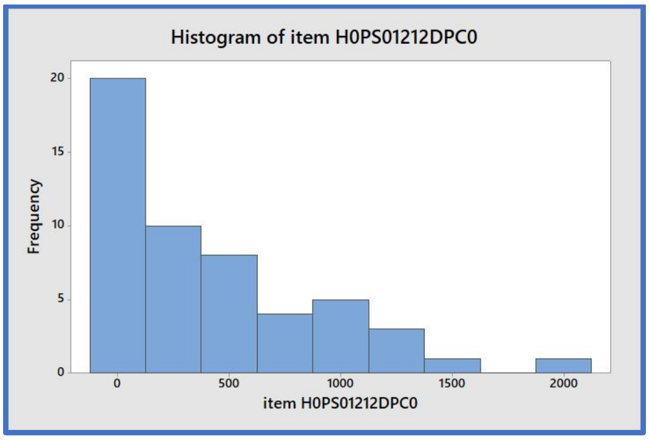


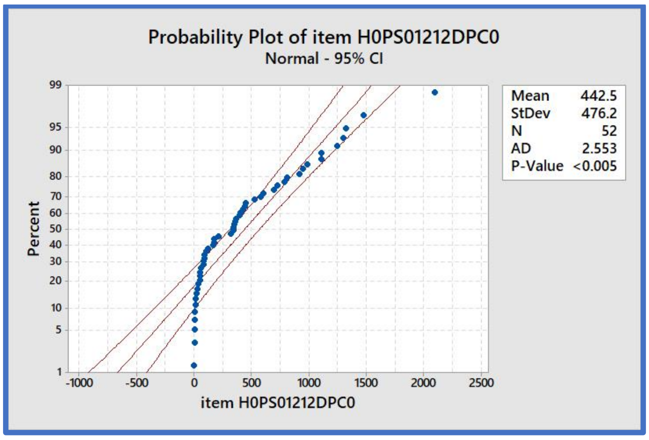


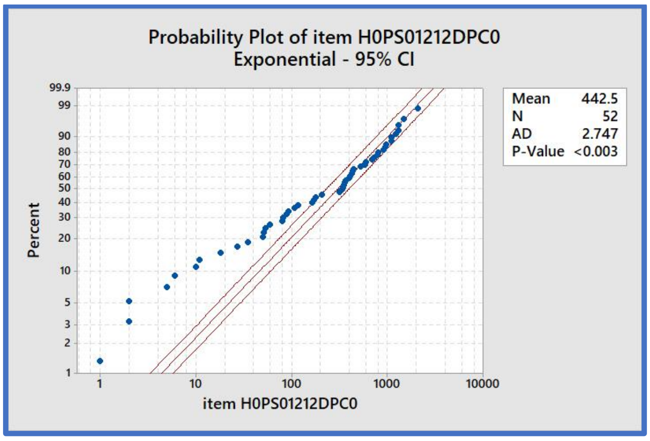


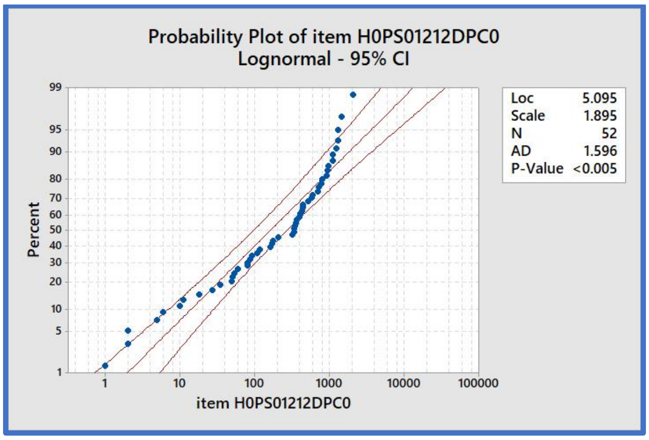


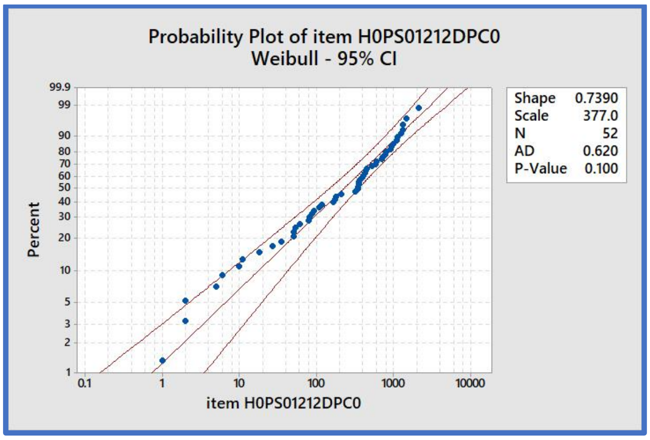
Item H0PS01212DPC0



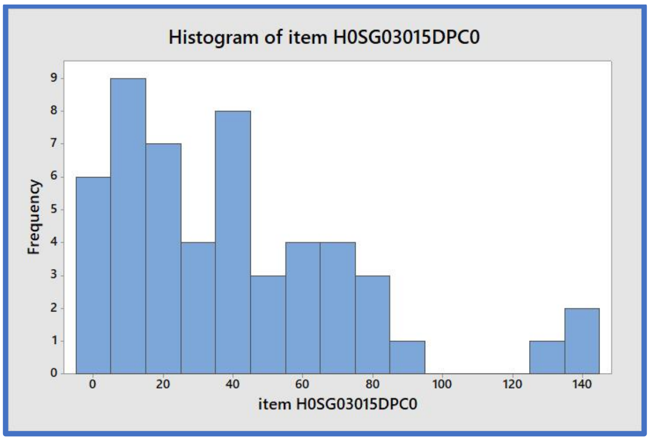


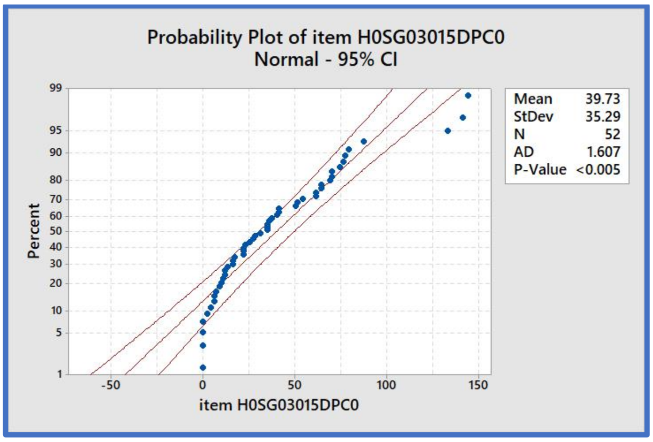


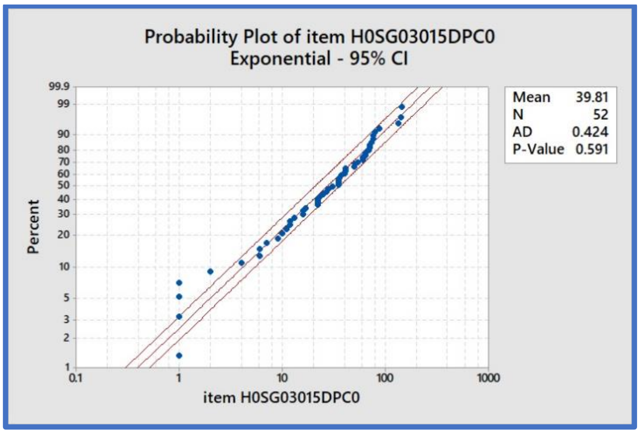


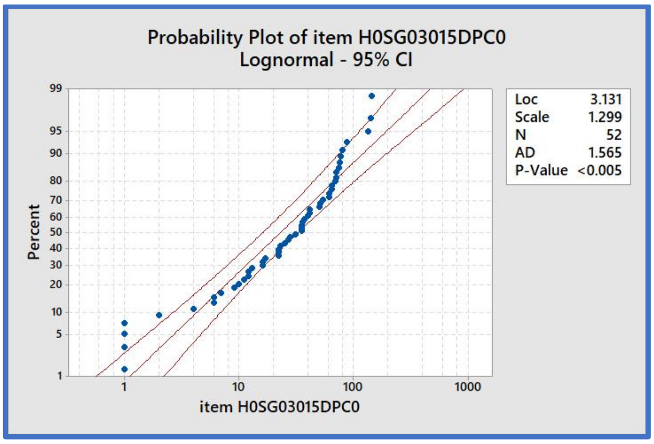


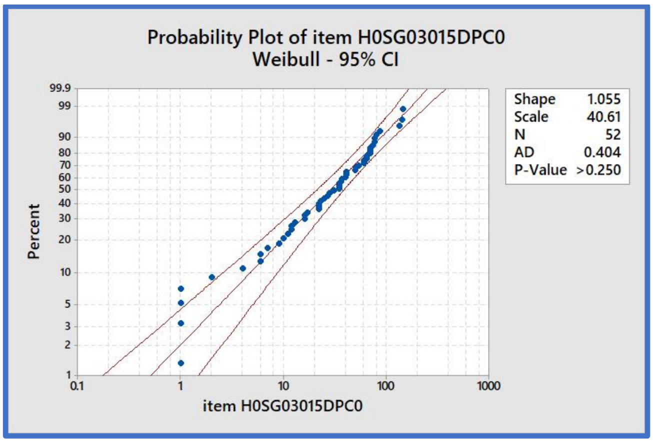
Item H0SG03015DPC0











Appendix E – Demand Distributions items

C1 - Items with Weibull distribution

Item	Shape parameter	Scale parameter
7777234A06M00	0,9036	47,83
50E0400000010	1,397	69,67
A0158716000A4	1,529	228,5
162C002600000	1,182	147,6
22F0Z10000001	1,256	34,43
270F000000000	0,9081	24,47
PR-00099-3	1,053	20,14
AB-00133-L-1	1,394	36,68
H0PS01212DPC0	0,739	227

C2 - Items with an exponential distribution

Items	Mean
AB-02749-1	39,67
7777600D03911	13,12
24U1600327000	73,02
H0SG03015DPC0	39,81

C3 - Items with a discrete distribution

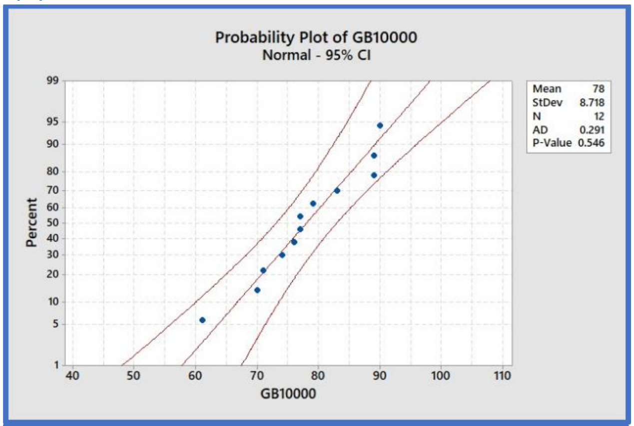
Item	Interval		Frequency	Chance
	Left bound	Right bound		
GB10000	D = 0	D = 0	27	0,52
	D = 300	D = 300	24	0,46
	D = 600	D = 600	1	0,02
10DN00M050M00	D = 0	D = 15	5	0,10
	D = 15	D = 45	17	0,33
	D = 45	D = 75	15	0,29
	D = 75	D = 105	3	0,06
	D = 105	D = 135	4	0,08
	D = 135	D = 165	5	0,10
	D = 165	D = 195	2	0,04
	D = 225	D = 255	1	0,02
44D0600C18001	D = 0	D = 2.5	29	0,56
	D = 2.5	D = 7.5	7	0,13
	D = 7.5	D = 12.5	4	0,08
	D = 12.5	D = 17.5	1	0,02
	D = 17.5	D = 22.5	3	0,06
	D = 22.5	D = 27.5	4	0,08
	D = 27.5	D = 32.5	1	0,02
	D = 32.5	D = 37.5	2	0,04
	D = 37.5	D = 42.5	1	0,02

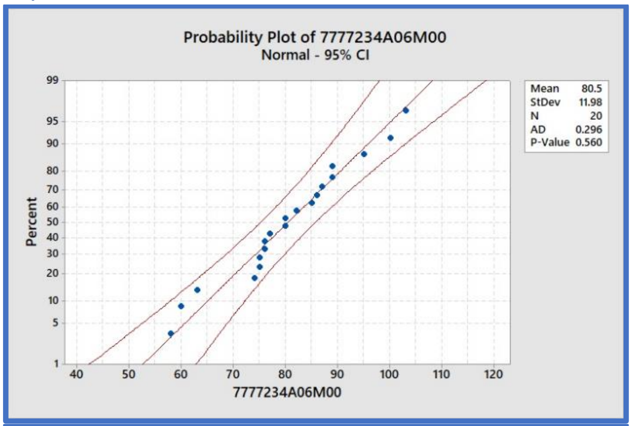
44EZ200000000	D = 0	D = 7.5	23	0,44
	D = 7.5	D = 22.5	12	0,23
	D = 22.5	D = 37.5	3	0,06
	D = 37.5	D = 52.5	7	0,13
	D = 52.5	D = 67.5	2	0,04
	D = 67.5	D = 82.5	2	0,04
	D = 82.5	D = 97.5	1	0,02
	D = 97.5	D = 112.5	1	0,02
	D = 112.5	D = 127.5	1	0,02
AB-00285-L-3	D = 0	D = 10	14	0,27
	D = 10	D = 30	16	0,31
	D = 30	D = 50	6	0,12
	D = 50	D = 70	8	0,15
	D = 70	D = 90	5	0,10
	D = 90	D = 110	1	0,02
	D = 110	D = 130	1	0,02
	D = 150	D = 170	1	0,02

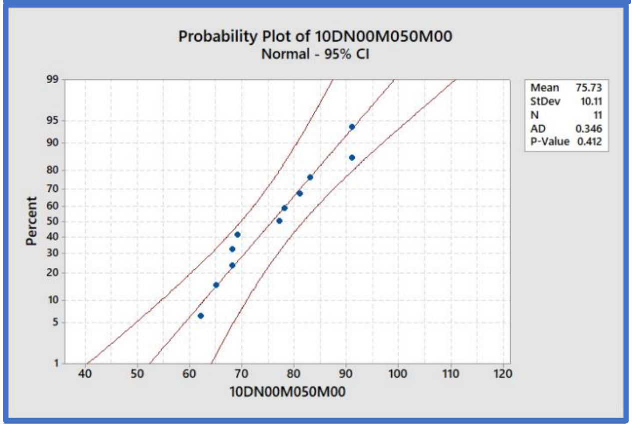
44BZ200000005	D = 0	D = 15	12	0,23
	D = 15	D = 45	6	0,12
	D = 45	D = 75	5	0,10
	D = 75	D = 105	7	0,13
	D = 105	D = 135	9	0,17
	D = 135	D = 165	5	0,10
	D = 165	D = 195	2	0,04
	D = 225	D = 255	3	0,06
	D = 255	D = 285	1	0,02
	D = 285	D = 315	2	0,04
44CZ200000000	D = 0	D = 25	10	0,19
	D = 25	D = 75	7	0,13
	D = 75	D = 125	15	0,29
	D = 125	D = 175	7	0,13
	D = 175	D = 225	6	0,12
	D = 225	D = 275	2	0,04
	D = 275	D = 325	2	0,04
	D = 325	D = 375	3	0,06
21U4Z10000006	D = 0	D = 2.5	14	0,27
	D = 2.5	D = 7.5	12	0,23
	D = 7.5	D = 12.5	5	0,10
	D = 12.5	D = 17.5	5	0,10
	D = 17.5	D = 22.5	6	0,12
	D = 22.5	D = 27.5	4	0,08
	D = 27.5	D = 32.5	1	0,02
	D = 32.5	D = 37.5	2	0,04
	D = 37.5	D = 42.5	3	0,06

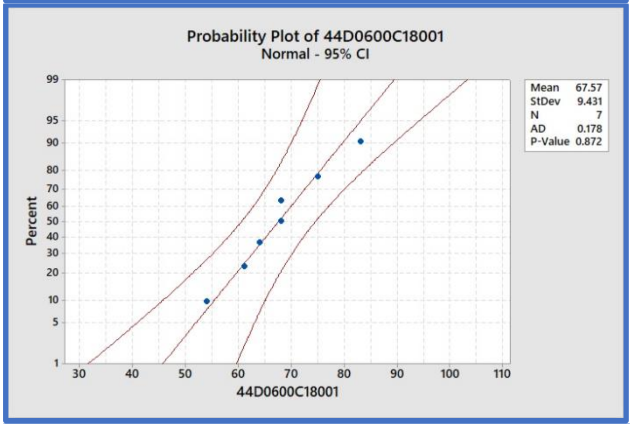
22E2000K00002	D = 0	D = 1.25	22	0,42
	D = 1.25	D = 3.75	12	0,23
	D = 3.75	D = 6.25	2	0,04
	D = 6.25	D = 8.75	3	0,06
	D = 8.75	D = 11.25	3	0,06
	D = 11.25	D = 13.75	4	0,08
	D = 13.75	D = 16.25	2	0,04
	D = 16.25	D = 18.75	2	0,04
	D = 18.75	D = 21.25	1	0,02
	D = 21.25	D = 23.75	1	0,02

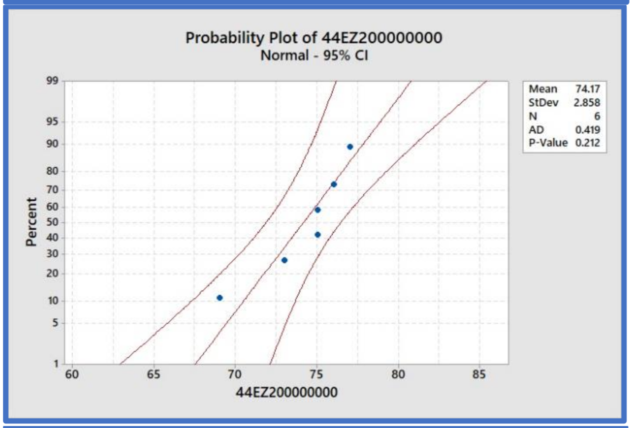
Appendix F – Lead time distribution analysis

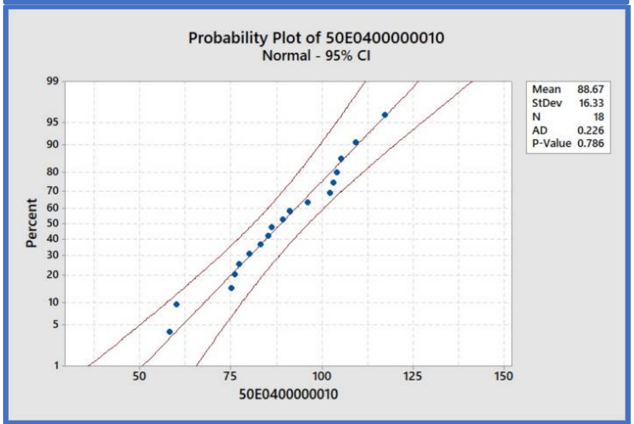


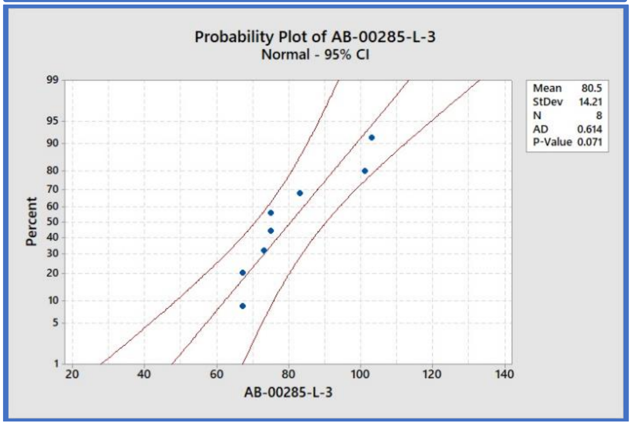


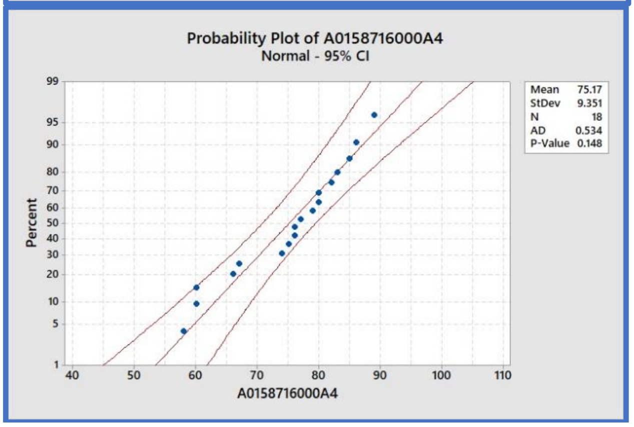


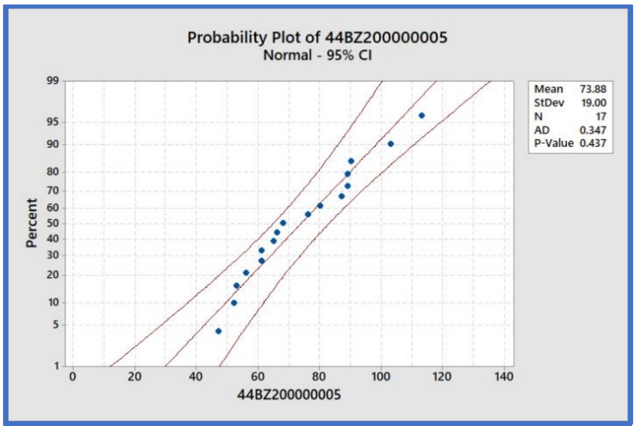


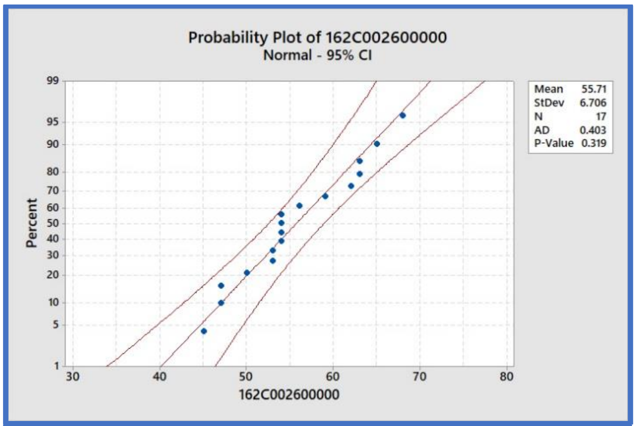


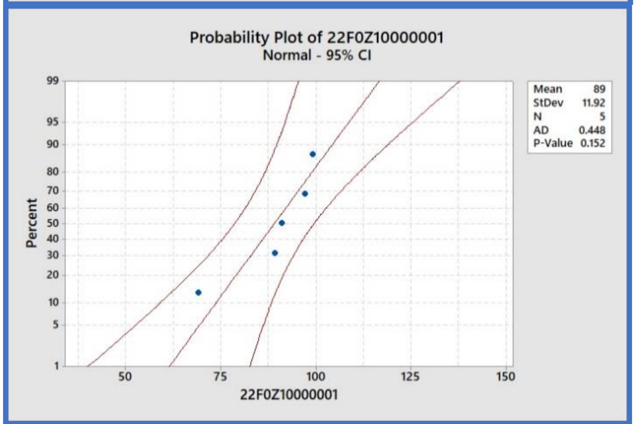


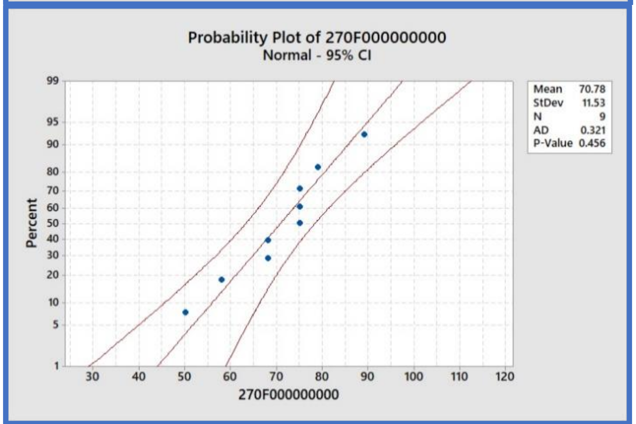


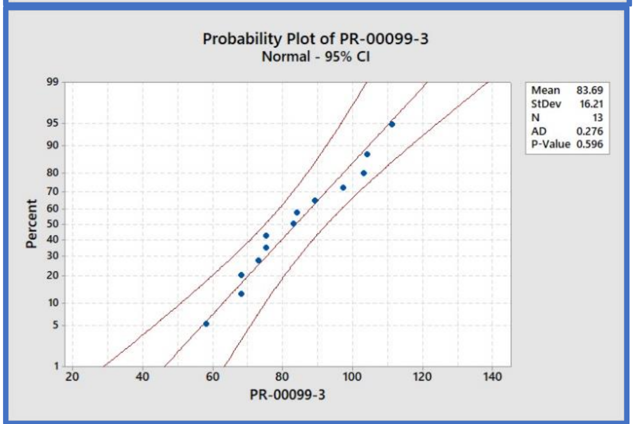


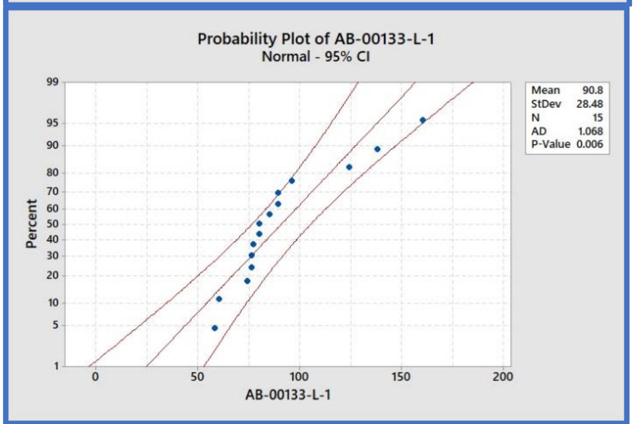

Probability Plot of 44BZ200000005
Normal - 95% CI
Mean 73.88
StDev 19.00
N 17
AD 0.347
P-Value 0.437
Percent
44BZ200000005

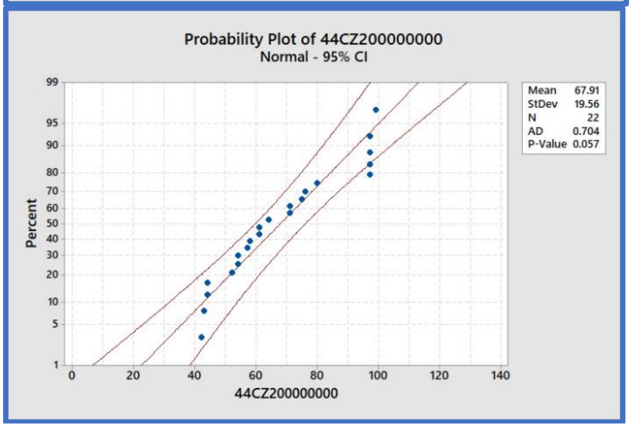

Probability Plot of 162C002600000
Normal - 95% CI
Mean 55.71
StDev 6.706
N 17
AD 0.403
P-Value 0.319
Percent
162C002600000

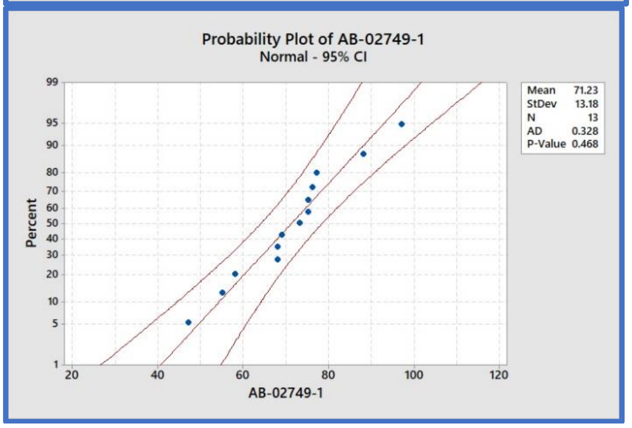

Probability Plot of 22F0Z10000001
Normal - 95% CI
Mean 89
StDev 11.92
N 5
AD 0.448
P-Value 0.152
Percent
22F0Z10000001

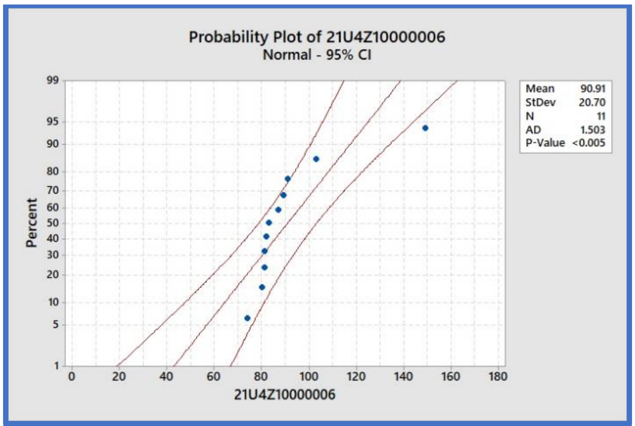

Probability Plot of 270F000000000
Normal - 95% CI
Mean 70.78
StDev 11.53
N 9
AD 0.321
P-Value 0.456
Percent
270F000000000

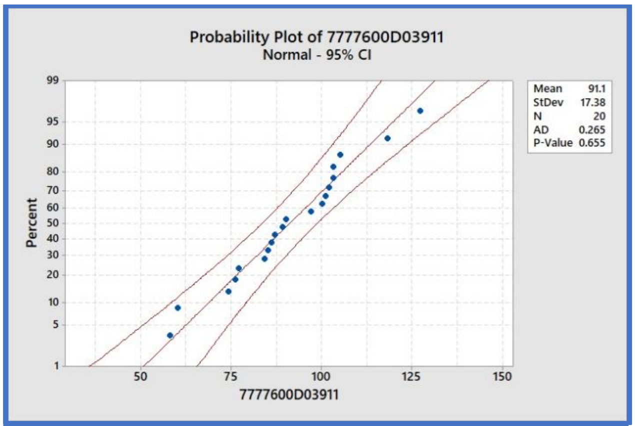

Probability Plot of PR-00099-3
Normal - 95% CI
Mean 83.69
StDev 16.21
N 13
AD 0.276
P-Value 0.596
Percent
PR-00099-3

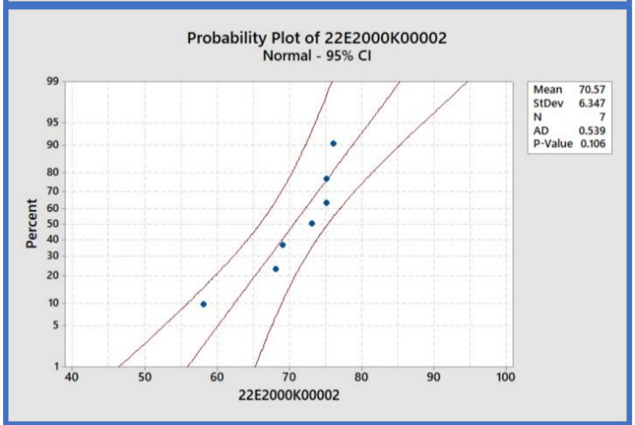

Probability Plot of AB-00133-L-1
Normal - 95% CI
Mean 90.8
StDev 28.48
N 15
AD 1.068
P-Value 0.006
Percent
AB-00133-L-1

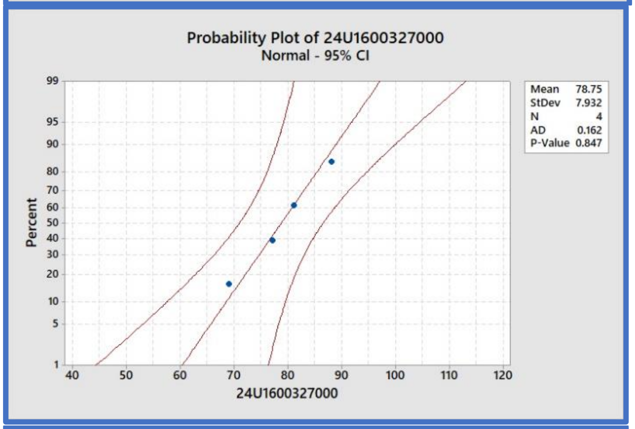

Probability Plot of 44CZ200000000
Normal - 95% CI
Mean 67.91
StDev 19.56
N 22
AD 0.704
P-Value 0.057
Percent
44CZ200000000

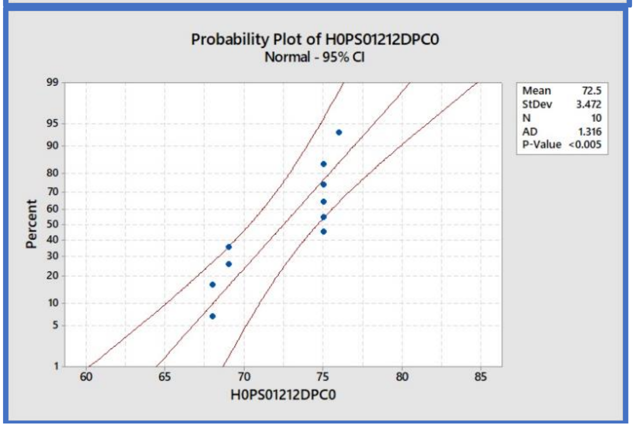

Probability Plot of AB-02749-1
Normal - 95% CI
Mean 71.23
StDev 13.18
N 13
AD 0.328
P-Value 0.468
Percent
AB-02749-1

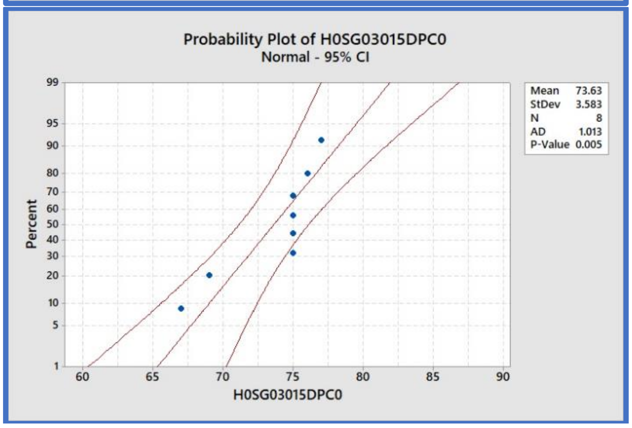

Probability Plot of 21U4Z10000006
Normal - 95% CI
Mean 90.91
StDev 20.70
N 11
AD 1.503
P-Value <0.005
Percent
21U4Z10000006


Probability Plot of 7777600D03911
Normal - 95% CI
Mean 91.1
StDev 17.38
N 20
AD 0.265
P-Value 0.655
Percent
7777600D03911


Probability Plot of 22E2000K00002
Normal - 95% CI
Mean 70.57
StDev 6.347
N 7
AD 0.539
P-Value 0.106
Percent
22E2000K00002


Probability Plot of 24U1600327000
Normal - 95% CI
Mean 78.75
StDev 7.932
N 4
AD 0.162
P-Value 0.847
Percent
24U1600327000


Probability Plot of H0PS01212DPC0
Normal - 95% CI
Mean 72.5
StDev 3.472
N 10
AD 1.316
P-Value <0.005
Percent
H0PS01212DPC0


Probability Plot of H0SG03015DPC0
Normal - 95% CI
Mean 73.63
StDev 3.583
N 8
AD 1.013
P-Value 0.005
Percent
H0SG03015DPC0

Appendix G - Lead time distribution

Item	Mean	standard deviation	Lead time Purchasing model	Difference	Adjusted lead time	Adjusted standard deviation
GB10000	11	1	12	-1	11	1
7777234A06M00	12	2	12	0	12	2
10DN00M050M00	11	1	11	0	11	1
44D0600C18001	10	1	12	-2	10	1
44EZ200000000	11	0	10	1	11	1
50E0400000010	13	2	12	1	13	2
AB-00285-L-3	12	2	12	0	12	2
A0158716000A4	11	1	12	-1	11	1
44BZ200000005	11	3	10	1	11	2
162C002600000	8	1	10	-2	8	1
22F0Z10000001	13	2	11	2	13	2
270F000000000	10	2	12	-2	10	2
PR-00099-3	12	2	12	0	12	2
AB-00133-L-1	13	4	12	1	13	2
44CZ200000000	10	3	10	0	10	2
AB-02749-1	10	2	12	-2	10	2
21U4Z10000006	13	3	13	0	13	2
7777600D03911	13	2	12	1	13	2
22E2000K00002	10	1	12	-2	10	1
24U1600327000	11	1	12	-1	11	1
H0PS01212DPC0	10	0	12	-2	10	1
H0SG03015DPC0	11	1	12	-1	11	1

Appendix H – Sensitivity analysis tables

output sensitivity analysis of the lead time of item 7777234A06M00

Lead time	Total Handling costs	Total Shipping costs	Total Shortage costs	Total Holding costs	Total Ordering cost	Sum Total costs	Achieved service level 1	Achieved service level 2	Average end inventory	Average inventory in transit	Total cost 2	Total costs
1	€ 1.988	€ 35.385	€ 19.593	€ 26.065	€ 1.679	€ 84.710	98,0%	97,9%	202	0	€ 52.274	€ 84.710
2	€ 2.031	€ 36.288	€ 24.929	€ 30.684	€ 1.679	€ 95.611	97,8%	97,4%	238	49	€ 62.622	€ 95.611
3	€ 1.993	€ 35.529	€ 20.664	€ 34.899	€ 1.692	€ 94.777	97,9%	97,8%	271	97	€ 62.801	€ 94.777
4	€ 2.013	€ 35.854	€ 28.148	€ 37.828	€ 1.671	€ 105.515	97,9%	97,0%	294	147	€ 71.548	€ 105.515
5	€ 2.055	€ 36.523	€ 34.927	€ 40.148	€ 1.692	€ 115.345	96,7%	96,4%	312	199	€ 83.388	€ 115.345
6	€ 2.058	€ 36.595	€ 18.925	€ 42.385	€ 1.699	€ 101.662	98,2%	98,0%	329	249	€ 70.295	€ 101.662
7	€ 2.064	€ 36.685	€ 20.979	€ 44.513	€ 1.709	€ 105.950	97,8%	97,8%	346	300	€ 75.379	€ 105.950
8	€ 2.109	€ 37.679	€ 31.040	€ 45.216	€ 1.654	€ 117.697	97,5%	96,9%	351	359	€ 87.554	€ 117.697
9	€ 2.010	€ 35.692	€ 25.521	€ 50.396	€ 1.676	€ 115.296	97,6%	97,3%	392	389	€ 88.527	€ 115.296
10	€ 1.992	€ 35.601	€ 22.945	€ 52.714	€ 1.678	€ 114.930	98,3%	97,6%	410	437	€ 91.196	€ 114.930
11	€ 1.926	€ 34.301	€ 12.663	€ 57.022	€ 1.673	€ 107.586	98,8%	98,6%	443	468	€ 90.435	€ 107.586
12	€ 1.975	€ 35.312	€ 15.782	€ 57.042	€ 1.673	€ 111.784	98,8%	98,3%	443	529	€ 111.784	€ 111.784

Output sensitivity analysis of the lead time of item 7777600D03911

Total Handling costs	Total Shipping costs	Total Shortage costs	Total Holding costs	Total Ordering cost	Sum Total costs	Achieved service level 1	Achieved service level 2	Average end inventory	Average inventory in transit	Lead time	Total costs 2	Total costs
€ 1.565	€ 27.905	€ 13.050	€ 17.017	€ 1.619	€ 61.156	97,7%	98,4%	38	0	1	€ 35.398	€ 61.156
€ 1.517	€ 27.129	€ 16.482	€ 20.165	€ 1.592	€ 66.885	97,9%	97,8%	45	10	2	€ 42.017	€ 66.885
€ 1.561	€ 27.833	€ 10.670	€ 21.541	€ 1.628	€ 63.233	98,2%	98,6%	48	20	3	€ 37.931	€ 63.233
€ 1.500	€ 26.840	€ 13.943	€ 24.055	€ 1.599	€ 67.937	98,3%	98,2%	54	28	4	€ 43.781	€ 67.937
€ 1.515	€ 27.002	€ 10.770	€ 25.828	€ 1.585	€ 66.700	98,7%	98,6%	58	38	5	€ 42.698	€ 66.700
€ 1.533	€ 27.363	€ 15.311	€ 27.044	€ 1.588	€ 72.840	98,3%	98,0%	61	48	6	€ 48.897	€ 72.840
€ 1.552	€ 27.670	€ 14.399	€ 27.906	€ 1.635	€ 73.162	98,3%	98,1%	62	58	7	€ 49.445	€ 73.162
€ 1.547	€ 27.652	€ 6.763	€ 29.197	€ 1.629	€ 66.788	98,9%	99,1%	65	68	8	€ 43.744	€ 66.788
€ 1.569	€ 27.959	€ 16.541	€ 30.033	€ 1.595	€ 77.697	97,8%	97,9%	67	79	9	€ 55.330	€ 77.697
€ 1.536	€ 27.490	€ 12.436	€ 31.664	€ 1.605	€ 74.731	97,9%	98,4%	71	86	10	€ 54.114	€ 74.731
€ 1.588	€ 28.339	€ 12.098	€ 31.386	€ 1.638	€ 75.049	98,0%	98,5%	70	99	11	€ 56.156	€ 75.049
€ 1.488	€ 26.713	€ 9.480	€ 35.119	€ 1.591	€ 74.392	98,9%	98,7%	78	103	12	€ 61.035	€ 74.392
€ 1.511	€ 27.237	€ 16.521	€ 35.027	€ 1.606	€ 81.903	98,1%	97,9%	78	114	13	€ 81.903	€ 81.903

Appendix I – Costs of interventions

Appendix I1 - Output costs intervention 1

Item	Service level	Total Handling costs	Total Shipping costs	Total Shortage costs	Total Holding costs	Total Ordering cost	Sum Total costs
GB10000	0.95	€ 1,506	€ 27,054	€ 3,640	€ 41,300	€ 1,562	€ 75,062
7777234A06M00	0.95	€ 1,975	€ 35,565	€ 22,157	€ 62,205	€ 1,692	€ 123,594
10DN00M050M00	0.95	€ 3,570	€ 63,430	€ 20,227	€ 35,511	€ 2,047	€ 124,786
44D0600C18001	0.95	€ 150	€ 2,668	€ 2,121	€ 2,573	€ 1,626	€ 9,139
44EZ200000000	0.95	€ 804	€ 14,258	€ 11,891	€ 14,682	€ 1,026	€ 42,660
50E0400000010	0.95	€ 194	€ 3,475	€ -00	€ 23,462	€ 2,103	€ 29,234
AB-00285-L-3	0.95	€ 2,149	€ 38,192	€ 17,939	€ 28,225	€ 1,755	€ 88,259
A0158716000A4	0.95	€ 101	€ 1,675	€ 166	€ 8,429	€ 1,990	€ 12,361
44BZ200000005	0.95	€ 761	€ 13,413	€ 2,313	€ 13,643	€ 1,059	€ 31,187
162C002600000	0.95	€ 406	€ 7,266	€ 4,990	€ 9,730	€ 2,110	€ 24,502
22F0Z10000001	0.95	€ 1,385	€ 24,579	€ 10,778	€ 16,885	€ 1,629	€ 55,257
270F000000000	0.95	€ 70	€ 1,238	€ 201	€ 3,859	€ 1,012	€ 6,378
PR-99-3	0.95	€ 138	€ 244	€ 97	€ 4,726	€ 2,023	€ 7,227
AB-133-L-1	0.95	€ 268	€ 4,741	€ 1,789	€ 10,749	€ 2,111	€ 19,659
44CZ200000000	0.95	€ 1,939	€ 34,143	€ 7,406	€ 23,941	€ 1,778	€ 69,206
AB-2749-1	0.95	€ 324	€ 5,775	€ 3,310	€ 7,114	€ 1,368	€ 17,891
21U4Z10000006	0.95	€ 491	€ 8,783	€ 1,290	€ 8,218	€ 726	€ 19,508
7777600D03911	0.95	€ 1,536	€ 27,652	€ 14,102	€ 38,530	€ 1,602	€ 83,422
22E2000K00002	0.95	€ 750	€ 13,291	€ 2,548	€ 5,584	€ 1,069	€ 23,242
24 U1600327000	0.95	€ 2,251	€ 3,942	€ 4,337	€ 4,026	€ 2,106	€ 16,661
H0PS01212DPC0	0.95	€ 420	€ 743	€ -00	€ 25,361	€ 571	€ 27,094
H0SG03015DPC0	0.95	€ 562	€ 10,051	€ 2,890	€ 6,835	€ 790	€ 21,129

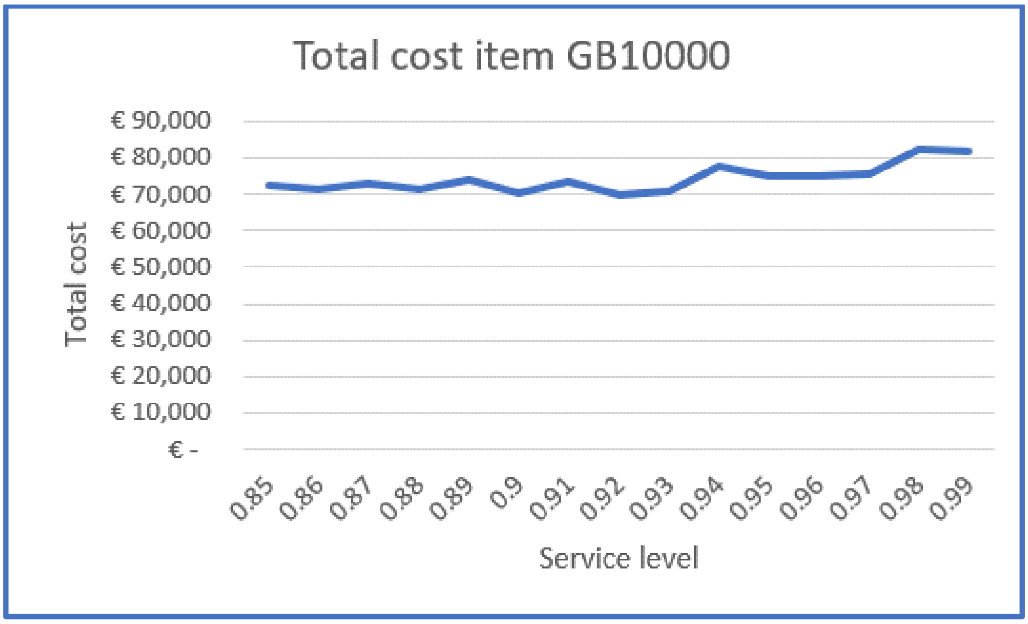
Appendix I2 - Output costs intervention 2

Item	Service level	Total Handling costs	Total Shipping costs	Total Shortage costs	Total Holding costs	Total Ordering cost	Sum Total costs
GB10000	0.92	€ 1,449	€ 25,988	€ 7,000	€ 33,878	€ 1,522	€ 69,838
7777234A06M00	0.91	€ 2,004	€ 36,053	€ 17,060	€ 52,594	€ 1,675	€ 109,387
10DN00M050M00	0.99	€ 3,653	€ 64,826	€ 7,461	€ 44,042	€ 2,054	€ 122,036
44D0600C18001	0.99	€ 143	€ 2,517	€ 266	€ 3,647	€ 1,545	€ 8,117
44EZ200000000	0.96	€ 784	€ 13,918	€ 4,153	€ 15,696	€ 1,027	€ 35,577
50E0400000010	0.85	€ 204	€ 3,643	€ -00	€ 19,267	€ 2,103	€ 25,216
AB-00285-L-3	0.99	€ 2,217	€ 39,444	€ 4,419	€ 36,174	€ 1,772	€ 84,025
A0158716000A4	0.85	€ 101	€ 1,688	€ 822	€ 6,086	€ 1,982	€ 10,679
44BZ200000005	0.95	€ 761	€ 13,413	€ 2,313	€ 13,643	€ 1,059	€ 31,187
162C002600000	0.96	€ 412	€ 7,346	€ 2,994	€ 9,914	€ 2,113	€ 22,779
22F0Z10000001	0.99	€ 1,397	€ 24,776	€ 42	€ 21,301	€ 1,618	€ 49,134
270F000000000	0.85	€ 68	€ 1,213	€ 374	€ 2,884	€ 979	€ 5,517
PR-99-3	0.88	€ 136	€ 242	€ 231	€ 3,799	€ 2,014	€ 6,424
AB-133-L-1	0.92	€ 256	€ 4,564	€ 1,545	€ 10,352	€ 2,114	€ 18,830
44CZ200000000	0.99	€ 1,913	€ 33,821	€ 139	€ 30,817	€ 1,783	€ 68,473
AB-2749-1	0.98	€ 322	€ 5,750	€ 1,067	€ 8,351	€ 1,377	€ 16,867
21U4Z10000006	0.93	€ 466	€ 8,300	€ 1,327	€ 8,156	€ 691	€ 18,939
7777600D03911	0.97	€ 1,583	€ 28,429	€ 7,160	€ 40,438	€ 1,615	€ 79,225
22E2000K00002	0.98	€ 737	€ 13,058	€ 1,019	€ 6,653	€ 1,076	€ 22,544
24 U1600327000	0.99	€ 2,242	€ 3,905	€ 2,872	€ 5,240	€ 2,111	€ 16,371
H0PS01212DPC0	0.86	€ 435	€ 763	€ 23	€ 21,184	€ 595	€ 22,999
H0SG03015DPC0	0.99	€ 553	€ 9,765	€ 105	€ 8,544	€ 773	€ 19,741

Appendix J – Output per item

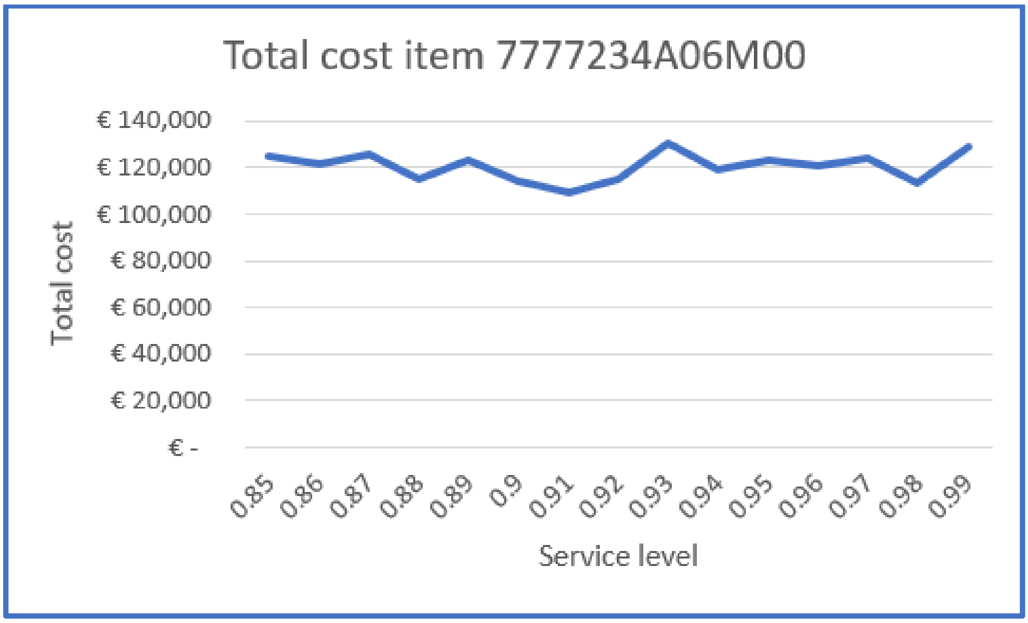
Item GB10000

Service level	Total Handling costs	Total Shipping costs	Total Shortage costs	Total Holding costs	Total Ordering cost	Sum Total costs	Order fill rate	Product fill rate	Average end inventory	Average inventory in transit
0.85	€ 1,483	€ 26,675	€ 10,640	€ 32,316	€ 1,544	€ 72,657	97.5%	97.5%	981	1494
0.86	€ 1,477	€ 26,422	€ 8,960	€ 33,047	€ 1,545	€ 71,451	97.9%	97.9%	1003	1474
0.87	€ 1,443	€ 25,916	€ 9,800	€ 34,101	€ 1,517	€ 72,777	97.6%	97.6%	1035	1446
0.88	€ 1,457	€ 26,024	€ 8,120	€ 34,168	€ 1,529	€ 71,299	98.0%	98.0%	1037	1446
0.89	€ 1,444	€ 25,790	€ 10,920	€ 34,284	€ 1,507	€ 73,945	97.4%	97.3%	1040	1443
0.9	€ 1,491	€ 26,566	€ 8,120	€ 32,781	€ 1,545	€ 70,503	98.1%	98.1%	995	1484
0.91	€ 1,467	€ 26,350	€ 10,920	€ 33,253	€ 1,539	€ 73,529	97.5%	97.4%	1009	1471
0.92	€ 1,449	€ 25,988	€ 7,000	€ 33,878	€ 1,522	€ 69,838	98.3%	98.3%	1028	1455
0.93	€ 1,446	€ 25,934	€ 7,560	€ 34,440	€ 1,537	€ 70,917	98.1%	98.2%	1045	1439
0.94	€ 1,494	€ 26,783	€ 5,600	€ 42,095	€ 1,519	€ 77,491	98.6%	98.7%	1277	1500
0.95	€ 1,506	€ 27,054	€ 3,640	€ 41,300	€ 1,562	€ 75,062	99.1%	99.2%	1253	1524
0.96	€ 1,434	€ 25,699	€ 1,960	€ 44,296	€ 1,495	€ 74,884	99.5%	99.5%	1344	1441
0.97	€ 1,533	€ 27,487	€ 4,200	€ 40,632	€ 1,551	€ 75,403	99.0%	99.0%	1233	1538
0.98	€ 1,516	€ 27,180	€ 840	€ 51,202	€ 1,572	€ 82,310	99.8%	99.8%	1554	1520
0.99	€ 1,535	€ 27,578	€ 280	€ 50,753	€ 1,579	€ 81,725	99.9%	99.9%	1540	1529



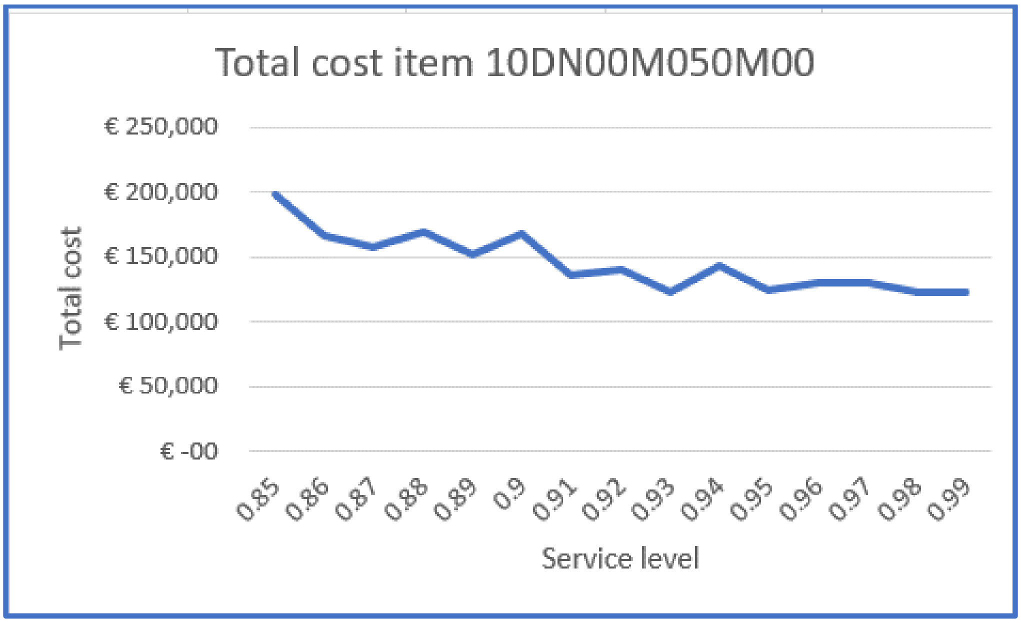
Item 7777234A06M00

Service level	Total Handling costs	Total Shipping costs	Total Shortage costs	Total Holding costs	Total Ordering cost	Sum Total costs	Order fill rate	Product fill rate	Average end inventory	Average inventory in transit
0.85	€ 1,961	€ 35,150	€ 39,722	€ 46,333	€ 1,646	€ 124,811	95.6%	95.8%	360	524
0.86	€ 1,983	€ 35,601	€ 35,771	€ 46,243	€ 1,665	€ 121,263	96.7%	96.2%	359	533
0.87	€ 1,971	€ 35,439	€ 38,197	€ 48,192	€ 1,669	€ 125,468	96.2%	96.0%	375	528
0.88	€ 1,948	€ 34,897	€ 25,578	€ 50,877	€ 1,661	€ 114,961	97.3%	97.3%	395	521
0.89	€ 1,997	€ 36,035	€ 34,253	€ 49,320	€ 1,656	€ 123,262	97.2%	96.4%	383	540
0.9	€ 1,992	€ 35,565	€ 23,008	€ 52,006	€ 1,675	€ 114,246	97.5%	97.5%	404	532
0.91	€ 2,004	€ 36,053	€ 17,060	€ 52,594	€ 1,675	€ 109,387	97.9%	98.2%	409	539
0.92	€ 1,941	€ 34,951	€ 19,322	€ 56,940	€ 1,624	€ 114,777	97.6%	97.9%	443	522
0.93	€ 1,999	€ 35,981	€ 33,976	€ 56,995	€ 1,695	€ 130,646	97.6%	96.6%	443	534
0.94	€ 2,005	€ 35,963	€ 21,363	€ 58,412	€ 1,666	€ 119,410	97.9%	97.7%	454	539
0.95	€ 1,975	€ 35,565	€ 22,157	€ 62,205	€ 1,692	€ 123,594	98.5%	97.7%	483	529
0.96	€ 2,043	€ 36,613	€ 17,338	€ 62,871	€ 1,732	€ 120,596	98.6%	98.2%	489	545
0.97	€ 2,084	€ 37,498	€ 17,886	€ 64,671	€ 1,722	€ 123,861	98.5%	98.2%	503	557
0.98	€ 2,089	€ 37,480	€ 2,344	€ 69,615	€ 1,701	€ 113,229	99.6%	99.8%	541	556
0.99	€ 2,086	€ 37,372	€ 11,453	€ 76,519	€ 1,693	€ 129,124	98.9%	98.8%	595	560



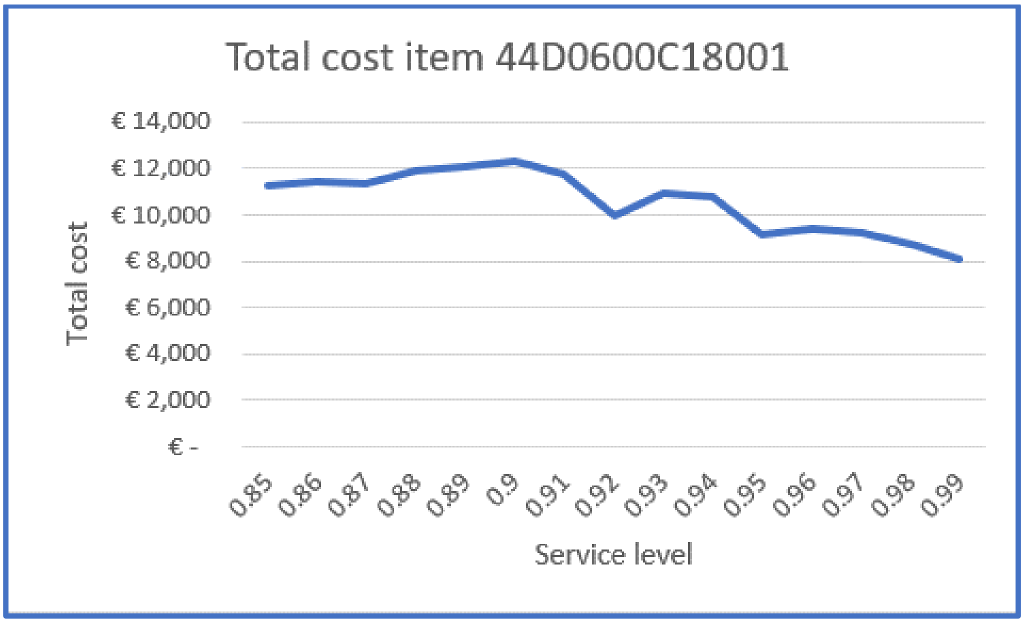
Item 10DN00M050M00

Service level	Total Handling costs	Total Shipping costs	Total Shortage costs	Total Holding costs	Total Ordering cost	Sum Total costs	Order fill rate	Product fill rate	Average end inventory	Average inventory in transit
0.85	€ 3,547	€ 62,929	€ 102,403	€ 26,776	€ 2,023	€ 197,679	95.3%	96.1%	332	653
0.86	€ 3,614	€ 64,110	€ 69,724	€ 26,326	€ 2,027	€ 165,801	96.4%	97.4%	327	663
0.87	€ 3,580	€ 63,538	€ 60,734	€ 27,682	€ 2,034	€ 157,568	97.2%	97.7%	344	656
0.88	€ 3,630	€ 64,199	€ 72,023	€ 27,477	€ 2,053	€ 169,383	96.9%	97.3%	341	667
0.89	€ 3,560	€ 63,251	€ 53,678	€ 29,124	€ 2,030	€ 151,643	97.2%	97.9%	361	657
0.9	€ 3,599	€ 63,555	€ 68,561	€ 29,591	€ 2,053	€ 167,358	96.9%	97.4%	367	661
0.91	€ 3,621	€ 64,182	€ 35,763	€ 30,490	€ 2,056	€ 136,112	98.2%	98.6%	378	661
0.92	€ 3,635	€ 64,414	€ 38,939	€ 30,877	€ 2,042	€ 139,906	98.0%	98.5%	383	666
0.93	€ 3,573	€ 63,448	€ 21,181	€ 33,023	€ 2,044	€ 123,270	98.6%	99.2%	410	655
0.94	€ 3,656	€ 64,593	€ 39,331	€ 33,219	€ 2,046	€ 142,845	98.2%	98.5%	412	665
0.95	€ 3,570	€ 63,430	€ 20,227	€ 35,511	€ 2,047	€ 124,786	99.1%	99.2%	441	655
0.96	€ 3,591	€ 63,681	€ 23,598	€ 36,723	€ 2,060	€ 129,653	99.0%	99.1%	456	660
0.97	€ 3,695	€ 65,273	€ 21,521	€ 36,925	€ 2,034	€ 129,448	99.1%	99.2%	458	679
0.98	€ 3,692	€ 65,505	€ 11,760	€ 39,429	€ 2,052	€ 122,437	99.4%	99.6%	489	680
0.99	€ 3,653	€ 64,826	€ 7,461	€ 44,042	€ 2,054	€ 122,036	99.8%	99.7%	547	672



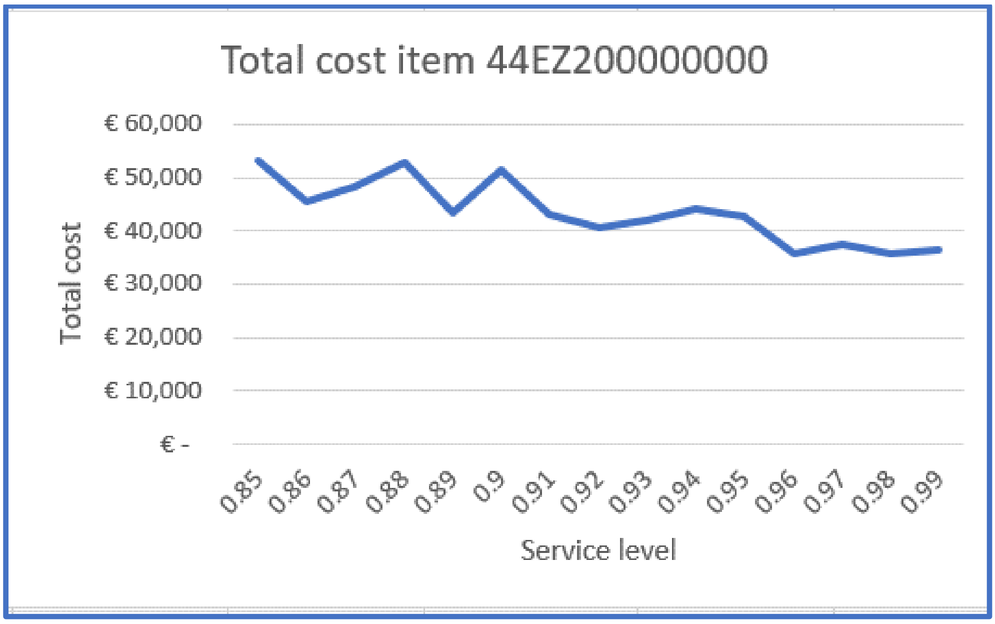
Item 44D0600C18001

Service level	Total Handling costs	Total Shipping costs	Total Shortage costs	Total Holding costs	Total Ordering cost	Sum Total costs	Order fill rate	Product fill rate	Average end inventory	Average inventory in transit
0.85	€ 140	€ 2,465	€ 5,121	€ 2,001	€ 1,511	€ 11,237	94.5%	94.3%	55	66
0.86	€ 141	€ 2,491	€ 5,171	€ 2,042	€ 1,591	€ 11,436	94.3%	94.3%	56	67
0.87	€ 147	€ 2,586	€ 5,044	€ 2,003	€ 1,527	€ 11,306	94.1%	94.6%	55	70
0.88	€ 142	€ 2,493	€ 5,625	€ 2,146	€ 1,545	€ 11,951	95.1%	93.9%	59	68
0.89	€ 142	€ 2,518	€ 5,690	€ 2,181	€ 1,548	€ 12,079	94.8%	93.9%	60	68
0.9	€ 145	€ 2,575	€ 5,879	€ 2,198	€ 1,544	€ 12,341	94.6%	93.8%	60	70
0.91	€ 146	€ 2,590	€ 5,248	€ 2,253	€ 1,549	€ 11,786	94.7%	94.5%	61	70
0.92	€ 142	€ 2,512	€ 3,273	€ 2,485	€ 1,529	€ 9,941	96.4%	96.4%	68	68
0.93	€ 147	€ 2,594	€ 4,208	€ 2,442	€ 1,517	€ 10,907	95.8%	95.5%	67	70
0.94	€ 146	€ 2,579	€ 3,962	€ 2,564	€ 1,522	€ 10,773	95.8%	95.7%	70	70
0.95	€ 150	€ 2,668	€ 2,121	€ 2,573	€ 1,626	€ 9,139	97.7%	97.7%	70	72
0.96	€ 151	€ 2,671	€ 2,341	€ 2,694	€ 1,566	€ 9,424	97.5%	97.5%	74	73
0.97	€ 154	€ 2,711	€ 1,937	€ 2,842	€ 1,582	€ 9,226	98.3%	98.0%	78	74
0.98	€ 156	€ 2,767	€ 1,247	€ 3,022	€ 1,565	€ 8,757	98.2%	98.7%	82	75
0.99	€ 143	€ 2,517	€ 266	€ 3,647	€ 1,545	€ 8,117	99.7%	99.7%	100	69



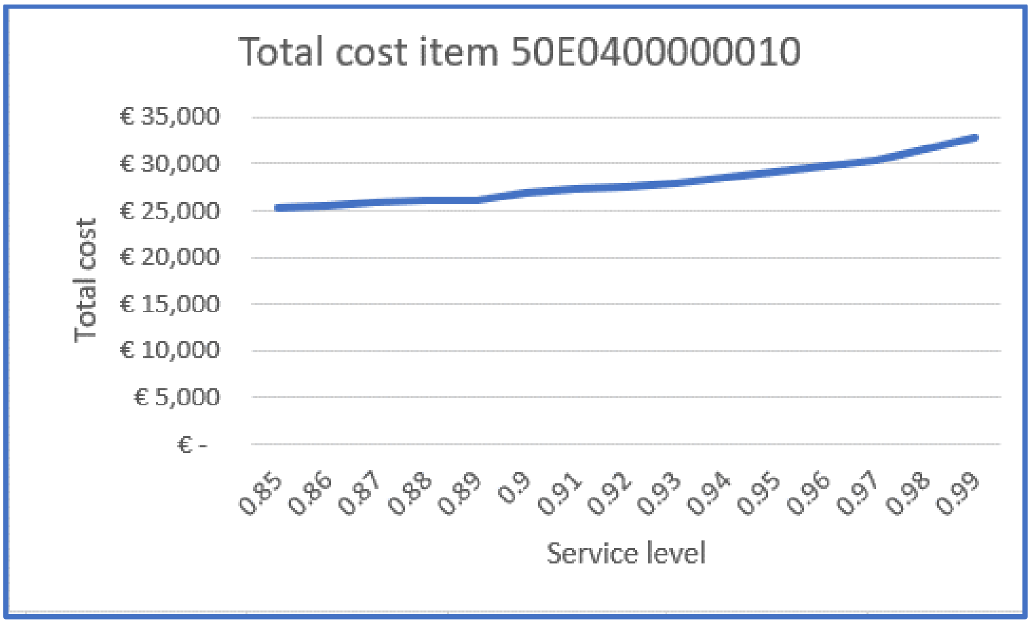
Item 44EZ200000000

Service level	Total Handling costs	Total Shipping costs	Total Shortage costs	Total Holding costs	Total Ordering cost	Sum Total costs	Order fill rate	Product fill rate	Average end inventory	Average inventory in transit
0.85	€ 801	€ 14,150	€ 26,199	€ 11,112	€ 1,041	€ 53,303	96.0%	96.3%	181	240
0.86	€ 801	€ 14,258	€ 18,079	€ 11,213	€ 1,046	€ 45,395	97.3%	97.4%	183	242
0.87	€ 788	€ 14,025	€ 20,552	€ 11,924	€ 1,041	€ 48,330	96.9%	97.0%	194	235
0.88	€ 811	€ 14,347	€ 24,808	€ 11,779	€ 1,040	€ 52,785	96.5%	96.5%	192	243
0.89	€ 791	€ 14,007	€ 14,924	€ 12,506	€ 1,039	€ 43,266	97.8%	97.8%	204	237
0.9	€ 773	€ 13,631	€ 22,820	€ 13,164	€ 990	€ 51,379	96.8%	96.6%	215	231
0.91	€ 755	€ 13,417	€ 13,832	€ 13,883	€ 996	€ 42,883	98.1%	97.9%	226	226
0.92	€ 795	€ 14,043	€ 11,275	€ 13,512	€ 1,051	€ 40,675	98.7%	98.3%	220	238
0.93	€ 792	€ 14,097	€ 12,021	€ 14,093	€ 1,026	€ 42,028	98.2%	98.2%	230	238
0.94	€ 810	€ 14,419	€ 13,785	€ 14,071	€ 1,053	€ 44,137	98.0%	98.0%	229	242
0.95	€ 804	€ 14,258	€ 11,891	€ 14,682	€ 1,026	€ 42,660	98.0%	98.3%	239	242
0.96	€ 784	€ 13,918	€ 4,153	€ 15,696	€ 1,027	€ 35,577	99.3%	99.3%	256	236
0.97	€ 812	€ 14,436	€ 5,292	€ 16,029	€ 1,033	€ 37,602	98.9%	99.2%	261	244
0.98	€ 790	€ 14,007	€ 2,352	€ 17,550	€ 1,036	€ 35,735	99.7%	99.7%	286	237
0.99	€ 795	€ 14,114	€ 1,409	€ 19,113	€ 1,004	€ 36,436	99.7%	99.8%	312	239



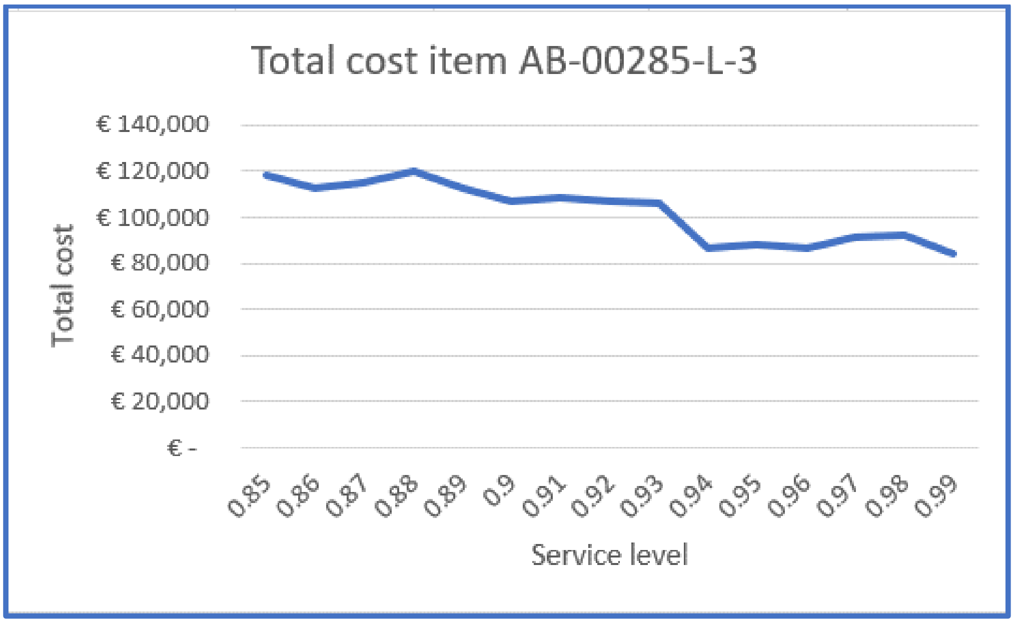
Item 50E0400000010

Service level	Total Handling costs	Total Shipping costs	Total Shortage costs	Total Holding costs	Total Ordering cost	Sum Total costs	Order fill rate	Product fill rate	Average end inventory	Average inventory in transit
0.85	€ 204	€ 3,643	€ -00	€ 19,267	€ 2,103	€ 25,216	100.0%	100.0%	685	442
0.86	€ 203	€ 3,621	€ -00	€ 19,622	€ 2,107	€ 25,554	100.0%	100.0%	698	440
0.87	€ 200	€ 3,567	€ -00	€ 20,098	€ 2,109	€ 25,973	100.0%	100.0%	715	433
0.88	€ 203	€ 3,599	€ -00	€ 20,193	€ 2,109	€ 26,103	100.0%	100.0%	718	439
0.89	€ 204	€ 3,639	€ -00	€ 20,262	€ 2,106	€ 26,210	100.0%	100.0%	721	447
0.9	€ 198	€ 3,552	€ -00	€ 21,105	€ 2,099	€ 26,954	100.0%	100.0%	751	430
0.91	€ 196	€ 3,516	€ -00	€ 21,541	€ 2,101	€ 27,356	100.0%	100.0%	766	428
0.92	€ 200	€ 3,578	€ -00	€ 21,677	€ 2,106	€ 27,561	100.0%	100.0%	771	436
0.93	€ 201	€ 3,569	€ -00	€ 22,006	€ 2,111	€ 27,888	100.0%	100.0%	783	440
0.94	€ 199	€ 3,555	€ -00	€ 22,657	€ 2,093	€ 28,504	100.0%	100.0%	806	433
0.95	€ 194	€ 3,475	€ -00	€ 23,462	€ 2,103	€ 29,234	100.0%	100.0%	834	424
0.96	€ 198	€ 3,544	€ -00	€ 23,875	€ 2,097	€ 29,715	100.0%	100.0%	849	431
0.97	€ 203	€ 3,617	€ -00	€ 24,386	€ 2,096	€ 30,301	100.0%	100.0%	867	439
0.98	€ 198	€ 3,555	€ -00	€ 25,693	€ 2,109	€ 31,554	100.0%	100.0%	914	431
0.99	€ 205	€ 3,660	€ -00	€ 26,834	€ 2,106	€ 32,804	100.0%	100.0%	954	446



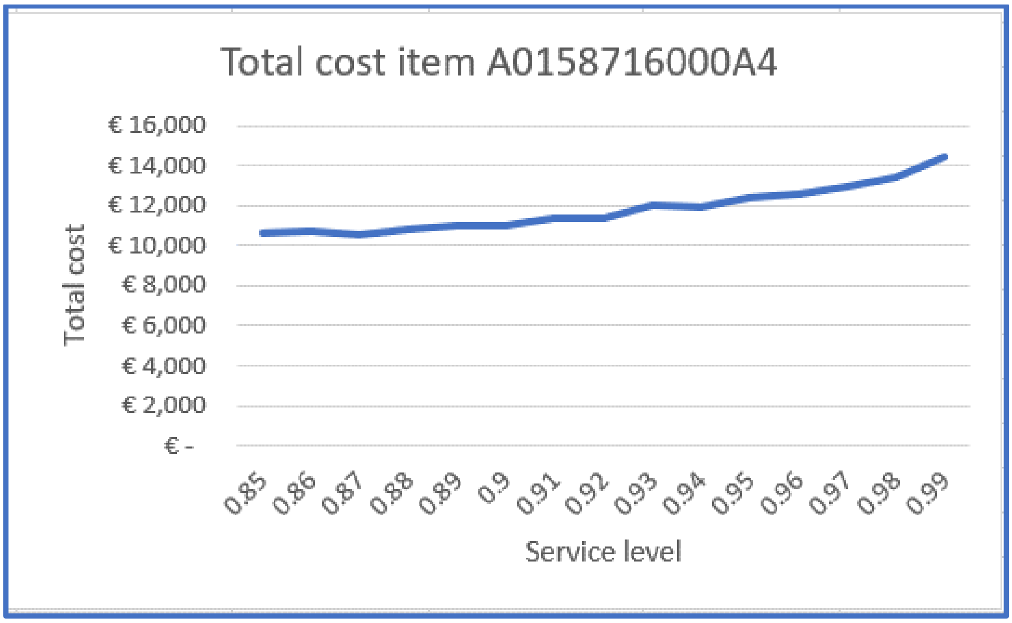
Item AB-00285-L-3

Service level	Total Handling costs	Total Shipping costs	Total Shortage costs	Total Holding costs	Total Ordering cost	Sum Total costs	Order fill rate	Product fill rate	Average end inventory	Average inventory in transit
0.85	€ 2,062	€ 36,546	€ 55,738	€ 22,162	€ 1,716	€ 118,224	95.6%	95.8%	222	376
0.86	€ 2,025	€ 35,973	€ 50,171	€ 22,911	€ 1,719	€ 112,800	96.0%	96.2%	229	375
0.87	€ 2,087	€ 37,261	€ 51,294	€ 22,454	€ 1,742	€ 114,838	95.8%	96.2%	225	383
0.88	€ 2,058	€ 36,600	€ 55,576	€ 23,741	€ 1,731	€ 119,704	95.6%	95.8%	238	378
0.89	€ 2,121	€ 37,583	€ 48,011	€ 23,194	€ 1,748	€ 112,657	96.2%	96.5%	232	391
0.9	€ 2,110	€ 37,494	€ 41,520	€ 24,194	€ 1,753	€ 107,072	96.7%	97.0%	242	388
0.91	€ 2,129	€ 37,673	€ 42,294	€ 25,059	€ 1,741	€ 108,894	96.6%	96.9%	251	386
0.92	€ 2,128	€ 37,852	€ 39,447	€ 25,801	€ 1,743	€ 106,971	96.8%	97.1%	258	387
0.93	€ 2,169	€ 38,514	€ 37,849	€ 25,790	€ 1,789	€ 106,111	97.5%	97.3%	258	396
0.94	€ 2,066	€ 36,671	€ 17,077	€ 28,838	€ 1,763	€ 86,416	98.9%	98.7%	289	379
0.95	€ 2,149	€ 38,192	€ 17,939	€ 28,225	€ 1,755	€ 88,259	98.4%	98.7%	283	397
0.96	€ 2,146	€ 38,120	€ 14,918	€ 29,919	€ 1,790	€ 86,892	98.7%	98.9%	300	393
0.97	€ 2,142	€ 38,066	€ 18,338	€ 31,180	€ 1,775	€ 91,501	98.3%	98.7%	312	399
0.98	€ 2,173	€ 38,657	€ 16,079	€ 33,623	€ 1,789	€ 92,320	98.6%	98.8%	337	397
0.99	€ 2,217	€ 39,444	€ 4,419	€ 36,174	€ 1,772	€ 84,025	99.6%	99.7%	362	408



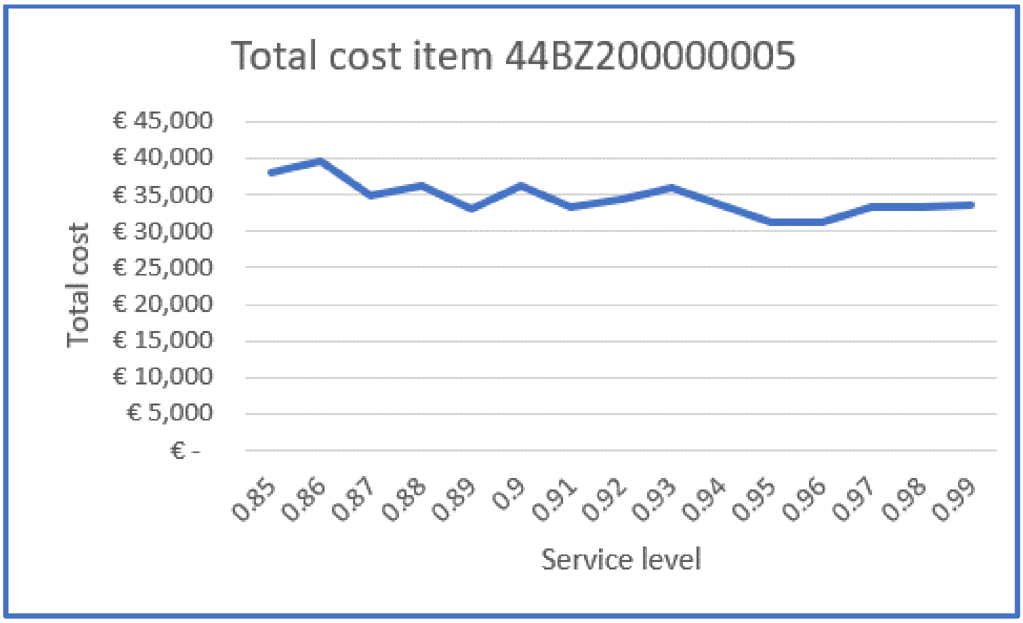
Item A0158716000A4

Service level	Total Handling costs	Total Shipping costs	Total Shortage costs	Total Holding costs	Total Ordering cost	Sum Total costs	Order fill rate	Product fill rate	Average end inventory	Average inventory in transit
0.85	€ 101	€ 1,688	€ 822	€ 6,086	€ 1,982	€ 10,679	98.4%	98.9%	1144	2056
0.86	€ 99	€ 1,649	€ 506	€ 6,553	€ 1,952	€ 10,758	99.1%	99.3%	1231	2001
0.87	€ 102	€ 1,699	€ 358	€ 6,381	€ 1,987	€ 10,528	99.3%	99.5%	1199	2060
0.88	€ 101	€ 1,684	€ 423	€ 6,608	€ 1,992	€ 10,808	99.1%	99.4%	1242	2049
0.89	€ 101	€ 1,675	€ 365	€ 6,928	€ 1,975	€ 11,042	99.2%	99.5%	1302	2027
0.9	€ 102	€ 1,686	€ 311	€ 6,927	€ 1,975	€ 11,000	99.3%	99.6%	1302	2062
0.91	€ 98	€ 1,641	€ 119	€ 7,521	€ 1,979	€ 11,358	99.6%	99.8%	1413	2001
0.92	€ 101	€ 1,684	€ 201	€ 7,449	€ 1,987	€ 11,423	99.7%	99.7%	1400	2046
0.93	€ 100	€ 1,658	€ 431	€ 7,892	€ 1,976	€ 12,057	99.3%	99.4%	1483	2015
0.94	€ 103	€ 1,710	€ 391	€ 7,769	€ 2,004	€ 11,977	99.4%	99.5%	1460	2084
0.95	€ 101	€ 1,675	€ 166	€ 8,429	€ 1,990	€ 12,361	99.7%	99.8%	1584	2029
0.96	€ 100	€ 1,674	€ 80	€ 8,771	€ 2,003	€ 12,628	99.8%	99.9%	1648	2036
0.97	€ 102	€ 1,698	€ 10	€ 9,111	€ 2,000	€ 12,921	100.0%	100.0%	1712	2055
0.98	€ 102	€ 1,697	€ 56	€ 9,632	€ 1,977	€ 13,465	99.9%	99.9%	1810	2072
0.99	€ 102	€ 1,700	€ -00	€ 10,652	€ 1,986	€ 14,441	100.0%	100.0%	2002	2062



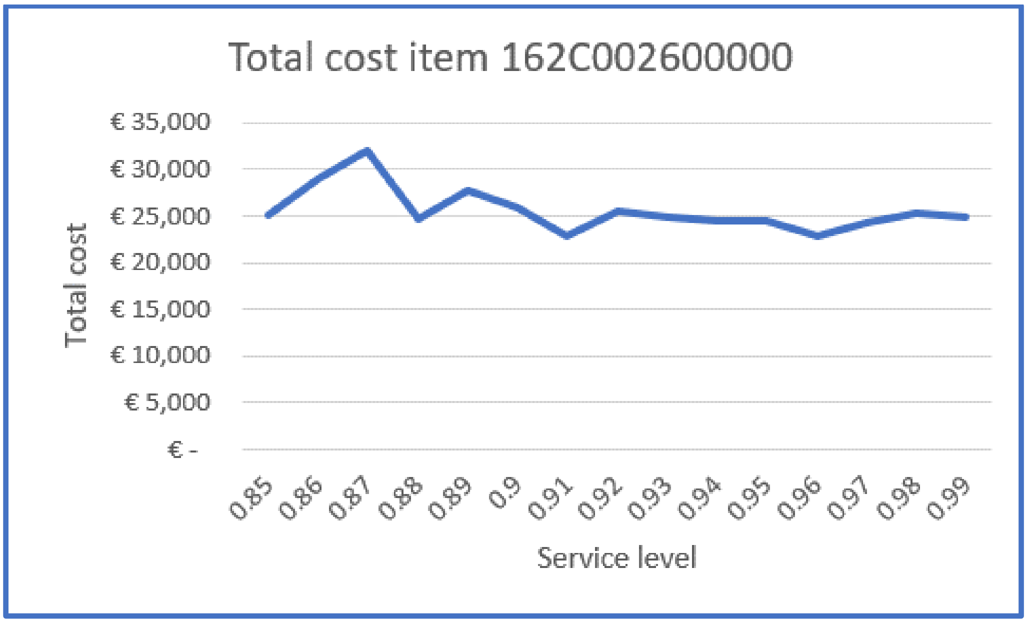
Item 44BZ200000005

Service level	Total Handling costs	Total Shipping costs	Total Shortage costs	Total Holding costs	Total Ordering cost	Sum Total costs	Order fill rate	Product fill rate	Average end inventory	Average inventory in transit
0.85	€ 764	€ 13,573	€ 11,969	€ 10,648	€ 1,070	€ 38,024	97.6%	97.8%	661	939
0.86	€ 761	€ 13,484	€ 13,548	€ 10,720	€ 1,064	€ 39,577	97.2%	97.5%	666	941
0.87	€ 783	€ 13,842	€ 8,706	€ 10,383	€ 1,096	€ 34,810	98.1%	98.4%	645	976
0.88	€ 765	€ 13,520	€ 9,602	€ 11,193	€ 1,064	€ 36,144	98.1%	98.2%	695	943
0.89	€ 744	€ 13,252	€ 6,100	€ 11,839	€ 1,036	€ 32,971	98.5%	98.8%	735	920
0.9	€ 775	€ 13,770	€ 9,076	€ 11,499	€ 1,079	€ 36,198	98.1%	98.3%	714	956
0.91	€ 760	€ 13,484	€ 5,940	€ 12,150	€ 1,053	€ 33,386	98.8%	98.9%	754	938
0.92	€ 771	€ 13,627	€ 6,474	€ 12,315	€ 1,056	€ 34,243	98.7%	98.8%	765	945
0.93	€ 779	€ 13,788	€ 7,485	€ 12,742	€ 1,074	€ 35,869	98.4%	98.6%	791	946
0.94	€ 753	€ 13,395	€ 4,947	€ 13,375	€ 1,056	€ 33,525	99.1%	99.1%	831	936
0.95	€ 761	€ 13,413	€ 2,313	€ 13,643	€ 1,059	€ 31,187	99.5%	99.6%	847	942
0.96	€ 790	€ 13,985	€ 1,674	€ 13,780	€ 1,097	€ 31,326	99.5%	99.7%	856	965
0.97	€ 774	€ 13,699	€ 3,297	€ 14,526	€ 1,074	€ 33,369	99.3%	99.4%	902	965
0.98	€ 773	€ 13,752	€ 2,177	€ 15,552	€ 1,069	€ 33,322	99.3%	99.6%	966	959
0.99	€ 767	€ 13,538	€ 784	€ 17,320	€ 1,060	€ 33,468	99.9%	99.9%	1076	937



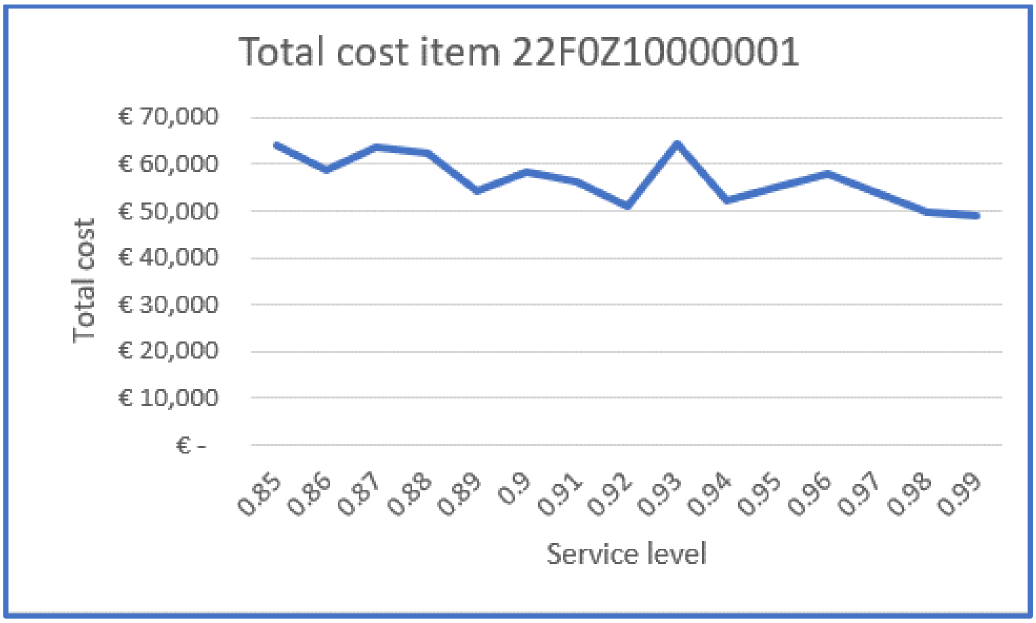
Item 162C002600000

Service level	Total Handling costs	Total Shipping costs	Total Shortage costs	Total Holding costs	Total Ordering cost	Sum Total costs	Order fill rate	Product fill rate	Average end inventory	Average inventory in transit
0.85	€ 395	€ 7,078	€ 8,208	€ 7,312	€ 2,109	€ 25,101	96.1%	97.1%	610	929
0.86	€ 398	€ 7,115	€ 11,880	€ 7,383	€ 2,107	€ 28,884	95.8%	95.9%	616	940
0.87	€ 408	€ 7,296	€ 15,032	€ 7,194	€ 2,103	€ 32,033	94.4%	95.0%	600	964
0.88	€ 397	€ 7,076	€ 7,327	€ 7,888	€ 2,109	€ 24,796	96.9%	97.4%	658	935
0.89	€ 413	€ 7,364	€ 10,333	€ 7,625	€ 2,109	€ 27,844	96.1%	96.5%	636	967
0.9	€ 399	€ 7,120	€ 8,125	€ 8,183	€ 2,104	€ 25,931	96.8%	97.2%	683	946
0.91	€ 401	€ 7,171	€ 4,877	€ 8,404	€ 2,113	€ 22,966	97.5%	98.3%	701	951
0.92	€ 411	€ 7,356	€ 7,231	€ 8,439	€ 2,111	€ 25,548	96.8%	97.6%	704	964
0.93	€ 404	€ 7,223	€ 6,143	€ 8,942	€ 2,114	€ 24,827	97.4%	97.9%	746	953
0.94	€ 393	€ 7,047	€ 5,219	€ 9,694	€ 2,116	€ 24,469	97.8%	98.1%	809	924
0.95	€ 406	€ 7,266	€ 4,990	€ 9,730	€ 2,110	€ 24,502	98.0%	98.3%	812	948
0.96	€ 412	€ 7,346	€ 2,994	€ 9,914	€ 2,113	€ 22,779	98.4%	99.0%	827	968
0.97	€ 413	€ 7,390	€ 3,816	€ 10,474	€ 2,113	€ 24,205	98.2%	98.7%	874	969
0.98	€ 422	€ 7,526	€ 4,393	€ 10,919	€ 2,111	€ 25,370	98.4%	98.5%	911	994
0.99	€ 412	€ 7,383	€ 2,621	€ 12,438	€ 2,116	€ 24,970	99.1%	99.1%	1038	971



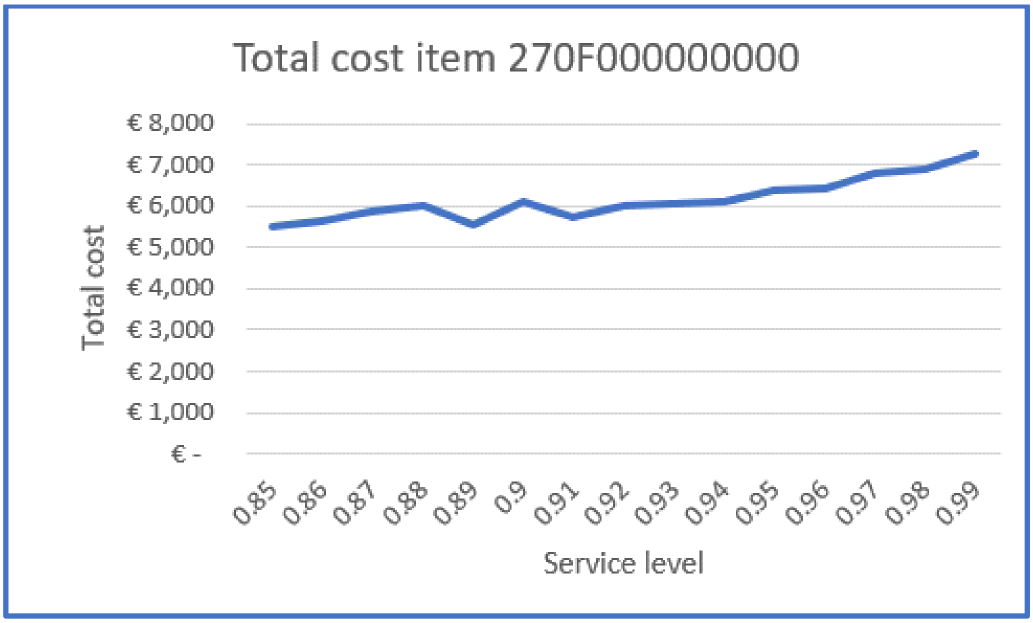
Item 22F0Z10000001

Service level	Total Handling costs	Total Shipping costs	Total Shortage costs	Total Holding costs	Total Ordering cost	Sum Total costs	Order fill rate	Product fill rate	Average end inventory	Average inventory in transit
0.85	€ 1,398	€ 24,866	€ 24,089	€ 12,242	€ 1,625	€ 64,220	96.9%	97.6%	199	380
0.86	€ 1,395	€ 24,830	€ 18,171	€ 12,879	€ 1,614	€ 58,889	97.9%	98.2%	209	376
0.87	€ 1,405	€ 24,955	€ 22,573	€ 13,009	€ 1,599	€ 63,542	97.5%	97.7%	212	380
0.88	€ 1,414	€ 25,045	€ 21,068	€ 13,403	€ 1,628	€ 62,558	97.5%	97.9%	218	378
0.89	€ 1,421	€ 25,313	€ 12,356	€ 13,425	€ 1,621	€ 54,136	98.3%	98.8%	218	382
0.9	€ 1,417	€ 25,223	€ 16,302	€ 13,793	€ 1,622	€ 58,358	98.1%	98.4%	224	383
0.91	€ 1,401	€ 24,919	€ 13,799	€ 14,560	€ 1,621	€ 56,301	98.4%	98.6%	237	376
0.92	€ 1,415	€ 25,098	€ 7,798	€ 14,926	€ 1,642	€ 50,879	99.1%	99.2%	243	377
0.93	€ 1,419	€ 25,223	€ 20,933	€ 15,208	€ 1,599	€ 64,383	98.1%	97.9%	247	381
0.94	€ 1,431	€ 25,420	€ 8,068	€ 15,501	€ 1,631	€ 52,050	98.8%	99.2%	252	384
0.95	€ 1,385	€ 24,579	€ 10,778	€ 16,885	€ 1,629	€ 55,257	98.9%	98.9%	275	372
0.96	€ 1,458	€ 25,975	€ 12,585	€ 16,207	€ 1,641	€ 57,865	98.6%	98.8%	264	392
0.97	€ 1,433	€ 25,617	€ 7,985	€ 17,195	€ 1,636	€ 53,866	99.0%	99.2%	280	389
0.98	€ 1,424	€ 25,402	€ 2,534	€ 18,774	€ 1,641	€ 49,775	99.6%	99.7%	305	383
0.99	€ 1,397	€ 24,776	€ 42	€ 21,301	€ 1,618	€ 49,134	100.0%	100.0%	346	374



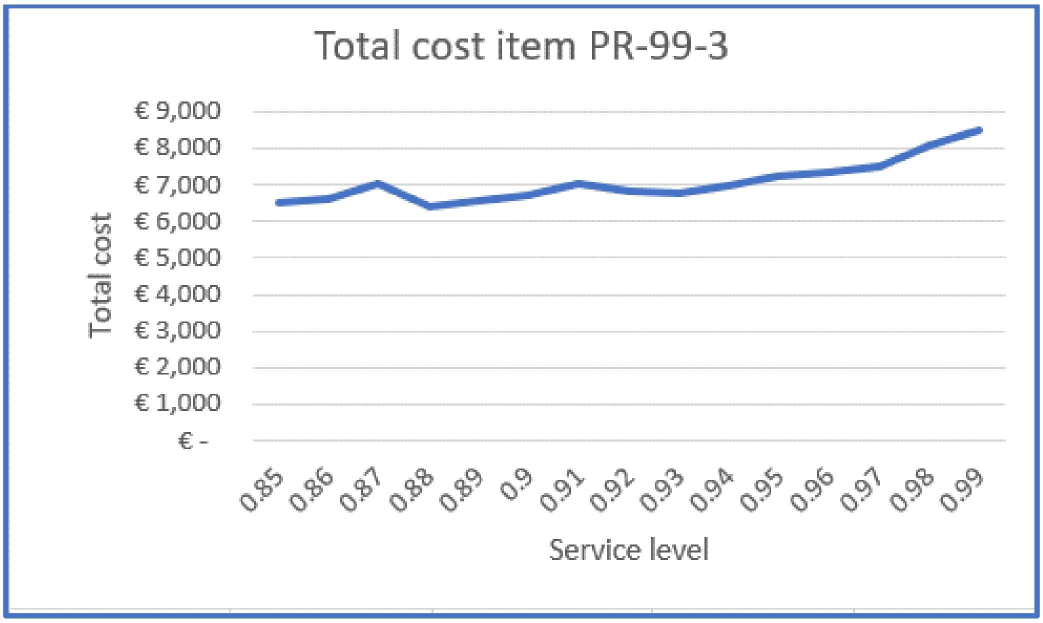
Item 270F000000000

Service level	Total Handling costs	Total Shipping costs	Total Shortage costs	Total Holding costs	Total Ordering cost	Sum Total costs	Order fill rate	Product fill rate	Average end inventory	Average inventory in transit
0.85	€ 68	€ 1,213	€ 374	€ 2,884	€ 979	€ 5,517	99.0%	99.3%	264	219
0.86	€ 71	€ 1,261	€ 460	€ 2,829	€ 1,033	€ 5,654	98.9%	99.2%	259	230
0.87	€ 69	€ 1,224	€ 585	€ 3,003	€ 987	€ 5,868	99.0%	98.9%	275	220
0.88	€ 71	€ 1,261	€ 692	€ 2,998	€ 999	€ 6,021	99.1%	98.7%	275	227
0.89	€ 70	€ 1,246	€ 145	€ 3,073	€ 1,004	€ 5,538	99.7%	99.7%	281	230
0.9	€ 70	€ 1,233	€ 618	€ 3,191	€ 990	€ 6,101	99.1%	98.8%	292	229
0.91	€ 72	€ 1,276	€ 173	€ 3,209	€ 1,021	€ 5,751	99.6%	99.7%	294	234
0.92	€ 68	€ 1,204	€ 269	€ 3,523	€ 972	€ 6,036	99.4%	99.5%	323	218
0.93	€ 71	€ 1,267	€ 180	€ 3,514	€ 1,031	€ 6,064	99.6%	99.7%	322	228
0.94	€ 71	€ 1,267	€ 133	€ 3,613	€ 1,030	€ 6,115	99.9%	99.8%	331	231
0.95	€ 70	€ 1,238	€ 201	€ 3,859	€ 1,012	€ 6,378	99.6%	99.6%	353	225
0.96	€ 72	€ 1,271	€ 128	€ 3,921	€ 1,029	€ 6,420	99.8%	99.8%	359	234
0.97	€ 71	€ 1,269	€ 239	€ 4,197	€ 1,007	€ 6,785	99.6%	99.6%	384	230
0.98	€ 70	€ 1,251	€ 34	€ 4,526	€ 1,012	€ 6,892	100.0%	99.9%	414	228
0.99	€ 71	€ 1,252	€ -00	€ 4,943	€ 999	€ 7,264	100.0%	100.0%	453	231



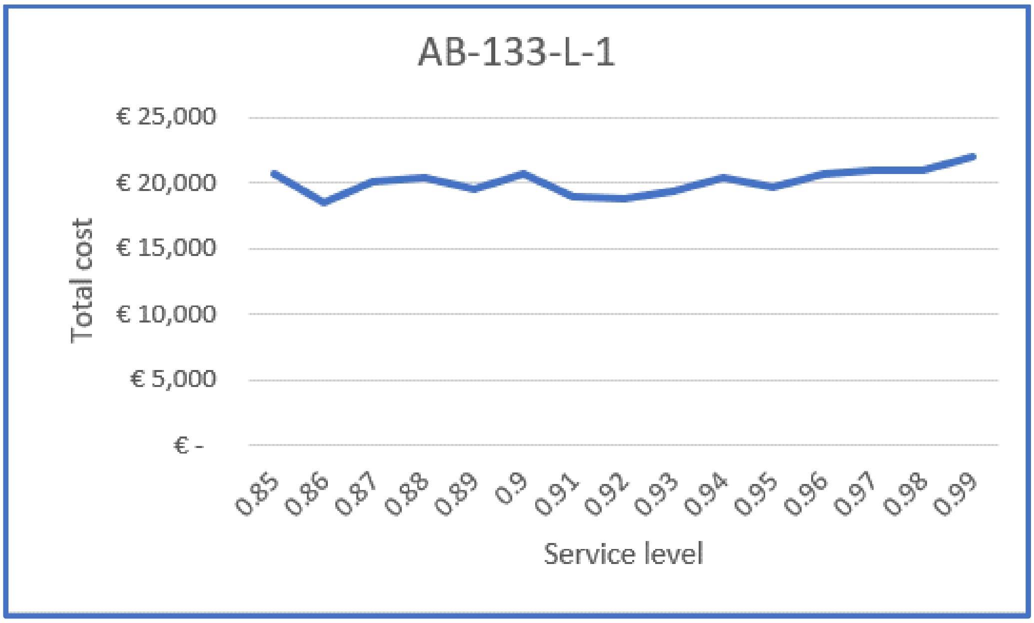
Item PR-99-3

Service level	Total Handling costs	Total Shipping costs	Total Shortage costs	Total Holding costs	Total Ordering cost	Sum Total costs	Order fill rate	Product fill rate	Average end inventory	Average inventory in transit
0.85	€ 139	€ 247	€ 707	€ 3,412	€ 2,023	€ 6,530	99.0%	99.3%	134	204
0.86	€ 135	€ 239	€ 577	€ 3,685	€ 1,994	€ 6,630	99.4%	99.4%	145	197
0.87	€ 137	€ 243	€ 973	€ 3,646	€ 2,024	€ 7,022	99.0%	99.1%	144	203
0.88	€ 136	€ 242	€ 231	€ 3,799	€ 2,014	€ 6,424	99.6%	99.8%	150	201
0.89	€ 138	€ 245	€ 330	€ 3,826	€ 1,996	€ 6,535	99.5%	99.7%	151	203
0.9	€ 136	€ 241	€ 347	€ 3,983	€ 2,016	€ 6,724	99.4%	99.7%	157	202
0.91	€ 137	€ 242	€ 500	€ 4,124	€ 2,002	€ 7,005	99.5%	99.5%	162	200
0.92	€ 137	€ 242	€ 248	€ 4,206	€ 2,010	€ 6,843	99.7%	99.8%	166	203
0.93	€ 137	€ 242	€ 24	€ 4,389	€ 1,996	€ 6,788	99.9%	100.0%	173	201
0.94	€ 136	€ 240	€ 26	€ 4,568	€ 2,017	€ 6,987	99.9%	100.0%	180	201
0.95	€ 138	€ 244	€ 97	€ 4,726	€ 2,023	€ 7,227	99.9%	99.9%	186	201
0.96	€ 139	€ 248	€ 77	€ 4,845	€ 2,027	€ 7,336	99.9%	99.9%	191	204
0.97	€ 139	€ 246	€ -00	€ 5,098	€ 2,014	€ 7,497	100.0%	100.0%	201	205
0.98	€ 135	€ 239	€ 84	€ 5,617	€ 1,989	€ 8,063	99.9%	99.9%	221	198
0.99	€ 137	€ 243	€ -00	€ 6,083	€ 2,020	€ 8,483	100.0%	100.0%	239	202



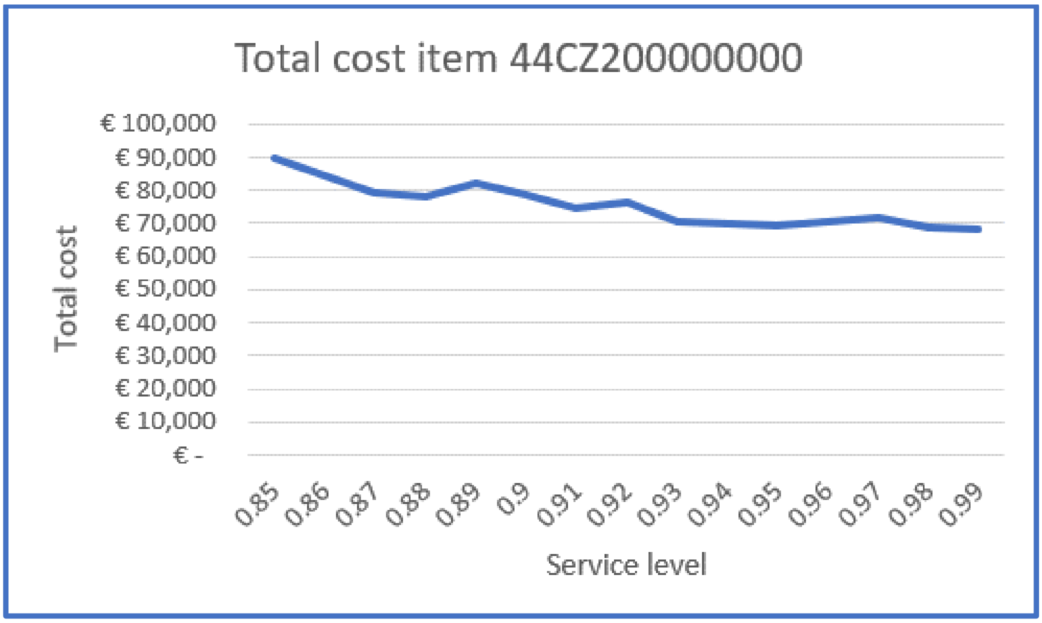
Item AB-133-L-1

Service level	Total Handling costs	Total Shipping costs	Total Shortage costs	Total Holding costs	Total Ordering cost	Sum Total costs	Order fill rate	Product fill rate	Average end inventory	Average inventory in transit
0.85	€ 258	€ 4,588	€ 5,518	€ 8,274	€ 2,104	€ 20,741	96.7%	97.2%	178	393
0.86	€ 258	€ 4,582	€ 3,066	€ 8,549	€ 2,111	€ 18,567	97.8%	98.4%	184	393
0.87	€ 258	€ 4,573	€ 4,296	€ 8,864	€ 2,106	€ 20,096	97.4%	97.8%	191	391
0.88	€ 262	€ 4,679	€ 4,768	€ 8,631	€ 2,104	€ 20,445	97.4%	97.6%	186	400
0.89	€ 257	€ 4,568	€ 3,112	€ 9,415	€ 2,110	€ 19,462	98.0%	98.4%	203	390
0.9	€ 260	€ 4,629	€ 4,286	€ 9,348	€ 2,109	€ 20,633	97.5%	97.9%	201	396
0.91	€ 259	€ 4,585	€ 2,096	€ 9,873	€ 2,119	€ 18,933	98.6%	98.9%	212	393
0.92	€ 256	€ 4,564	€ 1,545	€ 10,352	€ 2,114	€ 18,830	98.9%	99.2%	223	390
0.93	€ 263	€ 4,687	€ 2,239	€ 10,137	€ 2,110	€ 19,436	98.5%	98.9%	218	400
0.94	€ 261	€ 4,641	€ 2,834	€ 10,615	€ 2,107	€ 20,459	98.1%	98.6%	228	399
0.95	€ 268	€ 4,741	€ 1,789	€ 10,749	€ 2,111	€ 19,659	98.8%	99.1%	231	405
0.96	€ 265	€ 4,719	€ 2,275	€ 11,291	€ 2,116	€ 20,667	98.6%	98.9%	243	405
0.97	€ 257	€ 4,563	€ 1,378	€ 12,671	€ 2,114	€ 20,984	99.2%	99.3%	273	391
0.98	€ 257	€ 4,544	€ 480	€ 13,552	€ 2,116	€ 20,948	99.7%	99.7%	292	391
0.99	€ 259	€ 4,608	€ 190	€ 14,766	€ 2,113	€ 21,937	99.9%	99.9%	318	394



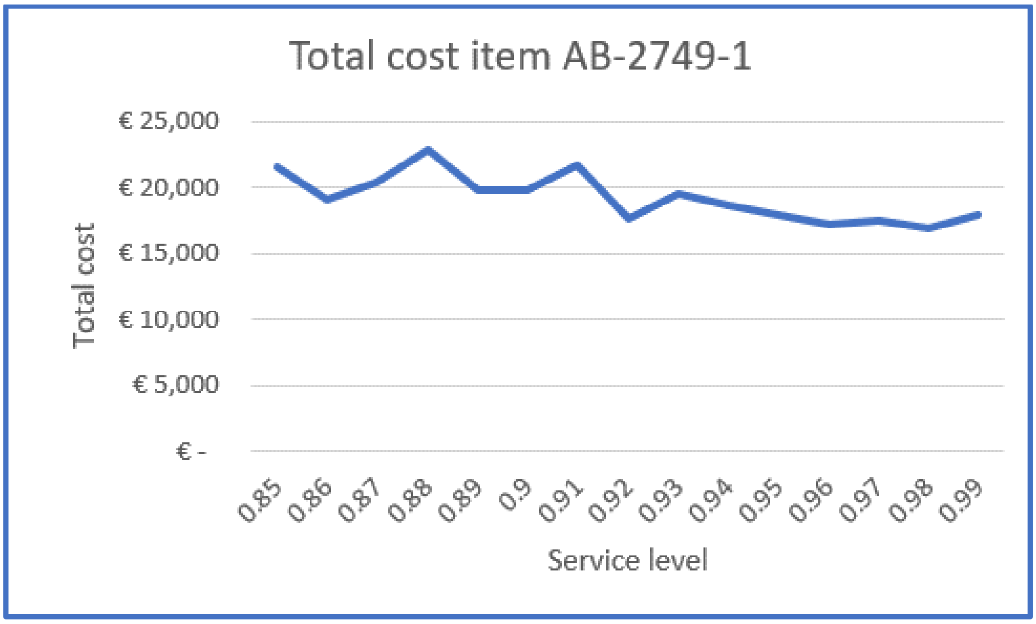
Item 44CZ200000000

Service level	Total Handling costs	Total Shipping costs	Total Shortage costs	Total Holding costs	Total Ordering cost	Sum Total costs	Order fill rate	Product fill rate	Average end inventory	Average inventory in transit
0.85	€ 1,888	€ 33,374	€ 34,058	€ 18,458	€ 1,818	€ 89,595	97.2%	97.6%	722	1074
0.86	€ 1,861	€ 32,945	€ 28,861	€ 19,289	€ 1,779	€ 84,736	97.4%	98.0%	754	1057
0.87	€ 1,919	€ 33,839	€ 23,142	€ 18,838	€ 1,796	€ 79,534	98.2%	98.4%	736	1089
0.88	€ 1,935	€ 34,107	€ 20,777	€ 19,308	€ 1,805	€ 77,933	98.3%	98.6%	755	1091
0.89	€ 1,918	€ 33,750	€ 24,962	€ 19,735	€ 1,782	€ 82,147	97.9%	98.3%	772	1097
0.9	€ 1,943	€ 34,376	€ 20,686	€ 19,821	€ 1,840	€ 78,666	98.1%	98.6%	775	1106
0.91	€ 1,893	€ 33,571	€ 16,204	€ 21,190	€ 1,768	€ 74,625	98.7%	98.9%	828	1084
0.92	€ 1,946	€ 34,358	€ 16,842	€ 21,235	€ 1,795	€ 76,175	98.6%	98.9%	830	1098
0.93	€ 1,932	€ 33,964	€ 10,698	€ 21,957	€ 1,793	€ 70,346	98.8%	99.3%	858	1100
0.94	€ 1,902	€ 33,642	€ 9,092	€ 23,645	€ 1,799	€ 70,080	99.2%	99.4%	924	1069
0.95	€ 1,939	€ 34,143	€ 7,406	€ 23,941	€ 1,778	€ 69,206	99.4%	99.5%	936	1092
0.96	€ 1,910	€ 33,911	€ 7,612	€ 25,360	€ 1,812	€ 70,605	99.4%	99.5%	991	1079
0.97	€ 1,968	€ 34,751	€ 7,989	€ 25,407	€ 1,825	€ 71,940	99.6%	99.5%	993	1121
0.98	€ 1,950	€ 34,358	€ 3,427	€ 27,141	€ 1,838	€ 68,713	99.8%	99.8%	1061	1123
0.99	€ 1,913	€ 33,821	€ 139	€ 30,817	€ 1,783	€ 68,473	99.9%	100.0%	1205	1087



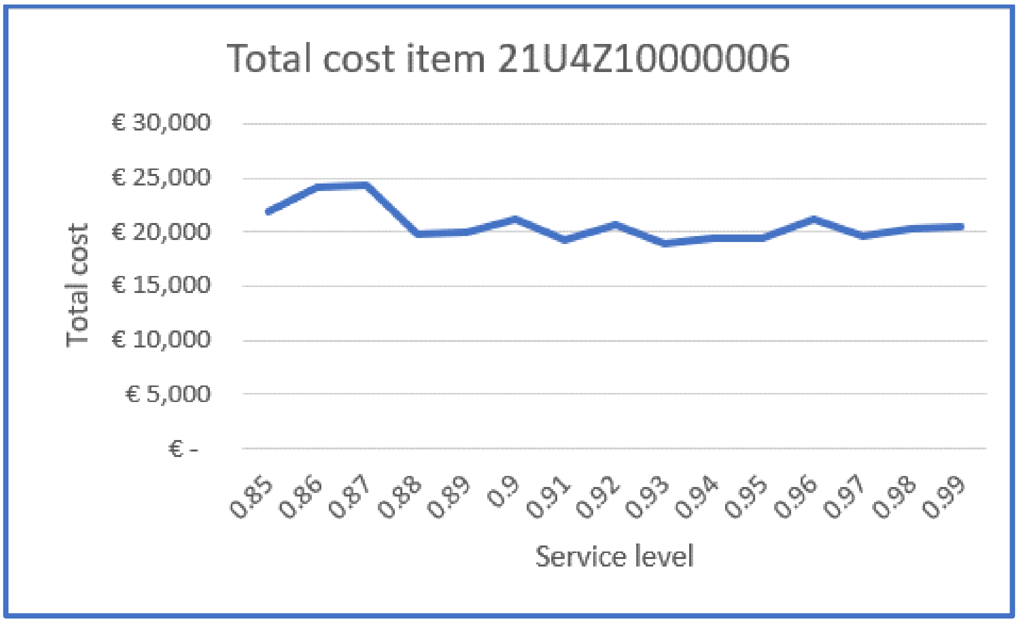
Item AB-2749-1

Service level	Total Handling costs	Total Shipping costs	Total Shortage costs	Total Holding costs	Total Ordering cost	Sum Total costs	Order fill rate	Product fill rate	Average end inventory	Average inventory in transit
0.85	€ 310	€ 5,492	€ 8,688	€ 5,724	€ 1,331	€ 21,544	96.6%	96.4%	281	337
0.86	€ 327	€ 5,805	€ 6,119	€ 5,459	€ 1,390	€ 19,099	97.3%	97.6%	268	354
0.87	€ 318	€ 5,636	€ 7,300	€ 5,820	€ 1,368	€ 20,441	97.0%	97.0%	285	343
0.88	€ 328	€ 5,810	€ 9,694	€ 5,668	€ 1,391	€ 22,890	96.2%	96.2%	278	356
0.89	€ 318	€ 5,636	€ 6,462	€ 6,043	€ 1,348	€ 19,807	97.3%	97.4%	296	347
0.9	€ 330	€ 5,870	€ 6,143	€ 6,066	€ 1,398	€ 19,806	97.3%	97.6%	297	351
0.91	€ 321	€ 5,725	€ 7,925	€ 6,429	€ 1,368	€ 21,770	97.4%	96.9%	315	343
0.92	€ 316	€ 5,626	€ 3,648	€ 6,627	€ 1,375	€ 17,593	98.5%	98.5%	325	344
0.93	€ 323	€ 5,745	€ 5,563	€ 6,601	€ 1,370	€ 19,602	98.0%	97.8%	324	353
0.94	€ 330	€ 5,880	€ 4,309	€ 6,728	€ 1,395	€ 18,642	98.2%	98.3%	330	356
0.95	€ 324	€ 5,775	€ 3,310	€ 7,114	€ 1,368	€ 17,891	99.0%	98.7%	349	353
0.96	€ 332	€ 5,899	€ 2,274	€ 7,278	€ 1,380	€ 17,163	98.8%	99.1%	357	359
0.97	€ 320	€ 5,676	€ 2,159	€ 7,954	€ 1,354	€ 17,462	99.0%	99.1%	390	346
0.98	€ 322	€ 5,750	€ 1,067	€ 8,351	€ 1,377	€ 16,867	99.5%	99.6%	409	351
0.99	€ 330	€ 5,880	€ 1,239	€ 9,073	€ 1,394	€ 17,915	99.6%	99.5%	445	353



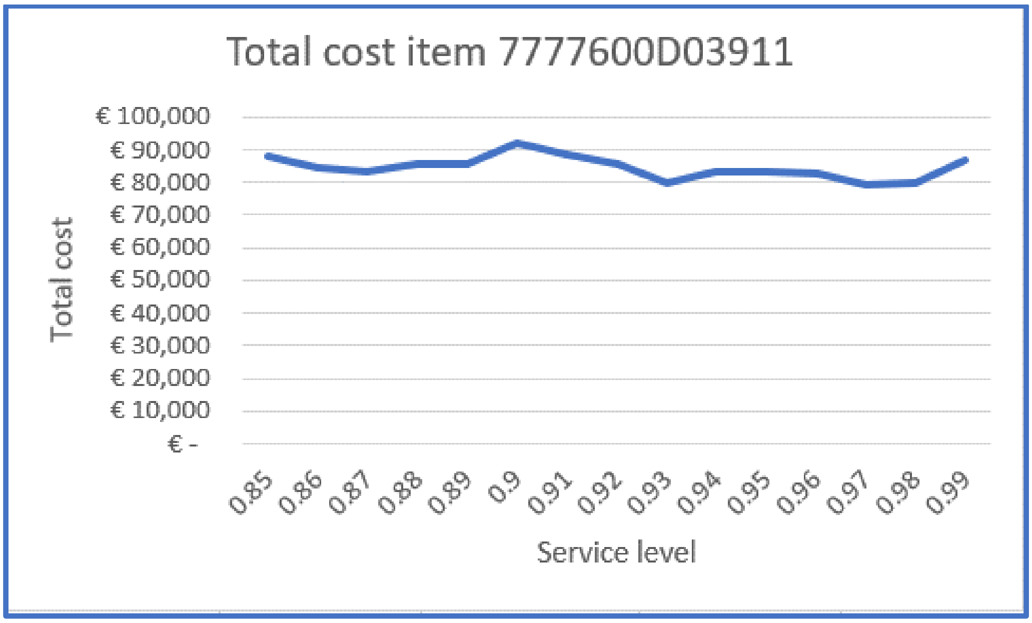
Item 21U4Z10000006

Service level	Total Handling costs	Total Shipping costs	Total Shortage costs	Total Holding costs	Total Ordering cost	Sum Total costs	Order fill rate	Product fill rate	Average end inventory	Average inventory in transit
0.85	€ 485	€ 8,640	€ 5,558	€ 6,458	€ 710	€ 21,851	97.9%	98.4%	109	148
0.86	€ 481	€ 8,604	€ 7,548	€ 6,791	€ 705	€ 24,129	97.7%	97.8%	114	145
0.87	€ 477	€ 8,514	€ 7,576	€ 6,976	€ 692	€ 24,235	97.8%	97.8%	117	145
0.88	€ 468	€ 8,353	€ 3,115	€ 7,189	€ 693	€ 19,819	98.6%	99.1%	121	142
0.89	€ 497	€ 8,854	€ 2,922	€ 6,947	€ 733	€ 19,953	99.0%	99.2%	117	149
0.9	€ 484	€ 8,658	€ 3,880	€ 7,414	€ 716	€ 21,151	98.7%	98.9%	125	145
0.91	€ 476	€ 8,461	€ 1,936	€ 7,667	€ 706	€ 19,246	99.4%	99.4%	129	143
0.92	€ 484	€ 8,640	€ 3,161	€ 7,645	€ 710	€ 20,640	98.9%	99.1%	129	147
0.93	€ 466	€ 8,300	€ 1,327	€ 8,156	€ 691	€ 18,939	99.4%	99.6%	137	140
0.94	€ 479	€ 8,568	€ 1,438	€ 8,227	€ 710	€ 19,422	99.4%	99.6%	139	143
0.95	€ 491	€ 8,783	€ 1,290	€ 8,218	€ 726	€ 19,508	99.5%	99.6%	138	148
0.96	€ 479	€ 8,514	€ 2,590	€ 8,818	€ 712	€ 21,113	99.3%	99.2%	148	144
0.97	€ 494	€ 8,765	€ 700	€ 8,853	€ 726	€ 19,539	99.7%	99.8%	149	148
0.98	€ 477	€ 8,532	€ 968	€ 9,564	€ 700	€ 20,241	99.6%	99.7%	161	145
0.99	€ 491	€ 8,765	€ 212	€ 10,320	€ 718	€ 20,506	99.9%	99.9%	174	147



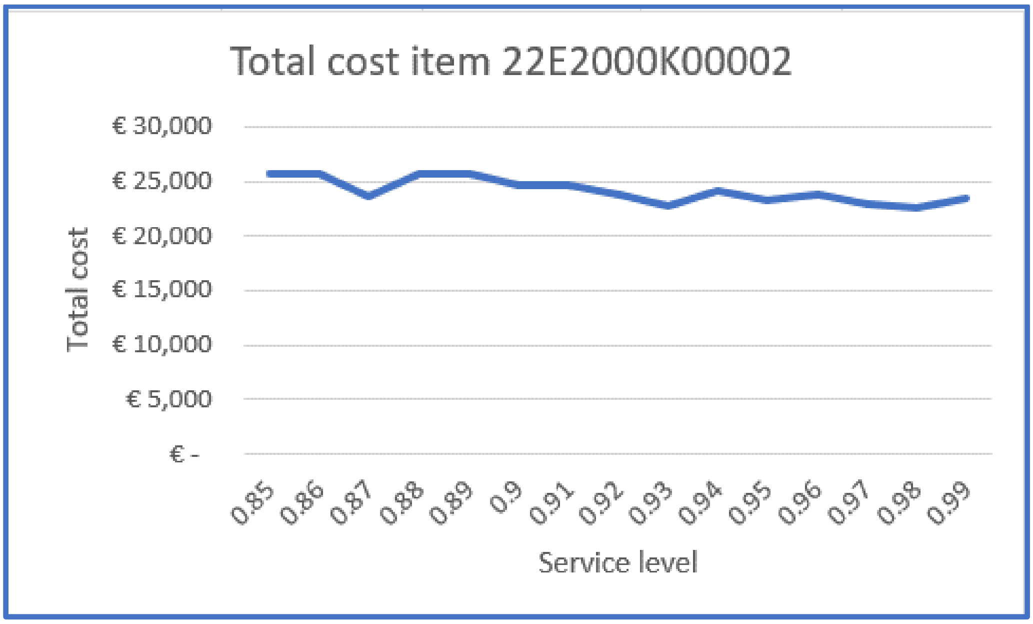
<u>Item 7777600D03911</u>

Service level	Total Handling costs	Total Shipping costs	Total Shortage costs	Total Holding costs	Total Ordering cost	Sum Total costs	Order fill rate	Product fill rate	Average end inventory	Average inventory in transit
0.85	€ 1,512	€ 27,129	€ 28,104	€ 29,620	€ 1,606	€ 87,971	96.1%	96.4%	88	150
0.86	€ 1,489	€ 26,894	€ 23,760	€ 30,681	€ 1,602	€ 84,426	97.1%	96.9%	91	148
0.87	€ 1,516	€ 27,273	€ 22,769	€ 30,204	€ 1,668	€ 83,430	97.2%	97.1%	90	153
0.88	€ 1,523	€ 27,327	€ 23,741	€ 31,283	€ 1,598	€ 85,472	97.0%	96.9%	93	153
0.89	€ 1,519	€ 27,291	€ 22,372	€ 32,665	€ 1,575	€ 85,423	97.4%	97.1%	97	151
0.9	€ 1,527	€ 27,472	€ 28,620	€ 32,741	€ 1,594	€ 91,954	96.6%	96.3%	97	153
0.91	€ 1,538	€ 27,707	€ 25,248	€ 32,666	€ 1,594	€ 88,752	96.0%	96.8%	97	156
0.92	€ 1,561	€ 28,014	€ 21,519	€ 32,759	€ 1,626	€ 85,479	97.1%	97.3%	97	158
0.93	€ 1,545	€ 27,815	€ 13,983	€ 34,706	€ 1,604	€ 79,652	98.1%	98.2%	103	156
0.94	€ 1,518	€ 27,255	€ 15,252	€ 37,627	€ 1,621	€ 83,273	98.3%	98.0%	112	152
0.95	€ 1,536	€ 27,652	€ 14,102	€ 38,530	€ 1,602	€ 83,422	98.1%	98.2%	115	152
0.96	€ 1,553	€ 28,068	€ 12,574	€ 38,784	€ 1,612	€ 82,591	98.6%	98.4%	115	157
0.97	€ 1,583	€ 28,429	€ 7,160	€ 40,438	€ 1,615	€ 79,225	99.0%	99.1%	120	159
0.98	€ 1,566	€ 28,140	€ 4,978	€ 43,654	€ 1,628	€ 79,966	99.3%	99.4%	130	157
0.99	€ 1,499	€ 26,876	€ 5,573	€ 51,282	€ 1,614	€ 86,844	99.5%	99.3%	153	150



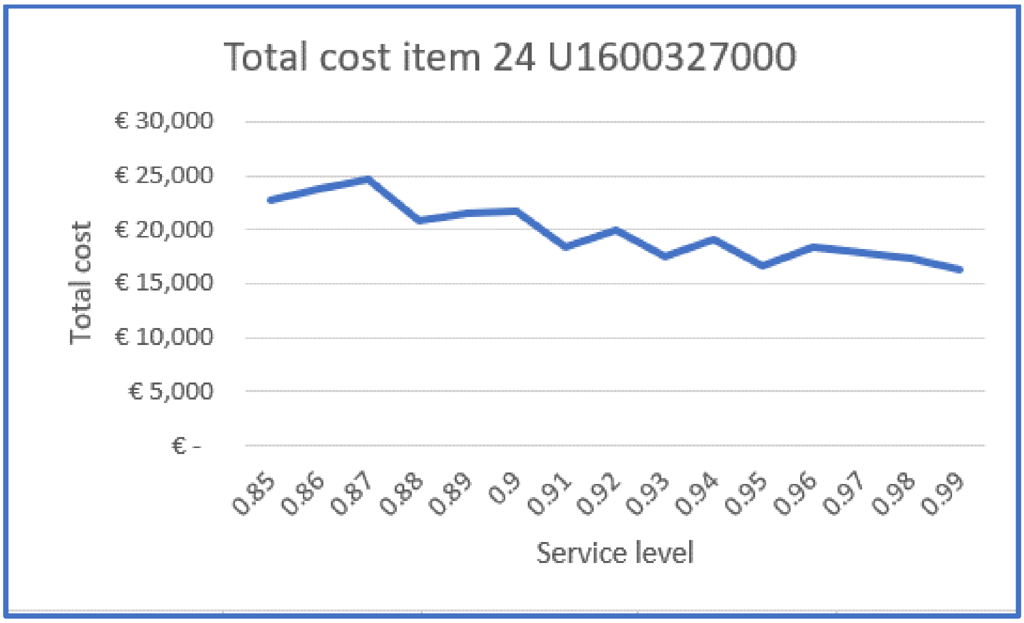
Item 22E2000K00002

Service level	Total Handling costs	Total Shipping costs	Total Shortage costs	Total Holding costs	Total Ordering cost	Sum Total costs	Order fill rate	Product fill rate	Average end inventory	Average inventory in transit
0.85	€ 704	€ 12,468	€ 6,916	€ 4,556	€ 1,036	€ 25,680	96.4%	96.1%	39	42
0.86	€ 734	€ 12,969	€ 6,503	€ 4,445	€ 1,117	€ 25,769	96.4%	96.4%	38	44
0.87	€ 725	€ 12,754	€ 4,356	€ 4,754	€ 1,013	€ 23,602	97.4%	97.7%	40	43
0.88	€ 744	€ 13,291	€ 5,909	€ 4,662	€ 1,059	€ 25,665	96.9%	96.8%	40	45
0.89	€ 733	€ 12,987	€ 6,018	€ 4,893	€ 1,046	€ 25,677	96.5%	96.7%	42	44
0.9	€ 738	€ 13,058	€ 4,829	€ 4,932	€ 1,069	€ 24,626	97.7%	97.4%	42	44
0.91	€ 731	€ 13,058	€ 4,683	€ 5,110	€ 1,030	€ 24,613	97.3%	97.5%	43	44
0.92	€ 727	€ 12,897	€ 3,931	€ 5,235	€ 1,046	€ 23,836	97.5%	97.8%	45	44
0.93	€ 735	€ 12,951	€ 2,657	€ 5,403	€ 1,034	€ 22,781	98.8%	98.5%	46	44
0.94	€ 736	€ 13,022	€ 3,725	€ 5,528	€ 1,051	€ 24,063	97.8%	97.9%	47	44
0.95	€ 750	€ 13,291	€ 2,548	€ 5,584	€ 1,069	€ 23,242	98.3%	98.6%	47	46
0.96	€ 762	€ 13,470	€ 2,609	€ 5,784	€ 1,083	€ 23,707	98.3%	98.6%	49	46
0.97	€ 748	€ 13,166	€ 1,662	€ 6,255	€ 1,073	€ 22,904	99.0%	99.1%	53	45
0.98	€ 737	€ 13,058	€ 1,019	€ 6,653	€ 1,076	€ 22,544	99.3%	99.4%	57	44
0.99	€ 730	€ 12,951	€ 1,298	€ 7,454	€ 1,024	€ 23,457	99.4%	99.3%	63	44



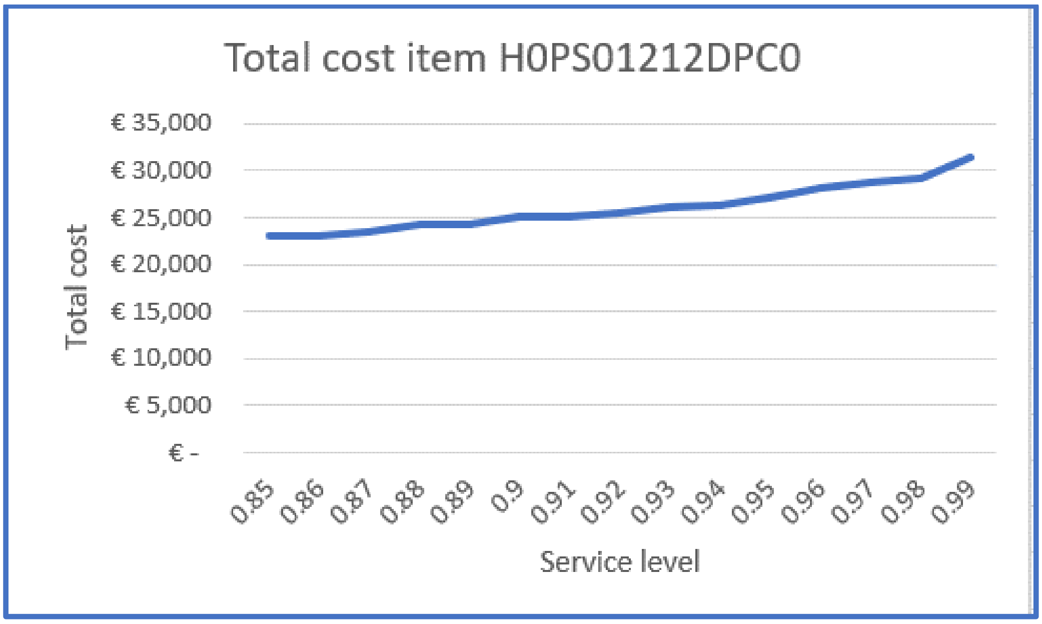
Item 24 U1600327000

Service level	Total Handling costs	Total Shipping costs	Total Shortage costs	Total Holding costs	Total Ordering cost	Sum Total costs	Order fill rate	Product fill rate	Average end inventory	Average inventory in transit
0.85	€ 2,186	€ 3,829	€ 11,563	€ 3,133	€ 2,090	€ 22,801	93.7%	94.3%	377	693
0.86	€ 2,172	€ 3,793	€ 12,357	€ 3,284	€ 2,101	€ 23,707	94.5%	93.9%	395	685
0.87	€ 2,199	€ 3,856	€ 13,275	€ 3,264	€ 2,104	€ 24,698	94.0%	93.6%	393	695
0.88	€ 2,214	€ 3,890	€ 9,334	€ 3,323	€ 2,100	€ 20,862	95.0%	95.5%	400	697
0.89	€ 2,217	€ 3,860	€ 9,966	€ 3,416	€ 2,087	€ 21,546	95.6%	95.1%	411	699
0.9	€ 2,265	€ 3,960	€ 10,061	€ 3,334	€ 2,106	€ 21,727	95.1%	95.2%	401	716
0.91	€ 2,229	€ 3,900	€ 6,572	€ 3,570	€ 2,097	€ 18,367	95.9%	96.7%	430	703
0.92	€ 2,170	€ 3,805	€ 8,036	€ 3,837	€ 2,099	€ 19,947	96.5%	96.0%	462	686
0.93	€ 2,239	€ 3,921	€ 5,542	€ 3,761	€ 2,104	€ 17,568	96.6%	97.3%	453	707
0.94	€ 2,263	€ 3,959	€ 6,844	€ 3,828	€ 2,104	€ 18,998	96.4%	96.7%	461	715
0.95	€ 2,251	€ 3,942	€ 4,337	€ 4,026	€ 2,106	€ 16,661	97.7%	97.9%	485	712
0.96	€ 2,289	€ 4,007	€ 5,849	€ 4,089	€ 2,117	€ 18,352	97.1%	97.2%	492	724
0.97	€ 2,219	€ 3,876	€ 5,054	€ 4,557	€ 2,096	€ 17,802	97.8%	97.5%	549	701
0.98	€ 2,207	€ 3,852	€ 4,333	€ 4,907	€ 2,110	€ 17,409	98.3%	97.8%	591	694
0.99	€ 2,242	€ 3,905	€ 2,872	€ 5,240	€ 2,111	€ 16,371	98.7%	98.6%	631	711



Item H0PS01212DPC0

Service level	Total Handling costs	Total Shipping costs	Total Shortage costs	Total Holding costs	Total Ordering cost	Sum Total costs	Order fill rate	Product fill rate	Average end inventory	Average inventory in transit
0.85	€ 434	€ 768	€ 380	€ 20,919	€ 596	€ 23,096	99.8%	99.8%	5014	2455
0.86	€ 435	€ 763	€ 23	€ 21,184	€ 595	€ 22,999	99.9%	100.0%	5077	2479
0.87	€ 446	€ 786	€ 412	€ 21,145	€ 609	€ 23,397	99.8%	99.8%	5068	2541
0.88	€ 434	€ 766	€ 544	€ 21,886	€ 592	€ 24,222	99.9%	99.7%	5246	2450
0.89	€ 447	€ 782	€ 654	€ 21,871	€ 608	€ 24,362	99.6%	99.7%	5242	2526
0.9	€ 435	€ 768	€ 986	€ 22,334	€ 602	€ 25,125	99.6%	99.5%	5353	2491
0.91	€ 440	€ 770	€ 349	€ 22,894	€ 596	€ 25,049	99.9%	99.8%	5487	2463
0.92	€ 431	€ 761	€ 492	€ 23,293	€ 586	€ 25,563	99.9%	99.7%	5583	2486
0.93	€ 423	€ 750	€ 280	€ 23,999	€ 582	€ 26,033	100.0%	99.8%	5752	2406
0.94	€ 427	€ 759	€ 2	€ 24,517	€ 593	€ 26,298	100.0%	100.0%	5876	2433
0.95	€ 420	€ 743	€ -00	€ 25,361	€ 571	€ 27,094	100.0%	100.0%	6079	2383
0.96	€ 419	€ 732	€ 284	€ 26,093	€ 568	€ 28,096	99.9%	99.8%	6254	2382
0.97	€ 411	€ 723	€ -00	€ 27,087	€ 561	€ 28,782	100.0%	100.0%	6492	2317
0.98	€ 447	€ 784	€ 75	€ 27,208	€ 599	€ 29,113	99.9%	100.0%	6521	2555
0.99	€ 420	€ 736	€ -00	€ 29,672	€ 574	€ 31,401	100.0%	100.0%	7112	2398



Item H0SG03015DPC0

Service level	Total Handling costs	Total Shipping costs	Total Shortage costs	Total Holding costs	Total Ordering cost	Sum Total costs	Order fill rate	Product fill rate	Average end inventory	Average inventory in transit
0.85	€ 555	€ 9,944	€ 6,676	€ 5,591	€ 796	€ 23,563	97.4%	97.2%	301	390
0.86	€ 556	€ 9,908	€ 7,854	€ 5,713	€ 782	€ 24,814	97.1%	96.8%	307	391
0.87	€ 542	€ 9,658	€ 3,721	€ 5,964	€ 766	€ 20,651	98.1%	98.4%	321	382
0.88	€ 561	€ 9,980	€ 4,639	€ 5,842	€ 800	€ 21,823	98.0%	98.1%	314	394
0.89	€ 552	€ 9,855	€ 5,444	€ 6,106	€ 785	€ 22,742	98.0%	97.7%	328	389
0.9	€ 551	€ 9,855	€ 2,957	€ 6,166	€ 796	€ 20,325	98.4%	98.7%	331	391
0.91	€ 557	€ 9,944	€ 3,881	€ 6,217	€ 779	€ 21,379	98.3%	98.4%	334	396
0.92	€ 541	€ 9,622	€ 4,133	€ 6,670	€ 769	€ 21,736	98.5%	98.2%	359	378
0.93	€ 557	€ 9,873	€ 2,386	€ 6,564	€ 785	€ 20,165	98.8%	99.0%	353	390
0.94	€ 543	€ 9,729	€ 3,633	€ 6,872	€ 778	€ 21,556	98.3%	98.4%	369	385
0.95	€ 562	€ 10,051	€ 2,890	€ 6,835	€ 790	€ 21,129	98.7%	98.8%	367	397
0.96	€ 559	€ 9,962	€ 2,860	€ 7,119	€ 788	€ 21,288	98.9%	98.8%	383	396
0.97	€ 557	€ 9,944	€ 2,424	€ 7,439	€ 790	€ 21,154	99.2%	99.0%	400	395
0.98	€ 582	€ 10,284	€ 1,057	€ 7,566	€ 815	€ 20,303	99.3%	99.6%	407	406
0.99	€ 553	€ 9,765	€ 105	€ 8,544	€ 773	€ 19,741	99.9%	100.0%	459	390