STRATEGIES FOR REDUCE EXCESS AND OBSOLETE INVENTORY

Lappeenranta–Lahti University of Technology LUT

Master's thesis

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ABSTRACT

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Strategies for reduce excess and obsolete inventory

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Keywords: Excess Inventory, Obsolete Inventory, Disposal of Excess and Obsolete Inventory, Strategies for dealing with obsolete inventory, Preventing the occurrence of excessive stocks.

The age of slow-moving, dead, or obsolete inventory is typically between one and two years. Excess inventory and obsolete inventory represent a problem for the company and the entire society from the technical, economic, and environmental aspects, depending on the type of inventory. Through research, it was found that close to 20 to 30% of all stock is excess or obsolete; therefore, this type of stock must be properly controlled and disposed of. Many company owners look for solutions in renting, buying, or building new warehouse spaces, not knowing that they could solve the problem of excess inventory through management systems. The question arises, whether to invest in a new storage space where the accumulation of excess and obsolete stocks would continue, or whether to invest in a new, better management system. Through the case company example, it was shown that by implementing the management strategies mentioned in the paper, there is a reduction in excess inventory, and a higher inventory turnover ratio, without disturbing the level of service.

The goals of the work were to do research and to assess the state of obsolete stocks in companies from Bosnia and Herzegovina with a focus on the process industry, wood industry, pulp and paper industry, and metal industry. Also, for at least one company, develop a system

for the prevention of excess and obsolete inventories, identify and qualify obsolete inventories, define a strategy for resolving obsolete inventories, and evaluate the effects of the implemented strategy. All the set goals have been reached, which can be seen in more detail further through the work.

The following expected research objectives and results were achieved:

The overview of obsolete inventory in B&H companies was done through a questionnaire.

The lists of key reasons that lead to inventory obsolescence were mentioned through research in surveyed companies as well as through case studies.

Strategies to prevent and solve obsolete stocks are also listed through research in surveyed companies as well as through case studies.

Effects of developed strategy for management and resolving obsolete inventory implemented in one real company was done, and through the example of raw materials and finished products, it was shown how the implementation of strategies leads to a reduction in inventory and an increase in the inventory turnover ratio.

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Peace to all good people.

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1 INTRODUCTION

Poor or improper inventory management can contribute to excess or obsolete inventory. The increase of this type of inventory is negative, brings economic losses to the company, and can bring economic and environmental losses to the state. For this reason, it was chosen to investigate this rarely treated topic.

Stocks are one of the fundamental aspects of each company. They represent raw materials, semi-finished products, or finished products that will be used for production or sale over a certain time, depending on a company's business model, i.e., whether it is a production, selling, or some other model. Stocks are non-use resources of any kind from which expect some economic gain. Stocks are everything that has been paid for and has not yet been sold. The challenge in inventory management is reconciling the supply and demand balance.

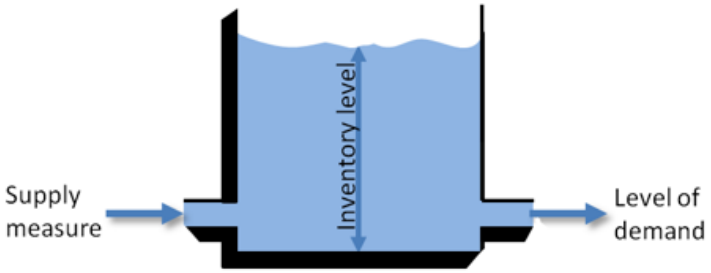

Figure 1. The analogy of a water tank with inventory

A water tank is a good analogy for stock flow concepts (see Figure 1). Namely, the water level in the tank corresponds to the stock. The inflow into the tank is analogous to the supply capacity, and the outflow amount corresponds to customer demand. The water level (the stock) is the link between supply and demand. If there is more demand than supply, the water level will decrease until the quantities of demand and supply return to balance or until the water tank is empty. Also, if a company has a larger supply than the demand, the water level will rise and fill the storage tank, in this case, the storage area.

Stocks are the subject of conflict where opinion is divided. On the one hand, it is suitable for a company to have as many stocks as possible. Larger stocks allow for easier planning, higher capacity utilization, flexibility, higher levels of service, so it is desirable for companies to hold larger stocks. There are advantages like much more economical procurement, greater

bargaining power, better use of production capacities, and much better customer service. On the other hand, reasons against inventories are costs generated by inventories, which typically amount to 20% to 50% of their value on an annual basis. Stocks are stolen or destroyed, a stock becomes obsolete, and stocks die. These all opposing sides of stocks lead to a considerable ballast and reduce our company´s profitability. It is also common knowledge that variability is one of the biggest enemies during the process of managing, and variability is paid for precisely by inventory.

Obsolete stocks are goods that, due to the loss of quality, properties, obsolescence, etc., cannot be sold, or the price is significantly lower when sold. It is a type of inventory from which it is difficult to expect economic profit in the future. Represent problem because of the reason that company must dispose of these types of stocks, that is, dispose or destroy them in the prescribed manner. Obsolete stocks stay on the market longer. They are characterized by poor sales, most often poor quality of goods, low selling price, seasonal oscillation, outdated technologies.

Lousy forecasting, misjudgement, error, reckless act, incompetence, lousy management, usually lead to excess and obsolete inventory. Thus, for each company that wants to business successfully, it is necessary for it to have strategy which will stop creating excess and obsolete inventory. Also, in the case when these types of inventories are produced, it is necessary to have strategies how to get rid of them. The paper consists of the following 7 chapters, and it's constructed in accordance with Figure 2.:

Chapter 1; The first chapter presents an introduction to the topic, on the basis of which this topic was reached, what are the problems, and what was done next through the work.

Chapter 2; In this chapter, a review of the literature on the existing topic is done. The first part was based more on excess inventory, while the second part was based on the literature on obsolete inventory.

Chapter 3; The third chapter establishes the state of stocks in BH companies. The data collected in the conversation with the owners of the companies were presented and a statistical framework of the state of this type of stock in BH companies was obtained.

Chapter 4; In the fourth chapter are presented models that companies could use to combat excess and obsolete stocks.

Chapter 5; In the fifth chapter are shown models for preventive and corrective measures of excess and obsolete inventory.

Chapter 6; This paper aimed to look at one company, so the proposals for corrective and preventive measures from the fifth chapter were implemented in this chapter. Using data from the case of the company "Neimax d.o.o.", it was shown that through the implementation of strategies there are positive results, that is, reduction of excess and obsolete inventory.

Chapter 7; Conclusion of the work was presented in this chapter.

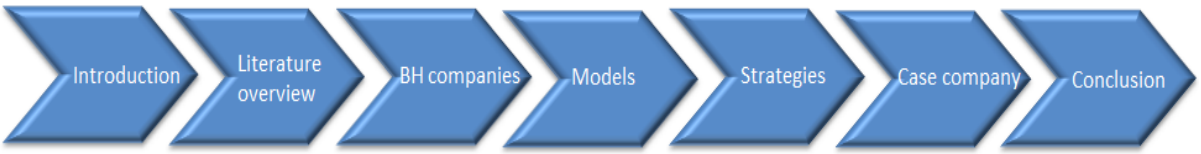

Figure 2. Research outline

2 LITERATURE OVERVIEW

To research the excess and obsolete inventory, literature research was performed using Google search, Google Scholar, Research gate, Direct science, and PDF Drive. Keywords searched are Excess Inventory, Obsolete Inventory, Disposal of Excess and Obsolete Inventory, Inventory Management, Strategies and tactics for dealing with obsolete inventory, Preventing the occurrence of excessive stocks.

2.1 Excess inventory

Excess inventory exists if the potential value of excess inventory, which is reduced by expected storage costs, fails to match the salvage value (Rosenfield, 1989). In moments when stocks become excess, management has to decide which and how much is excess inventory and what to do about that. Often, this type of inventory in the company is not recognized, because the management reporting system does not adequately identify where and how much excess inventory exists (Crandall R. and Crandall W., 2003). In the situation when a company wants to increase its development, to increase its business scale, at the same time it has to upgrade management in terms of implementing new business models, strategies and tactics. If there is the intention to increase the productivity of the company, the very efficacy way for that is to reduce excess inventory (Dubelaar et al., 2001).

Crandall R. and Crandall W. (2003) mentioned some caveats about excess inventory:

- Excess inventory management represents a complex problem that is influenced by elements of open and closed systems and can be the result of rational and irrational decisions. This problem involves all functions of business and is part of all levels of planning and execution.
- If a company has excess inventory, it can significantly affect short-term costs and long-term market position. It may have to be sold at a lower price than the initial price. Funding constraints may affect the inventory of other products. Based on that they are financially significant, excess inventory requires attention.

- The company's focus is not on excess inventory but on the main business, so excess inventory can be temporarily ignored, but if it is ignored for a long time, it can have a deeper impact on the core business.
- It is important to have good communication between customers and suppliers. If the right cooperation is established, it will lead to a more effective surplus inventory management program.
- It is necessary for companies to develop an excess inventory management program considering that products today have a shorter life cycle; there is also an increased demand for faster and more accurate deliveries, increased global competition and the demand for variety.

It is very important to control the inventory well because it has a big impact on the total costs, namely the excessive amount of stocks creates the need for more space, more equipment and labour for transport, storage and management of stocks without added value. If there are excessive stocks, the shortcomings are much harder to detect, and thus a larger amount of processing and waste is obtained. (Luh et al., 2003)

Carelessness in the management of excess stocks and obsolete stocks not only leads to economic losses, but can also harm human health, which is of course an even bigger problem. With the poor control of the introduction of pesticides, there was an accumulation of this type of stock in the EAR countries (Ethiopia, Tanzania, Kenya, Uganda, Malawi and Rwanda), and there was an obsolescence of pesticides. Obsolete pesticides are defined as storage pesticides that cannot be used for commercial purposes or for any other purpose and therefore need to be disposed of. Environmental pollution and spillage are among the main problems caused by the use of expired pesticides. Thus, due to improper management of pesticide stocks, serious health, ecological and economic problems can occur (Loha, 2018). Among the health problems, there have been deaths of farmers in Ethiopia and Ghana due to misuse of pesticides (Williams et al., 2008). The lack of information of donors of pesticides from developed countries and excessive amounts of imports led to the accumulation of stocks and subsequently to the expiry of the shelf life, which caused environmental pollution in developing countries (Wandiga, 2001).

If there is a situation where the products are out dated, defective, of poor quality, destructing such products can be useful because additional costs are avoided and also the prevention of damage to the brand image or reputation of the company engaged in e-commerce is achieved

(Pourhejazy, 2020). Handling excess inventory causes additional costs, so by destructing it, we can prevent further losses (Avlonitis, 1993). But sometimes destruction is not such a good idea due to the complex structure of the product or regulatory reasons. Also, some products have a high value, so it would not make sense to destroy them. In such situations, other methods of dealing with excess stock are sought (Pourhejazy, 2020).

Ahmed et al. (2020) mentioned that companies try to avoid excess and obsolete inventory. A product that is classified as obsolete is material that moves slowly, has no value, and takes up space. This refers to excess inventory being the main cause of obsolete inventory. Precise inventory management aims to reduce excess inventory and improve the overall performance of SCM (supply chain management).

2.2 Obsolete inventory

For any product-based business, inventory ties up the most cash and with that there is plenty of opportunities for saving and one of the way for that is reduce of excess and obsolete inventory. In inventory management, product obsolescence refers to slow-moving or excess inventory that remains unsold for a period of time, leading to a company's high cost of capital (Chae, 2009; Bartels et al., 2012). When a product is near the end of its life cycle, it can be classified as obsolete and slow mowing (Solomon et al., 2000). The word obsolescence comes from the Latin term obsolescere which means "to go out of use or fashion", and the adjective obsolescent originate from the Latin term obsoletus which means "worn out" (Bartels et al., 2012).

The causes that lead to obsolete inventory and excess inventory are mainly: poor forecasting, poor or wrong inventory management system, product design and quality are not satisfactory, lead time is inaccurate and careless purchasing (McCue, 2020). During the study in mass production, Grondys et al. (2014) concluded that the main reasons for the excess and obsolete inventories are the following: technological changes of technical equipment (27%), changes in the structure of production (42%), ordering parts at a level above the actual needs for servicing technical facilities (23%), errors in orders, which are the result of differences in construction and technical parameters (8%).

Excess inventory generally contributes to high carrying costs, affects work productivity, and increases equipment costs, so it is very important for the company to deal with the accumulation of inventory. If we have finished goods in our warehouse for 6 to 9 months, 50% provision associated with product type is considered to be lost. If it is in storage for 9 to 12 months, 75% provision is considered to be lost, and if it is in storage for more than 12 months, 100% provision is considered to be lost. If the semi-finished products are in our warehouse for longer than 6 months, 100% provision is considered to be lost. And if we have raw materials and procurement materials in the warehouse for 9 to 12 months, 25% provision associated with the product type is considered to be lost. If they are in storage between 12 and 18 months, 50% provision is considered to be lost, and if they are in storage longer than 18 months, 100% provision is considered to be lost (Negi and Kharde, 2021).

A company of this type of inventory can no longer obtain a previously planned economic profit. The company has already invested money and in the case of producers, time, and if this type of stock is not resolved, it will receive additional costs from the unprofitable inventory. Since 20% to 30% of the inventory is obsolete, it would be a turning point for struggling organizations to write off this type of inventory as lost and therefore other ways of dealing with these stocks must be tried before writing-off (McCue, 2020).

In most cases, companies do not want to recognize the costs of obsolete stocks and state that there are no obsolete inventories because the products will be consumed (one day). Such types of companies are looking for ways to remove obsolete supplies by giving up, throwing, selling, and returning products. Yet the basic question is how to avoid obsolete inventory in the first place. (Bonney & Jaber, 2011; Pay, 2010)

Bartels et al. (2012) listed methods that will minimize the impact of obsolete inventory in the company:

- Considering obsolescence management options during the part selection process.
- Maximizing the availability of components by identifying, using, and supporting all available resources for procurement of components that meet the application requirements.
- Developing strategic methods to define, share, procure, design and use (maintain) a product.

- Thinking beyond single parts and components and applying management above the piece-part level.
- Planning the life cycle management of the systems, that is, determining the optimum mix of reactive mitigation and design refreshes to manage obsolescence.

How to get rid of non-current stocks? Some of the ways to deal with obsolete inventory are as follows: Write-Off Obsolete Inventory (one of the most commonly used methods), donate obsolete inventory for tax deduction, remarket items, sell at a discount, liquidate your items, bundle products. (Tulchinsky, 2017)

Goods that failed to be sold according to plan drastically lose value over time and as such are classified as non-current or dead stocks. In a conversation with an employee in the sales department of Lidl Croatia, we learn that in the past, such stocks were sold through sales in tent parking lots. However, such an approach caused damage to the handling and sale of goods due to inadequate points of sale, further this approach required additional costs in terms of organization, tents, additional training, additional staff hours and so on. In order to avoid all the previously listed problems and costs, it was decided to sell this type of product directly to certain stores that are also open for the purpose of selling "problematic" goods. With this management of non-current inventories, we have sold goods at least with a positive zero business, which is much better than collecting additional costs, and at the same time we have a large relief of warehouses and free up space for new goods. (Arbanas, 2016)

Examining excess and obsolete stocks, it is necessary to mention certain costs that stocks bear. And increasing those stocks, i.e., not keeping track of them, will directly increase the costs of holding inventory. Richardson (1995) attempted to quantify inventory holding costs annually. They are expressed as a percentage of the total value of stocks in the warehouse, as shown in Table 1

Table 1. Inventory holding costs

Type of cost	***The percentage from the total value of stocks in the warehouse***
Cost of capital tied up in inventory	6 to 12%
Taxes	2 to 6%
Insurance	1 to 3%
Warehouse costs	2 to 5%
The costs of warehouse operations or the costs of physical handling of inventory	2 to 5%

Employees salaries	3 to 6%
Obsolescence	6 to 12%
Spoilage and petty theft	3 to 6%
In total	**25 to 55%**

2.3 Preventing excess and obsolete inventory as well as dealing with them

The approach to reduce excess inventory at the case study is based on the literature review explained below. Namely, the focus is on models for inventory management, with the help of which it is realized that excess inventory is reduced, and therefore the amount of obsolete inventory, that is, the optimal inventory management is approached. It was also mentioned that building good relationships and trust with partners leads to having an accurate lead time, and it was emphasized that it is necessary to use information technology as an inevitable tool, as well as to deal with the product life cycle as much as possible.

In his book, Vandeput (2020) states the answers to three questions through management policies hint at in the text. The first question touch on how much safety stock is held in the warehouse, and the second and third question refers to how much and when to order. These policies are:

- **Continuous Review and Reorder Point (s, Q)**

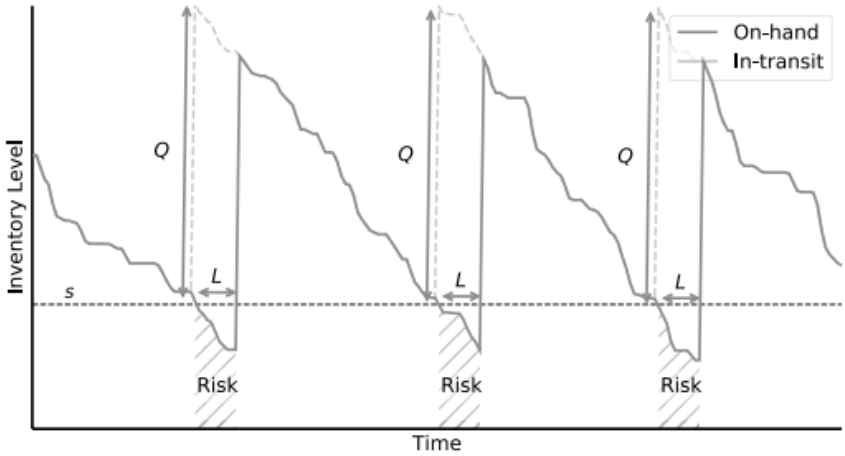

Figure 3. (s, Q) policy with stochastic demand

Using this policy, a fixed quantity is ordered when the inventory level reach reorder point s. The figure above is shown this kind of inventory management and it can be seen that demand is variational.

How Much Safety Stock?

Risk-period (X_τ) from the figure above is lead time L. Considering possible variations during the demand; it is indispensable to have safety stocks. Reduce of Risk-period should be the target for supply chain managers for the reason that it is profitable, it will reduce inventory level and the company will get less cash tied up in useless inventory. Safety stocks are proportional to the square root of lead time so that by reducing the lead time, the company will get convenience in the supply chain.

$$S_s = z_\alpha \sigma_d \sqrt{L} \tag{1}$$

Where,

z_α = Number of standard deviations for a specified service probability

σ_d = Standard deviation of demand over the lead time

L = Lead time in days (time between placing an order and receiving it)

How Much to Order?

A commonly known used order quantity that originates from the EOQ model is:

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

Where,

D = Annual demand

k = Order costs

h = Storage costs

When to Order?

The reorder point is the sum of demand d_L and safety stocks (S_s) during the lead time:

$$s = d_L + S_s \tag{3}$$

- **Periodic Review and Order Up-to Level (R, S)**

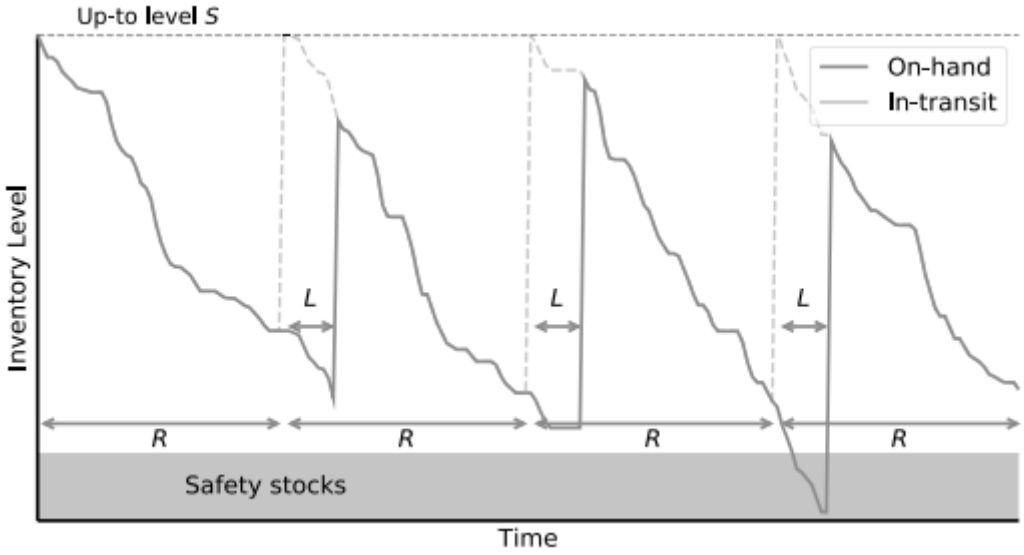

Figure 4. (R, S) policy with stochastic demand

The policy of this species of management consists that after the determined period level of stock is controlled, and based on insight into the current level of stock, the next order quantity is that with which stocks will be filled up to level S. During the calculation of safety stock in this policy, it's necessary to take into account review period R and target level S. The fixed period policy is shown above in Figure 4. and as it can be seen the demand is stochastic.

How Much Safety Stock?

The Risk-period is now R+L, so it is necessary to have the following amount of safety stock:

$$S_S = Z_\alpha \sigma_d \sqrt{X_\tau} = Z_\alpha \sigma_d \sqrt{R + L} \quad (4)$$

Where,

z_α = Number of standard deviations for a specified service probability

σ_d = Standard deviation of demand over the review and lead time

L = Lead time in days (time between placing an order and receiving it)

X_τ= Risk period

In the continuous review period, risk-period was only L; however in this case, risk period is R+L as it is shown in the Figure 5. When the inventory manager orders a certain amount in the time of the review R1, the next order will be possible only during the review period R2. And during that time, R2 will have to wait for the Lead period, and therefore, when ordering

in the review period of R1, enough stock must be ordered during the total R+L period so that the stockroom does not run out of stock.

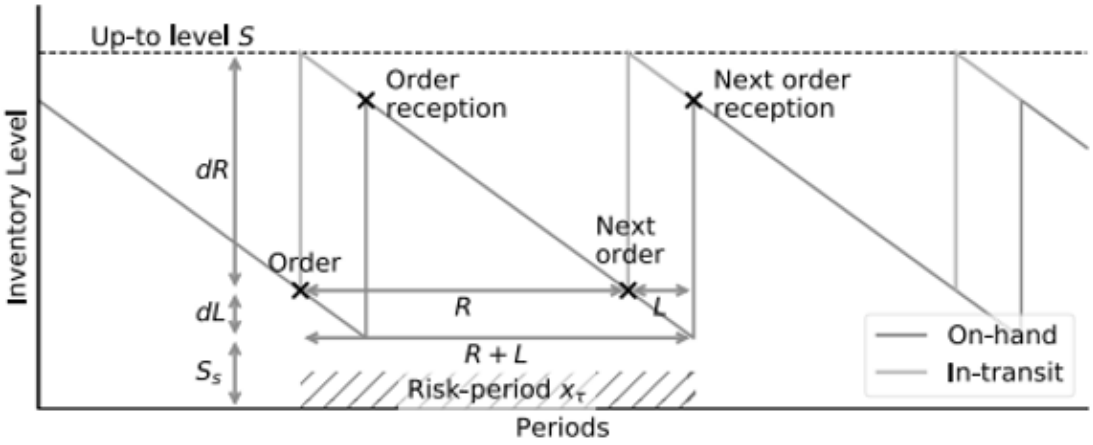

Figure 5. Risk-period for (R, S) policy

How Much to Order?

We need to meet the target stock level S during the order, so we have:

$$S = d_L + d_R + S_S \tag{5}$$

$$Q = S - net\ inventory \tag{6}$$

Where,

d_L = Demand during the lead time

d_R = Demand during the R period

S_s = Safety stocks

S = Target stock level

When to Order?

An order is made for each review period, the optimal reviewed period is based on the EOQ model:

$$Q^* = \sqrt{\frac{2kD}{h}} \tag{7}$$

$$T^* = \frac{Q^*}{D} \tag{8}$$

The optimal review period T* can be rounded to a practical number or use the power-of-2 policy:

$$\frac{T^*}{\sqrt{2}} \leq R = 2^k T_B \leq \sqrt{2} T^* \tag{9}$$

Fixed order period (P model) and Fixed order quantity (Q model) are models which arise from Economic order quantity (EOQ) model. Next to Vandeput (2020) in their works, Silver et al. (2009), Tranthu (2016), Simchi-Levi et al. (2008) also explained P and Q models.

In order to prevent the problem of excess and obsolete inventory from becoming a major headache, it is necessary to regularly monitor and dispose of excess inventory throughout the year, not just once a year. Bugs (2016) listed ten ways that could help reduce excess inventory:

- Return for a refund or credit. If you agree with the delivery company to return the excess stock, even though they would have transport and handling costs, that would be the best option.
- Divert the inventory to new products. Although it is necessary to refine certain things, some raw materials or components can be used for the production or development of other products.
- Trade with industry partners. It is necessary to build good relations with partners, and then through those relations to exchange some goods, for example something you have excess stock, you can give as a gift and then get something you need in return.
- Sell to customers. This method depends on whether it is sold to end customers or distributors. As for the end customers, many do not look at the latest model and will be happy to buy outdated inventory. For distributors, you can make special contracts for this type of goods.
- Consign your product. Independent distributors allow you to retain ownership when you take a portion of the sales. Consignment can be virtual, which means that you keep the goods and that you are responsible after the sale, in this case you must

quickly respond to the sale. Consignment distributor stores the goods and manages the delivery.

- Liquidate excess inventory. This is the case when you just simply get rid of the goods. The liquidator will buy what you have at the agreed price.
- Auction it yourself. If you decide to take this step, it will take a lot of time and in the end, everything may not even be sold. This is a method that is carried out by selling through online sales points, directly to whoever wants it.
- Scrap it. Scrap dealers will come and take it if it has any value. He will pay a small compensation, and in the worst case, you will have to pay to dispose of him.
- Recycle it. Most municipalities have recycling programs, and there are services that will take the goods if they can be recycled. This step is decided upon if nothing else works.
- Donate it. A lot of useful things can be done through cooperation between companies and non-profit organizations. Thus, through donating, certain tax obligations can be reduced.

Through research on companies in the Dutch apparel industry, Wijnia (2016) listed opportunities to reduce the amount of obsolete inventory. It is really important to bring supply and demand closer to each other and to achieve this, some of the basic challenges that companies should implement are Supply and demand dynamics, Product life cycle management, Supply chain integration, Postponement (Manufacturing postponement, Logistics postponement), Information technology.

Detecting the proactive measures for the prevention of the occurrence of excess and obsolete inventory can bring high benefits to a company. With lower storage costs, improved cash flow, and better inventory turnover rates, higher profits will occur. According to Baker (2021) proactive measures for prevention of excess and obsolete inventory are listed below:

- Better demand forecasting

If the company experiences excess or shortage of inventory, it is possible that it does not use the appropriate model for forecasting demand. If a prediction model is used only based on the number of days, errors will occur. Therefore, forecasting models that take into account demand trends, seasonality and promotional activities should be used. It is also possible to perform statistical forecasting with the help of inventory optimization software, where each

product is analyzed and assigned a type of demand according to its position in the product life cycle.

- Don’t use excess stock to mitigate supply risks

Keeping excess inventory in a warehouse is not a panacea for mitigating supply risk. This problem can be solved by monitoring the supplier's delivery time, i.e. whether they deliver the goods on time or often late, and by tracking suppliers' annual vacations in advance.

- Stop carrying excess inventory to prevent stockouts

Keeping a large inventory is not a way that will surely lead to product availability. It is possible to have a high service level and excellent stock availability without large quantities of each item in the warehouse. In order to achieve this, it is necessary to prioritize which inventory to store in the warehouse based on multidimensional criteria such as types of demand, pick frequency, profitability. All this enables the company to know how well a particular item is selling and how much it costs the business.

- Optimise inventory levels along your supply chain

Sometimes it is difficult to prevent excess inventory if we have decentralized ordering, most often in those cases, the order planners order "a little more", so if we have those "a little more orders" in more places, in sum we get a higher level of excess inventory. The solution to the problem is inventory planning and management with one centralized view. In this way, stocks in warehouses can be balanced, that means excess stock in one warehouse is transferred to other warehouses where the levels of the same item are low. Such management at all locations will quickly remove excess stock from the supply chain and the risk of obsolete items appearing in warehouses.

- Buy stock wisely

Buying in bulk is a good investment if we buy items that will quickly leave the shelves, but if the goods that were bought at a cheap price will tie up capital or worse become obsolete or sold at a reduced price, then buying in bulk is not a good thing. You need to act wisely and calculate, because sometimes it is better to buy a smaller quantity of the order at a higher price than to have stocks that do not move quickly enough through warehouses.

3 OVERVIEW OF OBSOLETE INVENTORY IN COMPANIES FROM BOSNIA AND HERZEGOVINA

In many situations, while companies are focused on the most significant possible profit, big mistakes are made in management methods by neglecting internal control and monitoring the consumption of funds, i.e., inventories. In the time where we live, the time of the fourth industrial revolution, where the gap between the digital, physical, and biological world is narrowing, and technology is changing faster than ever, it is impossible to imagine a successful business without very detailed monitoring of inventories, as well as without monitoring their value, turnover, and obsolescence. Based on the above, a study was conducted on whether and to what extent companies in Bosnia and Herzegovina implement an inventory management policy with a particular emphasis on managing obsolete inventories. The research also shows which methods and techniques are most often used in their business to reduce obsolete inventory's negative impact. The results were obtained by way of the interview or online questionnaire. In the period from 10.01.2022 to 20.04.2022, data were collected. First, a pilot survey was conducted on five small local businesses, and then larger companies were approached. The survey involved 30 companies operating and headquartered in Bosnia and Herzegovina. The questionnaire comprises general questions about the company and specific questions about the management of obsolete inventories.

3.1 General questions about the company

A survey as a research method was implemented to obtain quantitative results about height, flow, and reasons for the existence of obsolete stocks. The collected data were analysed logically and analytically, and certain conclusions from the survey were obtained.

In total, all companies are from the private sector, and 40% of interviews were conducted with CEO and/or company owner, while 50% of the people who participated in the questionnaire have functions in a company that are directly related to warehousing, i.e., stock recording. From Figure 6. can be seen that in questionnaire includes companies from different sectors, with the wood and metal industry-leading, with about 50% of participants. The smallest

number of companies that participated in the questionnaire is from the ALU and PVC joinery sector.

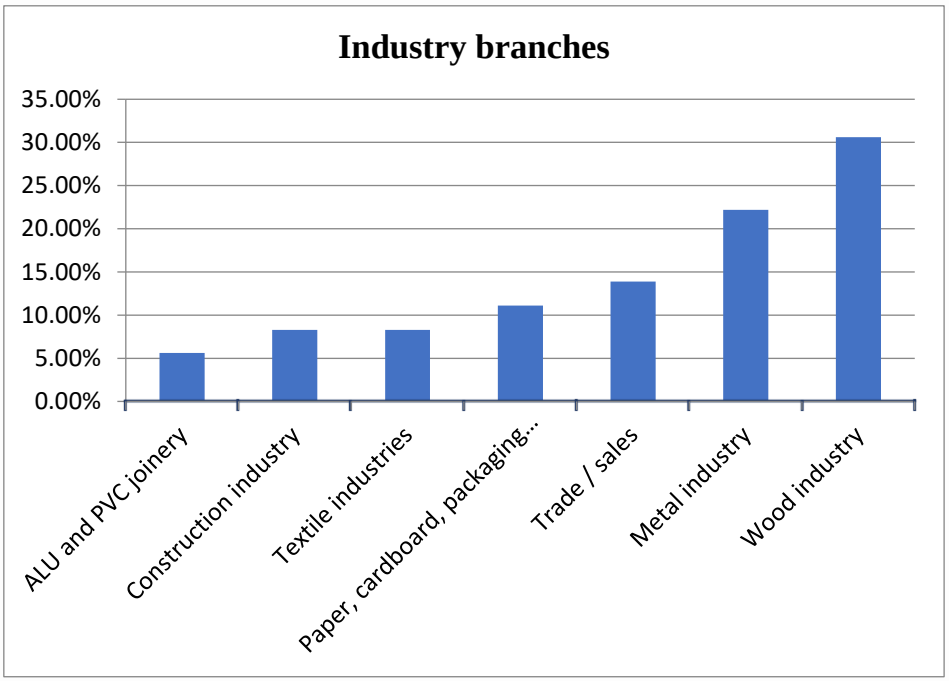

Figure 6. Graph of industry branches

As seen from Figure 7. four companies are exclusively engaged in sales, exclusively in the production of 12 companies, and in the sale and production of 14 companies.

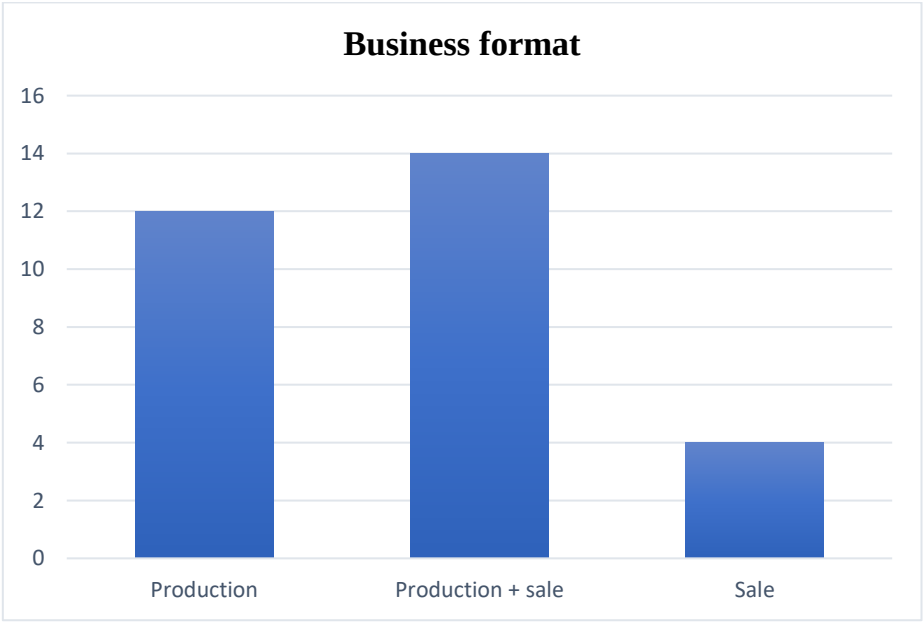

Figure 7. Business model

To present the collected data on the number of employees and the annual turnover of companies understandably and clearly, descriptive statistics were used. Regarding the number of company employees, the average value is 136 employees per company. The Median value is 57.5.

According to OECD (2017), the division of companies in compliance with the number of employees of the company was carried out in the following way: a company with 1-9 employees is said to belong to micro-enterprises, 10-49 employees, small enterprises, 50-249 medium-sized enterprises and large enterprises with 250 or more employees.

Figure 8. is depicted that out of the total number of respondents, 40% appertaining to small companies, 40% of respondents are medium-sized companies, and 20% of respondents have more than 250 or more employees, i.e., they belong to large companies.

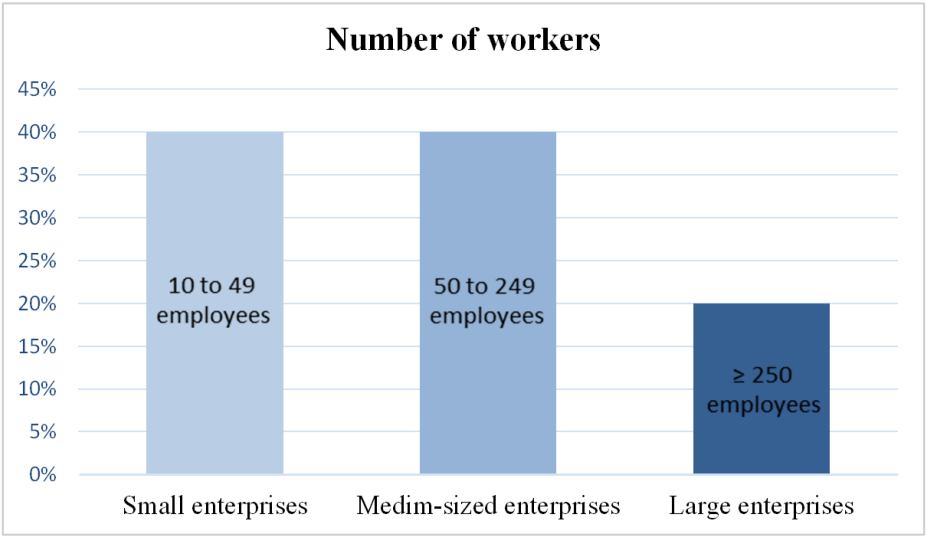

Figure 8. Number of employees

Regarding the annual turnover, with the help of Excel's functions for statistics "Average" and "Median," it was obtained that the average value is about 13.5 million BAM, and the value of the median is about 6 million BAM.

From Figure 9. can be seen that different components can be found in the warehouses of the companies. The most dominant are raw materials and materials procured for production and finished products for delivery manufactured in the company.

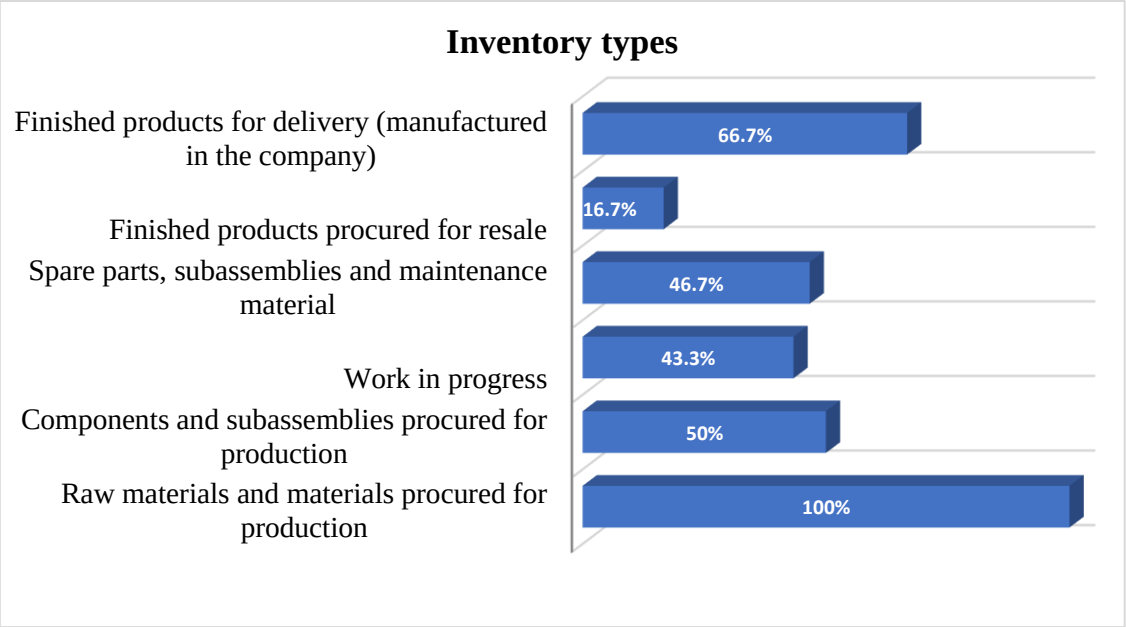

Figure 9. Types of inventory in the warehouse

Data collected through interviews and surveys with people dealing with inventory management policy represent that most companies decide when to order and how much to order through an internally developed system and budget tables in Excel, about 60% of such companies. A very high percentage of about 30% of companies make order decisions without the support of a computer system, more intuitively by counting the inputs and outputs and future needs of the company. Only a tiny percentage of companies order on the principle of an inventory management module integrated into the ERP (enterprise resource planning) system. The above-mentioned is presented in Figure 10.

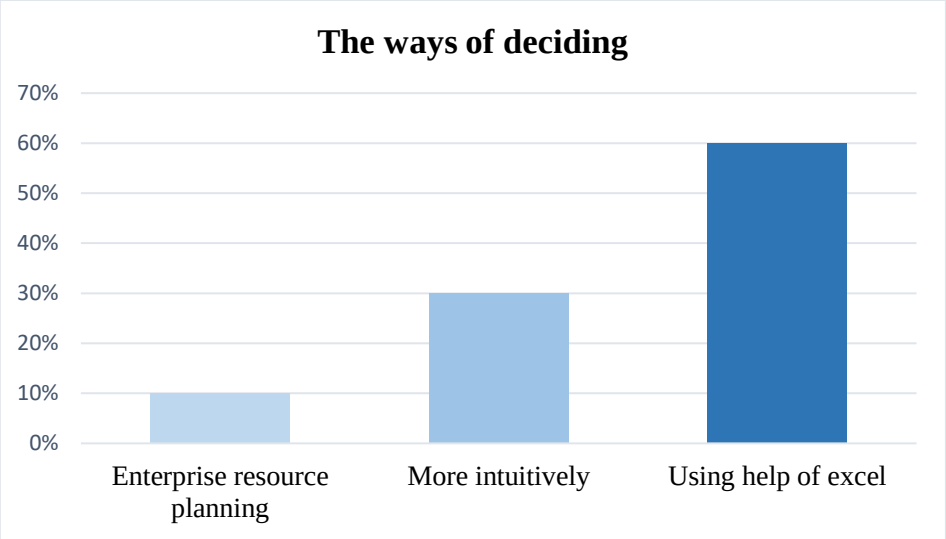

Figure 10. Deciding ways in companies

3.2 Criteria for classification of non-current stocks

Among the essential things for managing inventories is determining criteria for inventory classification. From all the answers received, there are ways that BH companies use to classify stocks as current and obsolete. Some of these are texted below:

- Almost 70% of companies say that they are aware of obsolete stocks, so in terms of time criteria, they classify stocks as obsolete if they do not have a turnover for 365 days.
- Inventories are classified through the class of raw materials and possible damage.
- Based on the number of orders, i.e., contracted works for the next period, the need for stocks for that period is identified, and if it is seen that a particular stock will not be used or used in that period, i.e., will be retained more than planned, it is classified in obsolete stock.
- FIFO (first in, first out) is a management process that ensures that older products are sold before they become unusable or obsolete. With this process, we are less likely to make products obsolete. This management system is used by certain companies in the classification of inventories into current and non-current
- What is important to point out is that the ERP system based on KUF (book of incoming invoices) and KIF (book of outgoing invoices) analyses the maturity of inventories.

To the question of how often obsolete stocks are analysed, i.e., how constantly the state of this type of stock is reviewed, the answers were received, and it is shown in Figure 11. The most significant percentage is occupied by companies that review stocks once a year, almost a third of companies, which is certainly not enough to well managed obsolete inventory.

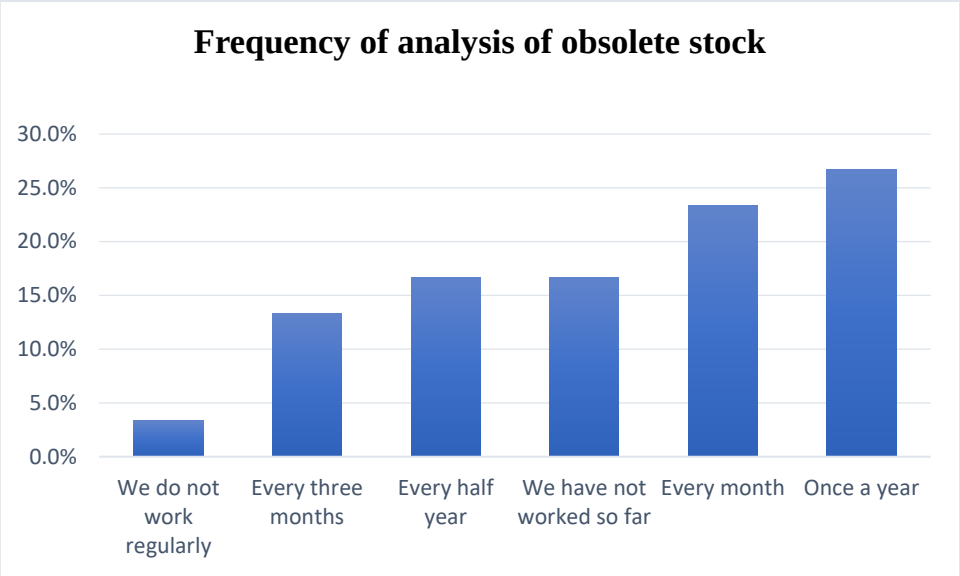

Figure 11. Analyzing obsolete inventories

3.3 Balance/quantities of obsolete stocks

Companies that analyse stocks every month or every three months have a 23% share of obsolete inventory in total inventory, and as can be seen from Figure X shows, 36,6% (23,3% + 13,3%) of such companies. Other companies that analyse their inventory once every six months, once a year, or do not analyse it at all, or have never analysed it until now, say that they have an average of 11% of obsolete inventory compared to the total inventory.

Clearly set KPI (Key performance indicator) has 30% of the companies. Well, according to the KPI, the maximum allowed percentage of non-current stocks is 10% of total stocks.

3.4 Obsolete inventory – prevention of occurrence

About 50% of companies analyse obsolete inventories, and about 30% of surveyed companies have precisely defined strategies for preventing non-current inventories. To prevent the emergence of this type of stock, the most commonly used methods, according to the recorded answers, are:

- Regular warehouse analysis and close market monitoring. Working with well-known customers is being forced.

- Work according to customer orders, no more than that, so that with this type of business, the excess of inventories is reduced and at the same time, the creation of non-current inventories is reduced.
- According to the company's rules of procedure, the method of storage, packaging, and handling of materials is precisely monitored.
- The risk of excess inventory (as well as the possibility of obsolete inventories) is transferred to the customer. If the customer does not order in advance, then it is invoiced.
- ABC analysis.
- By using the material for some other purpose. For example, cardboard panels can be used to produce a smaller box, compared to what it was originally intended. In this way, the cardboard is used and there is no possibility of it becoming obsolete.
- Quantity of order of cardboard boards in accordance with the customer's order, - keeping stock as needed and in agreement with the customer.

3.5 Obsolete inventory – get rid of

From the circle chart in Figure 12., it can be seen that the largest percentage (40%) of companies deal with this type of inventory once a year.

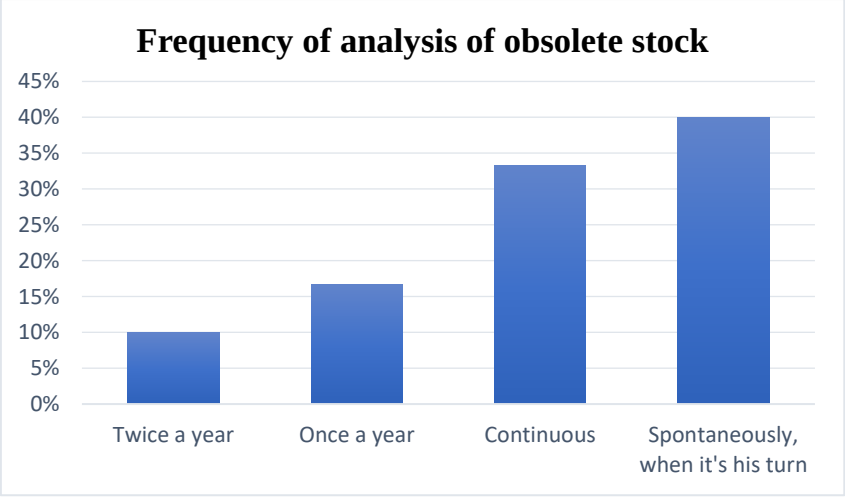

Figure 12. Dealing with obsolete inventories

The surveyed companies whose inventory management policy takes into account this type of inventory use the following precisely defined strategies for resolving obsolete inventories:

- Stocks of raw materials are incorporated into products for which quality and design are not important.
- Selling products that consist of parts that are obsolete.
- Promotions 1 + 1 for free.
- By selling to waste collectors.
- By giving.

3.6 The cost of stock obsolescence

When asked what percentage of the quantity discount is justified in order to order a larger amount of stock and keep stock longer, the respondents said that it depends on various parameters such as delivery time, availability of goods, turnover time, expected orders, etc. and also sometimes in the constant movement of prices it is difficult to determine.

However, according to the collected answers, on average, a volume discount of around 13% is enough to keep stocks longer.

The average optimal inventory holding is almost 4 months, more precisely 111 days; the median value in this case is 75 days. The supplier's delivery time depends on the supplier, that is, on whether finished products or raw materials are ordered. Repromaterials are usually delivered after 5 days, and if supplies are ordered from other continents (e.g. China), the delivery time can be up to 3 months. According to the answers collected, the goods arrive at the company in an average of 30 days, and the median value is 18 days.

3.7 Sub-conclusion

The goal of this survey was to see the state of obsolete stocks in BH companies, that is, to see how much companies care about this type of stock, and how much effort they put into

managing the company's stocks. Each question and answer were analysed, and certain answers are presented through pie or bar graphics.

The following conclusions were reached:

- Figure 1. in Appendix 2. shows a comparison in the management of obsolete stocks. In the situation of regular control, that is, more frequent control, companies have 23% of obsolete stocks, while in the situation of less frequent control or just by feeling, we see that companies have 11% of obsolete stocks. That's exactly where the problem lies, that if these stocks are ignored and placed somewhere at the end of the priority (or at the end of the warehouse), it can be seen that the owners have a bad feeling about that type of stock, and that's why they said that this percentage is only 11% , and it would certainly be higher if an in-depth inspection was carried out. The above is a problem in BH companies. The percentage of 23% is much more realistic, given that it can be seen from the literature that this type of inventory amounts to 20% to 30%.

- Also, with the answer that the percentage of companies that implement the policy of when and how much to order intuitively, without the support of an ERP system and without certain internally developed spreadsheets in excel, is as much as 30%, which in the age of modern technology is a very high percentage that in the future must repair.

- Positive answers from practice related to the prevention of obsolete stocks, were given by the companies participating in the survey.

- Bosnia and Herzegovina is a fertile ground for the implementation of strategies that would help with inventory management, so through this work and the example of the case study, company owners can see how the implementation of these strategies brings economic and other benefits.

- With the increase in the number of employees, the percentage of use of ERP systems as well as computers increases, where the company's resources are controlled through spreadsheets. This is shown graphically in Figure 2. in Appendix 2.

- The industry in BiH is mostly based on the metal and wood branches. Comparing these two industries, it was concluded that both industries decide on their resources in an approximate way, as shown in Figure 3. in Appendix 2.

4 MODELS FOR INVENTORY CONTROL

From the survey results, it is evident that many companies in Bosnia and Herzegovina do not monitor the situation regarding excess inventory and obsolete stocks. Also, it was seen that only 30% of companies regularly monitor and take care of these stocks, which is undoubtedly a low percentage. It was also seen that 30% of companies do not use the help of computers at all. For this reason, in this chapter, it will be enumerated and briefly explained the ideal inventory management models that could significantly improve the situation in the current BiH market. If some companies use this master thesis and choose some of the methods for inventory management, it could bring them additional economic profit. Given that BiH is currently facing a labor shortage, it would be good for companies to establish a sound management system, i.e., to eliminate those unnecessary stocks that are certainly holding them back and slow them down. By decreasing additional costs from inventory, they could invest in production automation, for example, or prevent people's departure from their company through salary increases. The work aims to list strategies that could largely prevent excess stocks and their obsolescence, so the models listed below are some of the methods for successful management.

4.1 ABC Analysis

ABC analysis represents the method that gives the possibility to classify stocks into A, B, or C classes. This analyse is based on Pareto's rule which is also called the rule 80:20, ABC rule, Pareto's law. Namely, Vilfredo Pareto discovered in 1906, while investigating the distribution of national wealth, that in Italy about 20% of the population owns about 80% of the wealth.

Later, this rule was used in other spheres of life, so for example, 20% of drivers, cause 80% of traffic accidents and violations, 20% of our time brings 80% of the money, 20% of customers give 80% of income, and 20% of articles in our inventory make 80% of income. ABC analysis of stocks of raw materials, semi-finished or finished products will reveal 20% of their varieties that are used in 80% of production or sales and are therefore the most valuable. The next 30% of stocks account for 15% of revenue and the other 50% of products represent 5% of revenue. Figure 13. shows a graph of those items mentioned above.

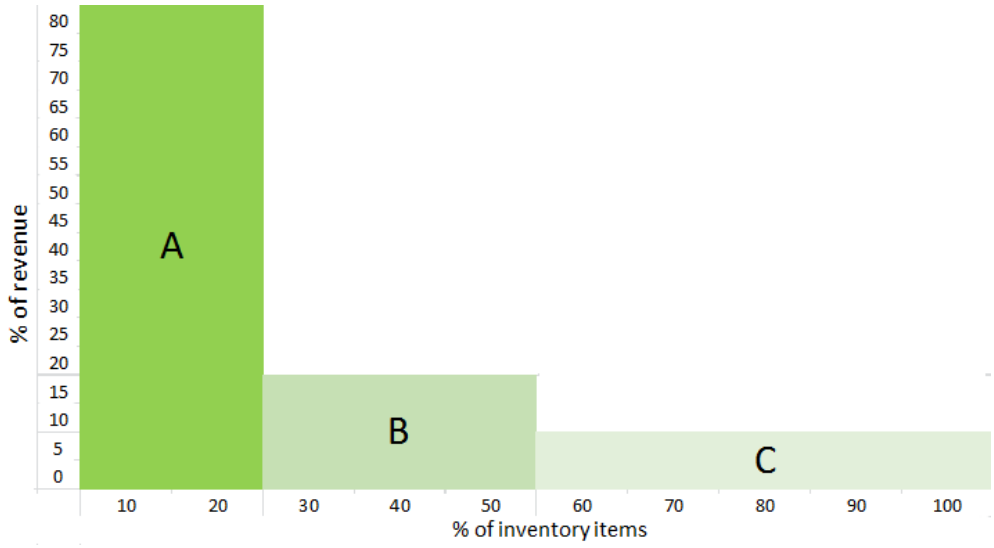

Figure 13. Ratio of inventory items and revenue through ABC analysis

ABC analysis helps to divide inventory according to the importance that has in our warehouse. And on the basis of the division, we know the stocks to which we should pay special attention, such as a higher level of service, better stock control, such as continuous monitoring, and the like. In other words, the most consideration is given to group A, less to group B, and the least to group C.

Onwubolu et al. (2006) in their work mentioned steps that should be followed in order to get the classification of inventory in A, B, and C categories:

- Determine the annual sales volume of each item.
- Multiply each item's annual sales by the item's price to get the total annual dollar usage of each item.
- Add the total dollar spent on all items to get the total annual inventory dollar cost.
- Divide the total annual dollar usage of each item by the total annual expenditure on supplies to get the percentage of total usage for each item.
- List items in order of percentage of total usage.
- Review the annual usage distribution and classify the items as A, B, or C.

The criterion of ABC analysis in inventory management is turnover expressed in monetary units. An example of ABC analysis is shown in Appendix 1.

$$Turnover = annual\ demand\ x\ item\ price \quad (10)$$

4.2 XYZ Analysis

As with ABC analysis, the purpose of applying XYZ analysis is to establish an optimal business control system in order to reduce costs of inventory, warehouse, procurement, etc. This Analysis also includes the variability of demand for individual products or items. While ABC analysis is the primary and basic technique for inventory control and analysis and gives more importance to products that have a large share of total sales, XYZ goes a step further in inventory analysis. The variability of the demand for a certain product is mentioned and on that basis, the products are classified into three groups X, Y, and Z. The XYZ analysis additionally classifies the results obtained by the ABC analysis and therefore represents a supplement to the ABC analysis.

When creating XYZ, according to Jašarević et al. (2020), it is essential to observe a large number of data:

- Cost of goods sold – it is necessary to see what is the annual purchase value of the goods that were sold by different items during one sales year.
- The sales value of the goods – it is necessary to see the annual financial turnover for different items during the sales year (most often).
- Average sales – average sales during one sales year must be considered.
- The standard deviation in the period is also observed.
- Average purchase price – the purchase price is obtained by dividing the total cost of goods sold by the total quantity of goods sold.
- Average inventory value - the average amount of inventory multiplied by the purchase price in the period of one sales year.
- Coefficient of variation - defines the standard deviation and average sales in the observed period. That coefficient tells about the stability of demand for a certain product.

The coefficient of variation represents the continuity of demand for a particular item as shown in Figure 14. Thus, it can be seen that the lower the CV coefficient, the more stable the demand for a particular type of inventory/item. In theory, articles are divided into three groups.

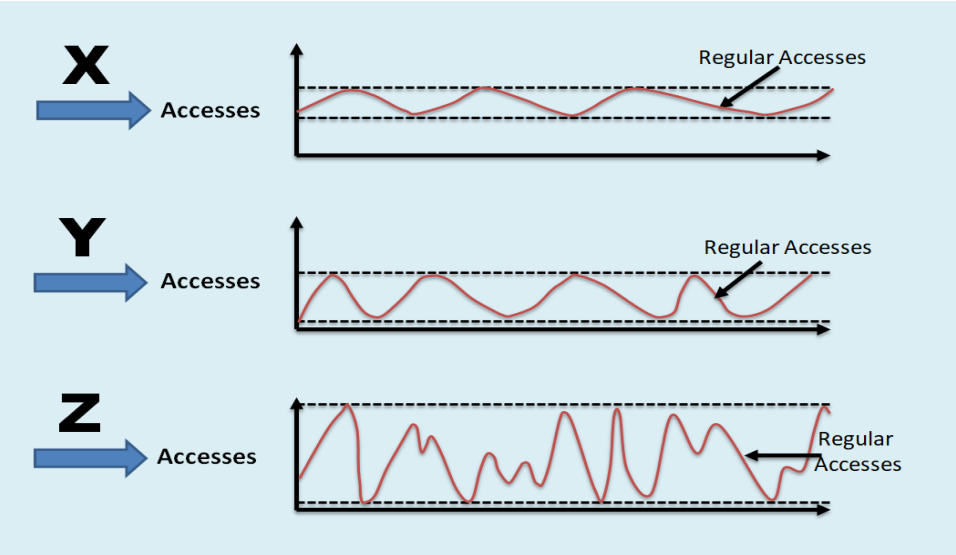

Figure 14. Continuity of demand in X, Y, and Z group

The previously mentioned CV coefficient of variation is calculated by dividing the standard deviation by the average sales or consumption for a certain period, as shown in the following formula:

$$CV = \frac{\text{st. dev.}}{\text{AVERAGE}} \tag{11}$$

Where,

st. dev. – standard deviation of a specific item for the observed period.

AVERAGE - the average sale of an item or consumption of inventory for a certain period.

It is considered that with regard to the continuity of demand, stocks/items are classified, so it is obtained that the characteristics of each of the groups X, Y, and Z are as follows:

- X components have a very small oscillation in demand (up to 10%), that is, the demand is continuous and this group makes up about 50% of the material.
- Y components represent discontinuous consumption. For this type of stock, the demand can fluctuate in time periods by up to 60%, thus achieving medium accuracy of the consumption forecast. About 20% of material types belong to the Y group.
- Z type components have demand oscillations of over 60%. It is very difficult to trace consumption/sales forecasts, so the consumption of this type of material is very difficult to forecast. Z group consists of 30% of material types. Also, due to the long period of use, automation is not recommended, but the manual calculation is preferred.

4.3 ABC/XYZ Analysis

Cross ABC-XYZ analysis is a method of classification where items can be classified into one of 9 groups. Through further analysis, three subgroups are determined: Group AX, AY, and BX, Group AZ, BY, and CX, and Group BZ, CY, and CZ. Items from groups AX, AY, and BX have a medium or large share in the total value, and predictable or less predictable consumption or demand. Items from the middle group AZ, BY and CX have different specifications, have a large or small share in consumption, and have a large or small possibility of forecasting consumption. In the group BZ, CY and CZ are items with a small to medium share in the total value, occasional or discontinuous consumption, and low to medium forecast accuracy. The aforementioned groups are shown in Figure 4 in Appendix 2.

A different management policy applies to each of the 9 categories which may include:

- Level of service.
- Continuous or periodic control.
- Automation of the ordering process.
- Accuracy of records (inventory number).
- Responsible person.
- Safety supplies.

Figure 15. shows an example of a simile of two categories of opposite specifications:

AX place	CZ place
➢ Service level 98%, ➢ Continuous control, ➢ Automated procurement, ➢ High accuracy of records, ➢ Responsible head of the procurement department	➢ Service level 80%, ➢ Periodic control, ➢ Buy to order, ➢ Low recording accuracy, ➢ Responsible officer in procurement.

Figure 15. Comparison of two places from ABC/XYZ matrix

4.4 Inventory Policy Choices

As it is generally known, the organization's inventory policy has the task of responding to which model (decision rules) for inventory control should be used. It is necessary to know which items should be kept in inventory, and also by managing inventory it should be responded to two basic questions: When to order and How much to order?

HOW MUCH TO ORDER?

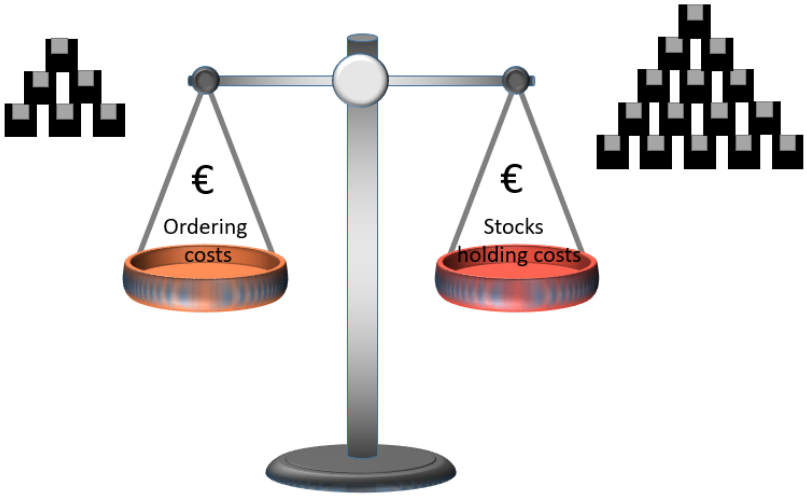

Figure 16. Decide when to order

If a company decides to more often order, they will have fewer stocks in the option, and in that case, ordering cost will be expressed. In the same way, if the company decides to less often ordering, there are stock keeping costs. It is shown in Figure 16.

With the aim of increasing sales, producers and sellers try to satisfy as many as a possible number of customers. However, having excess inventory and maintaining them is an expensive and risky job (costs of warehousing, limited shelf life, product obsolescence, dead stocks, etc.) The main challenge in inventory control is to find an appropriate ratio of costs: to satisfy demand, the company has to have the stock, but not too much, so that inventory costs could not recoup the benefits of the extra sales.

WHEN TO ORDER?

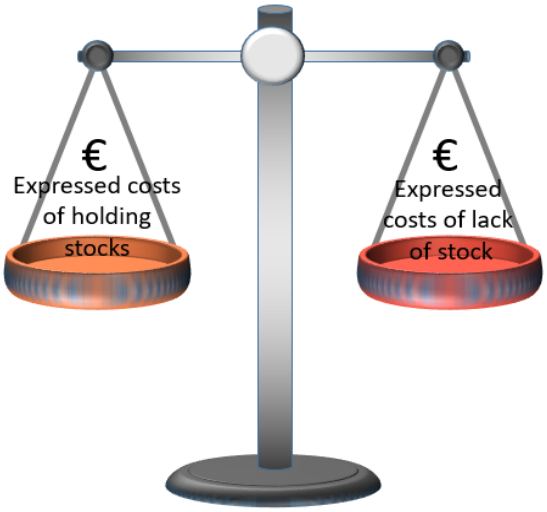

Figure 17. Decide how much to order

When a company decides to order earlier, stock keeping costs will be felt, that is, the average level of stock is higher. However, with this decision, a company will have a better service level for customers. For the later ordering, the average stock level is lower, so the risk of stock depletion is increased, and thus a company would come to exceed costs of deficiency of stock, i.e., loosed selling. It is shown in Figure 17.

In the policy of inventory control, there are two basic categories that achieve or execute this:

- Fixed-order quantity systems.
- Fixed-time period systems.

4.4.1 Fixed order quantity

Inventory models that are developed to assume that demand and/or delivery time are stochastic are called Probabilistic models. One of those models is the Fixed order-quantity model. In a continuous inventory control system, inventory is controlled after each transaction, that is, continuously. Namely, as seen in Figure 18., when the inventory falls to a predetermined point R, a new order is triggered. That inventory level that triggers an order is called the reorder point ROP or R.

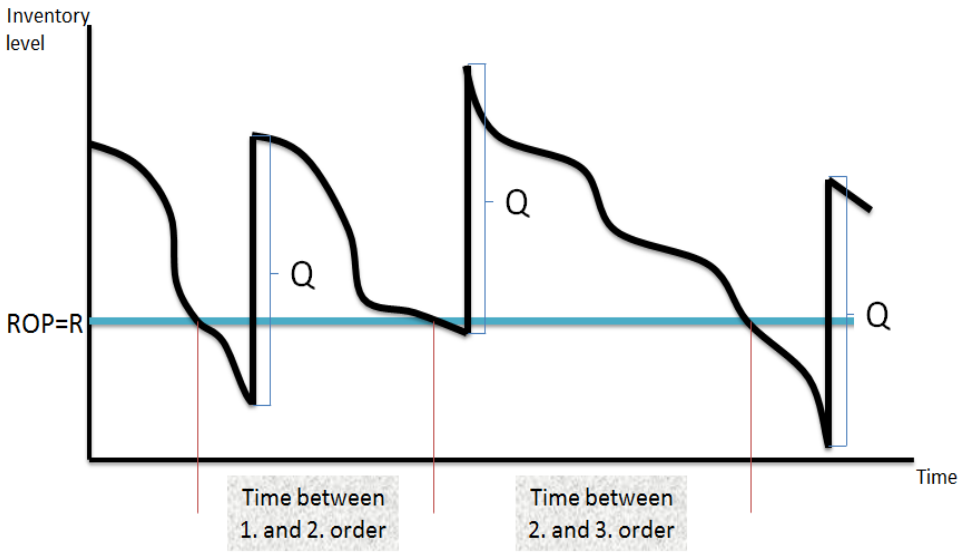

Figure 18. Fixed order quantity model

The ordering rule in a continuous inventory control system with a predetermined order quantity Q consists of two parameters: R and Q. The reorder point (R) can be determined on the basis of inventory costs or on the basis of the service level, while the order quantity Q can be approximated by the EOQ model where the average demand is used for calculation and the demand variability coefficient must be less than 0.2. This model is also called the Q model

According to the basic assumptions of the EOQ model, demand and delivery time are known and constant, and inventory depletion does not occur, however, if demand or delivery time is stochastic, inventory depletion may occur if the demand is higher than expected or if the lead time is longer than expected. Based on this, the three variants of the Q model will be explained.

- Demand - stochastic, lead time - constant

From Figure 19. can be seen stock behavior during the constant lead time (L) and stochastic demand. If there is a situation in lead time that demand is higher than average, i.e expected, the stock will be depleted.

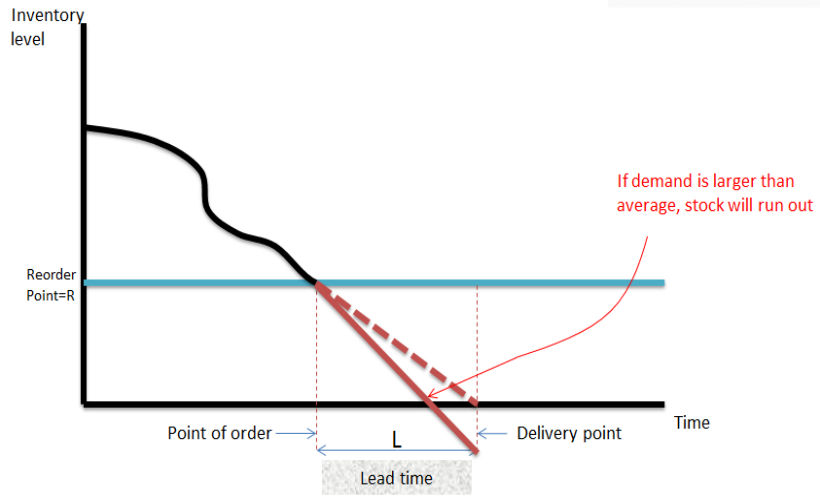

Figure 19. Stock out situation

It is necessary to determine the optimal amount of preventive (safety) stocks SS. Thus, it is obtained that the optimal level of inventory when a new order must be initiated is R, equal to the sum of the inventory of the expected demand during the lead time (LT) and the safety stocks. Well, in Figure 20. can be seen the old R without safety stocks and the new R with safety stocks.

The Q model plays an important role in monitoring current 'in-stock' items and reduces the risk of 'stock-out' of the items (The McGraw-Hill Companies, 2011).

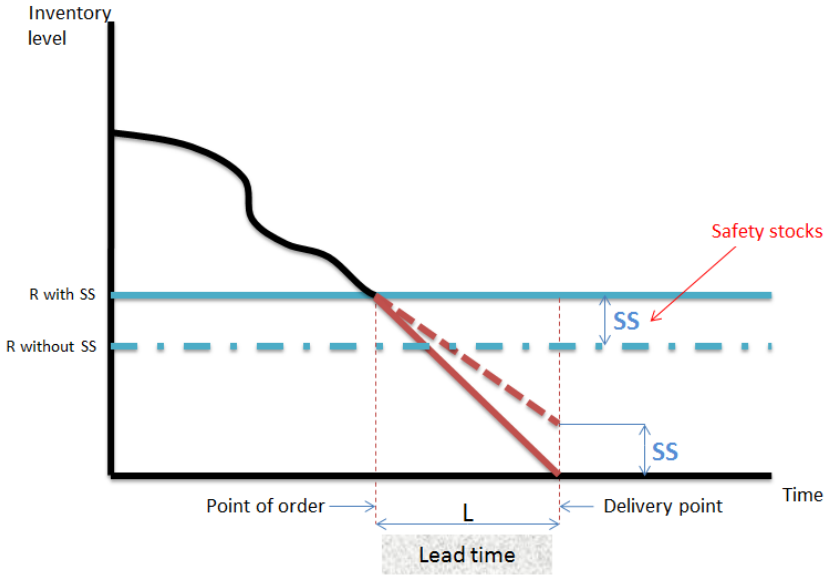

Figure 20. Higher level of Reorder point R

Determining the optimal reorder level R, i.e., optimal preventive (safety) stocks is possible if the unit costs of stock holding and the unit costs of stock shortages are known. The amount of

safety stock depends on the costs incurred in the event of stock-outs and the costs of holding excess stock.

If the company includes safety stocks in its stock management policy, the costs of these can be calculated in the following way:

Additional inventory holding costs = safety stock and unit annual inventory holding cost.

Cost of product shortage = (Quantity of product whose demand cannot be met) x (probability of demand for that quantity of product) x (unit cost of product shortage) x (number of orders in the year)

If there is no information about the costs of holding additional stocks and the costs of lack of stocks, the optimal amount of safety stocks can also be calculated using the service level. Service level is actually the percentage of customers served, and it can also be defined as a compliment to the probability of stock depletion.

The formula for calculating the optimal level R over the desired service level is:

R=Average daily demand x Lead time in days + Preventive quantity

$$R = m_L + ss_L \tag{12}$$

Where,

Expected demand during Lead time:

$$m_L = \bar{d} * L \tag{13}$$

Safety stock during Lead time:

$$ss_L = z * \sigma_{dL} \tag{14}$$

Standard deviation of demand during lead time:

$$\sigma_{dL} = \sigma_d * \sqrt{L} \tag{15}$$

Where, σ_d = standard deviation of daily demand

If the company wants to satisfy a certain level of service, it is necessary to determine the number of standard deviations z for that level of service. The z-value shows how many standard deviations the demand is away from the arithmetic mean. The higher the z value, the higher the service level. The value of z can be found using the table shown in Appendix 3.

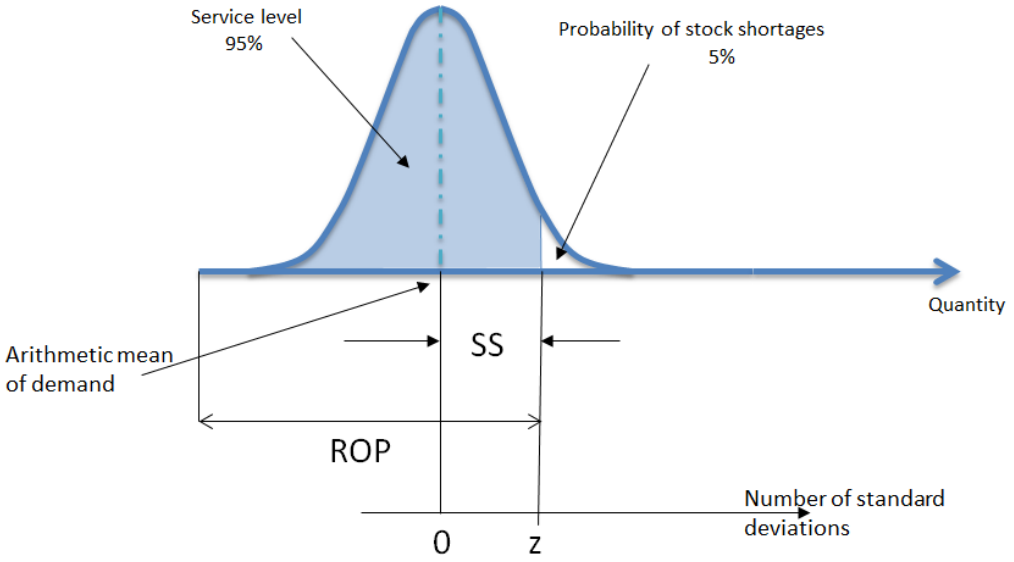

Figure 21. Normal distribution with 95% of service level

Figure 21. above shows a normal distribution, and if the probability is 0.05 that the stock will run out, then the service level is 0.95.

All stocks added above the arithmetic mean of demand represent safety stocks SS, that is, the reorder point R is increased from the arithmetic mean of demand by the value of Safety stocks, as it is shown in Figure 22.

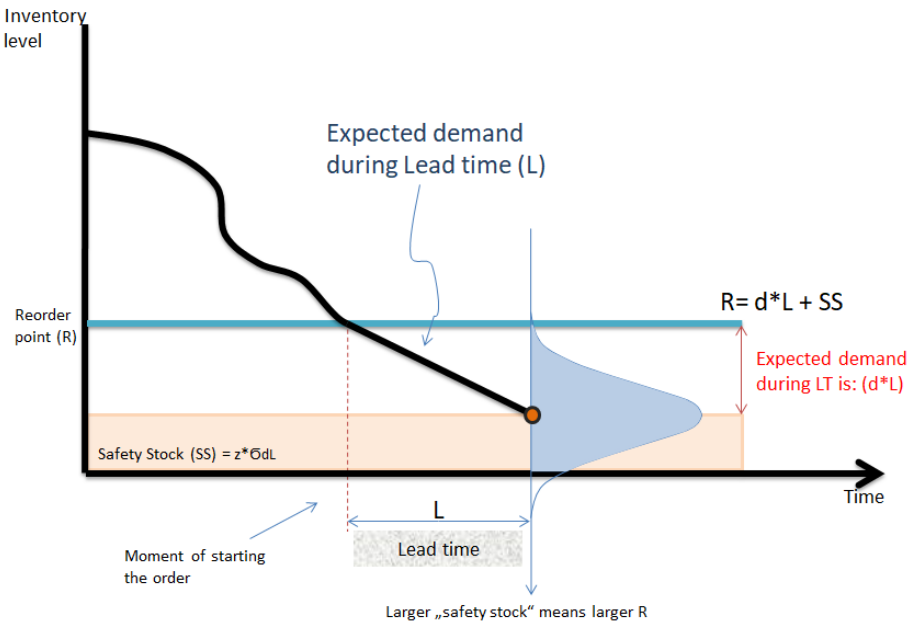

Figure 22. Increased Reorder point with value of Safety stocks

As mentioned earlier, the number of standard deviations z is used to calculate the safety stock, so if a service level of 95% is desired, the z value is sought in the table from Appendix 3. in the manner shown in Figure 23. So, first the value closest to the number 95 is found, which in

this case is .9505, then the z value is read to the left, in this case, 1.6, and after that, the second decimal value for the z value is read, which in this case is .05, so we get that the value of z for a service level of 95 percent is 1.65.

z	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
1.4	.9192	.9207	.9222	.9236	.9251	.9265	.9279	.9292	.9306	.9319
1.5	.9332	.9345	.9357	.9370	.9382	.9394	.9406	.9418	.9429	.9441
1.6	.9452	.9463	.9474	.9484	.9495	.9505	.9515	.9525	.9535	.9545
1.7	.9554	.9564	.9573	.9582	.9591	.9599	.9608	.9616	.9625	.9633
1.8	.9641	.9649	.9656	.9664	.9671	.9678	.9686	.9693	.9699	.9706
1.9	.9713	.9719	.9726	.9732	.9738	.9744	.9750	.9756	.9761	.9767

Figure 23. Finding the value of z using a table from Appendix 1 given by Stevenson

- Demand – constant, lead time – stochastic

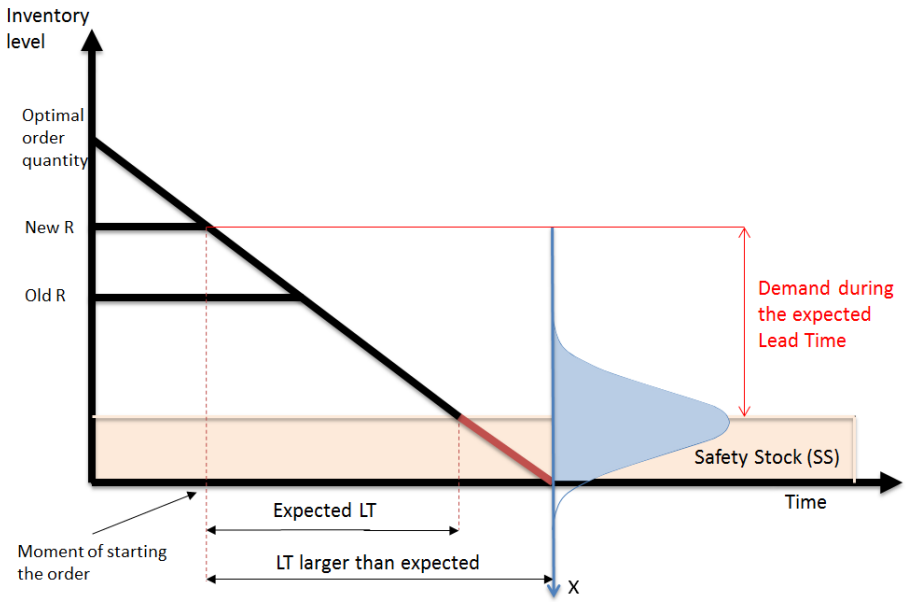

Figure 24. Constant Demand and Lead time

Figure 24. shows the inventory level over time when the demand is constant, and the lead time is stochastic. In order not to get into a situation of stock out due to the possibility of a longer lead time than expected, it can be seen that the old reorder point is R, increased by the value of the safety stock, so there is a new reorder point-R new.

The formula for determining the reorder point is:

$$R = m_L + ss_L \tag{16}$$

$$R = (Daily\ demand\ x\ Average\ lead\ time\ in\ days) + z\ x\ (Daily\ demand)\ x\ \sigma_L$$

Where now, σ_L = standard deviation of lead time in days, which is the only difference compared to the situation when the demand is constant and the delivery time is stochastic.

- Demand and Lead time - stochastic

In a situation where the organization has both demand and lead time stochastically, parameters are determined in the following way. To achieve the desired level of service, it is necessary to calculate R, that is, SS, so there is:

$$R = (Average\ daily\ demand\ x\ Average\ Lead\ time) + z\sigma_{dL}$$

Where,

$$\sigma_{dL} = \sqrt{(Average\ Lead\ time * \sigma_d^2) + (Average\ daily\ demand)^2 * \sigma_L^2} \qquad (17)$$

$$\sigma_d = Standard\ deviation\ of\ daily\ demand$$

$$\sigma_L = Standard\ deviation\ of\ Lead\ time\ in\ days$$

4.4.2 Fixed order-period model

In a periodic inventory control system, inventory is checked periodically at time periods (P), and after each check, inventory is ordered to replenish the target level (T). The check interval (P) is predetermined and fixed, and this model is called the fixed order quantity model. If P is fixed and demand is variable, the order quantity Q will also be variable, as shown in Figure 25. The advantage of this model is that it is not necessary to monitor the stock daily, it is not necessary to keep a record of the stock every time something is taken from the warehouse. The stock level will be determined when the moment P arrives, the inventory is counted and the missing quantity is ordered until the warehouse is full.

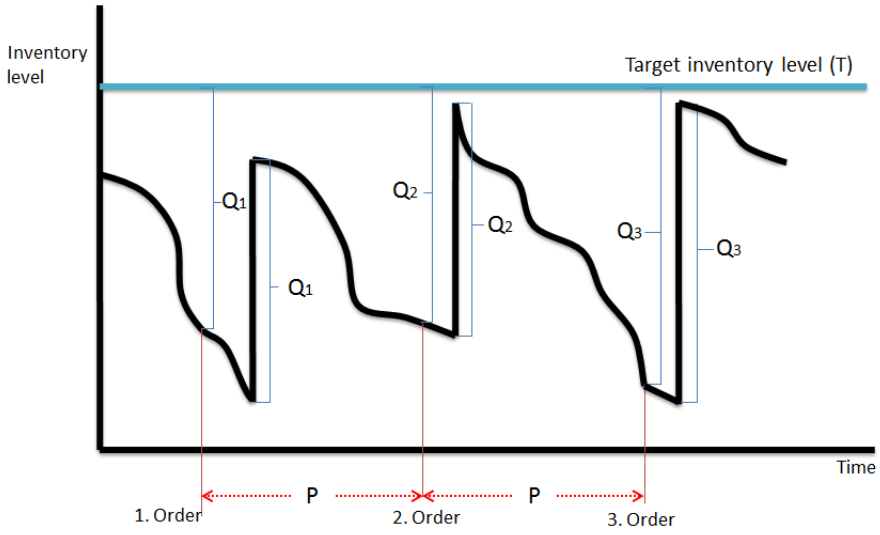

Figure 25. Fixed order period model

The model of fixed order quantities is also called the P model, and it is characterized by 2 parameters: P and T. The approximation of the optimal period P can be obtained using the EQO model with acceptable accuracy, provided that the demand variability is within acceptable limits, that is, the demand variability coefficient must be less than 0.2.

The time between the orders (P) is connected with the EOQ model in the next way:

$$P = \frac{Q}{D} \tag{18}$$

If instead of Q, the EOQ expression for the economic order quantity is included, it is obtained:

$$P = \frac{Q}{D} = \frac{\frac{\sqrt{(2*D*S)}}{\sqrt{H}}}{D} = \frac{\sqrt{(2*D*S)}}{D\sqrt{H}} = \sqrt{\frac{2*S}{D*H}} \tag{19}$$

Average demand is used to calculate P, and the target inventory level (T) can be determined based on the desired level of service. The target inventory level is determined to meet the demand between the two control points (reviews) and the demand during the lead time. Once the target inventory level (T) is determined, the order quantity is:

Order quantity = (Target inventory level) – (Available and ordered inventory at the time the order is placed).

Based on whether the demand is stochastic and the lead time is constant or the lead time is stochastic and the demand is constant or both the demand and the lead time are stochastic,

different formulations for the P model have been developed. Three variants are mentioned below:

- Demand - stochastic, lead time - constant

In a situation where the average demand during the period P+L and the standard deviation of demand for the period P+L are known, the lead time is known and constant. Order quantity is determined as follows:

Q = (Average demand for the period P+L) + Preventive quantity – Available stocks at the time of placing the order

$$Q = m_{(P+L)} + ss_{(P+L)} - I \quad (20)$$

$$Q = m_{(P+L)} + z * \sigma_{d_{(P+L)}} - I \quad (21)$$

Where,

$$\sigma_{d_{(P+L)}} = Standard\ deviation\ of\ demand\ for\ the\ period\ P + L$$

$$m_{(P+L)} = Expected\ demand\ for\ the\ period\ P + L$$

- Demand - comstant, lead time - stochastic

In this case, the daily demand is known and constant, while the lead time is stochastic. The average lead time and the standard deviation of the lead time in days are known. The quantity that should be ordered is determined by the following expression:

$$Q = Daily\ demand * (P + average\ lead\ time\ in\ days) + z * (Daily\ demand) * \sigma_L - I \quad (22)$$

Where,

$\sigma_L =$ Standard deviation of lead time in days

- Demand and Lead time - stochastic

Daily demand is stochastic, but its mean value and standard deviation are known, and lead time is also stochastic, but average lead time and standard deviation of lead time in days are known. So for this case, the order quantity is equal to:

$$Q = Average\ daily\ demand * (P + Average\ lead\ time) + z * \sigma_{d(P+L)} - I \quad (23)$$

$$\sigma_{dL} = \sqrt{[(P + Average\ lead\ time) * \sigma_d^2] + (Average\ lead\ time)^2 * \sigma_L^2} \qquad (24)$$

Where,

σ_d = Standard deviation of daily demand

σ_L = Standard deviation of lead time in days

Some of the differences between Fixed-time period and Fixed-order quantity models are decisions on when to order, size of inventory in the warehouse, ways of when and how much to order, and so on. Table 2. shows a comparison of these two inventory systems.

Table 2. Fixed-order quantity versus Fixed-time period

	Fixed-order quantity	**Fixed-time period**
How much to order?	Order quantity Q = EOQ	Order quantity Q = T - I
When to order?	When inventory level drops to reorder point - ROP	When review period arrives - P
Recordkeeping	Continual	Periodic - at review interval
Size of inventory	Lower	Higher
Order quantity	Fixed	Variable
Time to maintain	Higher	Lower
Type of items	Higher valued items	Quanity discount options

5 IDENTIFIED MANAGEMENT STRATEGIES FOR EXCESS AND OBSOLETE STOCKS IN THE CARDBOARD INDUSTRY

This chapter contains all the knowledge accumulated through the work. Namely, in order to reduce the impact of excess and obsolete stocks, it is necessary to determine and identify strategies that will help this. The best way to manage excess and obsolete stocks is actually the prevention of the creation of such stocks, and then the correction of already created stocks. In this chapter of the master's thesis, preventive and corrective measures for reducing this type of inventory are set.

5.1 Preventive measures

The first and strongest strategy for preventing excess and obsolete inventory is to establish a good inventory management system. It is recommended to use science and scientific methods in inventory management. Inventory control models, such as the Newsvendor model, ABC analysis, XYZ analysis, and combined ABC/XYZ analysis, Economic order quantity (EOQ) model on which the Fixed order period model and Fixed order quantity model are based, are the most commonly used models for inventory management in case of independent demand. The material requirements planning (MRP) system is very often used in production. It is a system for calculating the materials and components needed for production. It is mainly used for dependent production, so this system was not used in the case company.

Due to the small number of incoming raw materials, it is appropriate to use replenishment systems, which are models based on the EOQ model. The periodic model was chosen for the reason that the logical concept of the supplier is such that deliveries are made every week, Monday and Tuesday, and the delivery time is one or two weeks. So everything ordered by Friday will be delivered, depending on the lead time, in one or two weeks.

The company “Neimax d.o.o.” meets production needs through a small number of different raw materials, so a fixed order period model was established for the management of those raw materials, which gave significant results during the ten-month monitoring of raw materials.

ABC analysis can be used to rank or sort customers. Also, products by turnover, by quantity, and by the amount of obsolete stock can be sorted using ABC analysis, which would give the result of how much focus to put on a certain type of product. XYZ analysis can be performed to rank products according to their variability. For example, for those products that are periodic, that are unstable, it is necessary to create a system such that they are made only to order (make to order), while for products with less variability, the make to stock method can be used.

Also, in order to prevent the occurrence of surpluses and obsolete stocks, it is necessary to pay attention to the following items:

- The company must have a criterion for the selection of inventory into current and obsolete ones, generally, the division is made according to the time criterion.
- Goals must be defined for each inventory category, such as setting a key performance indicator (KPI), determining a turnover ratio, setting a Service Level for inventory shortages, setting the maximum value of obsolete inventory in relation to total inventory.
- Establish a reporting and monitoring system.
- Ensure that the FIFO (first in, first out) principle is respected through certain flow racks, that the goods, for example, must be picked up by a forklift that arrived at the warehouse earlier. In one place, the goods are placed in the rack, and in another, they are removed from the rack.
- Defining the principles of cooperation, rights and obligations both within the company and between the company and external collaborators.
- Do not produce with the make to stock method if it is about products with extremely variable demand.
- Clearly define the obligation to monitor the management process.

5.2 Corrective measures

When the company finds itself in a situation where there are already obsolete stocks, that is, when they have already been identified, it is necessary to deal with them. The company has obsolete stocks, the first question is whether it can be found an alternative use in other products, or sold to another customer. After that, can it be sold as some kind of secondary raw material? If the answer is that it cannot, then try repurposing for other purposes, that is, other products. If possible, use the raw material for other products, while trying to reshape the already finished products.

The applicable corrective measures are as follows:

- Attempt to sell to another buyer at the same price as the price for the buyer it was intended for.
- Offer an existing customer an additional discount or offer them certain products as freebies.
- Convert the product into another article, with the necessary changes.
- Write off what cannot be solved in the above way.
- Introducing a penalty for demurrage if the buyer does not withdraw the goods as agreed.

6 CASE STUDY – NEIMAX LTD

All previously mentioned models and strategies for reducing excess and obsolete inventory are covered through a real-world example. In order to carry out strategy simulations, data from the company "Neimax d.o.o." were used. Figure 26. shows the company "Neimax d.o.o.".

Figure 26. Company „Neimax d.o.o.“

6.1 General information about the company and project goals

The company "Neimax d.o.o." from town Visoko is the leading producer of cardboard packaging in Bosnia and Herzegovina. It employs 70 people and operates at two locations. This year, "Neimax d.o.o." also marks a significant anniversary, twenty years of successful production of corrugated cardboard and cardboard packaging for the needs of the wood, food and automotive industries. Products from "Neimax d.o.o." are two-layer, three-layer and five-layer corrugated cardboard and cardboard packaging in B, C, R, BC and BR waves. It conquers foreign markets with products that until today were mainly imported into Bosnia and Herzegovina. Business growth is the result of the strategic thinking of the company's management, which identified a long time ago that the BH market lacks a flexible and reliable manufacturer of cardboard packaging, which can achieve the required quality of customers

from the EU. Also, the company has a strategic goal for progress in the future. Assumptions were made in the company that they could grow even more in the coming years, so the plan for 2023 is a growth of 50% compared to 2022. The increasing demand for these products means that the company must expand, so in this regard, the organization of the company and the management of its resources must be raised to a higher level.

The lack of space and the desire to increase cash flow are the main reasons for starting the project. The goal is to reduce the average amount of inventory through good management and control. Also, to increase the inventory turnover ratio for both overall products and individual products. One of the goals is to satisfy the set service levels in different segments. The inventory tracking time frame is ten months. The strategies identified and listed in the fifth chapter are implemented in this chapter. Figure 27. shows the company's production facility.

Figure 27. Cardboard production line

6.2 Inventory management system

The preventive actions mentioned in the previous chapter were carried out through a real case and real data of the company. Three examples are shown in which the simulation of the fixed order period model is shown. Two examples refer to raw materials and the third to finished products. It is also shown how using a combined ABC/XYZ analysis, stocks can be sorted into those with higher or lower priority.

- First example – Raw material AL 170 220

Table 3. shows part of the fixed order period model (P model) simulation for a lead time value of one week and a review period value of two weeks.

Table 3. Simulation of P model

Control week	Demand	State at the beginning of the period	Current + ordered quantities at the beginning of the period	Order quantity	Quantity received	STATE
1	0	20000	20000	3243		20000
2	0	23243	23243		3243	23243
3	6524	23243	23243	6524	0	16719
4	1620	23243	23243		6524	21623
5	1246	21623	21623	1620	0	20377
6	7920	21997	21997		1620	14077
7	3290	14077	14077	9166	0	10787
8	4928	19953	19953		9166	15025

Before the simulation, it was necessary to determine the order quantity Q. The order quantity is determined in the way explained in chapter 4 where the P model with variable demand and fixed lead time is shown.

Once the target stock level and order quantity are known, the simulation is approached. Part of the simulation, two months to be exact, is shown in Table 3, and from the table, it can be seen that the balance is reviewed every two weeks and that then the quantity Q is ordered. The lead time is one week, so it can also be seen that the company has the ordered quantity on hand the next week. The state at the beginning of the period is determined by looking at the state from the previous week, the demand from the previous week, and the amount received from that period. Thus, for example, the value 19953 = 14077 – 3290 + 9166 is obtained. The rest of the simulation is shown in the Appendix 4.

Figure 28. shows the demand for this product. The company did nothing in the sixteenth and seventeenth weeks. It is possible that it was not reorded in time, so the output was moved to the following week. Or it was not completed on time, so the next week it was completed. Such demand situations could also be caused by a collective annual vacation or a machine breakdown. Also, it is possible that the person doing the control was not at work, so he recorded the output only the following week. All these things are characteristic of production,

so this demand diagram speaks as if there was no output at all for several weeks. This extreme demand is not natural but is caused by decisions or certain events in the company.

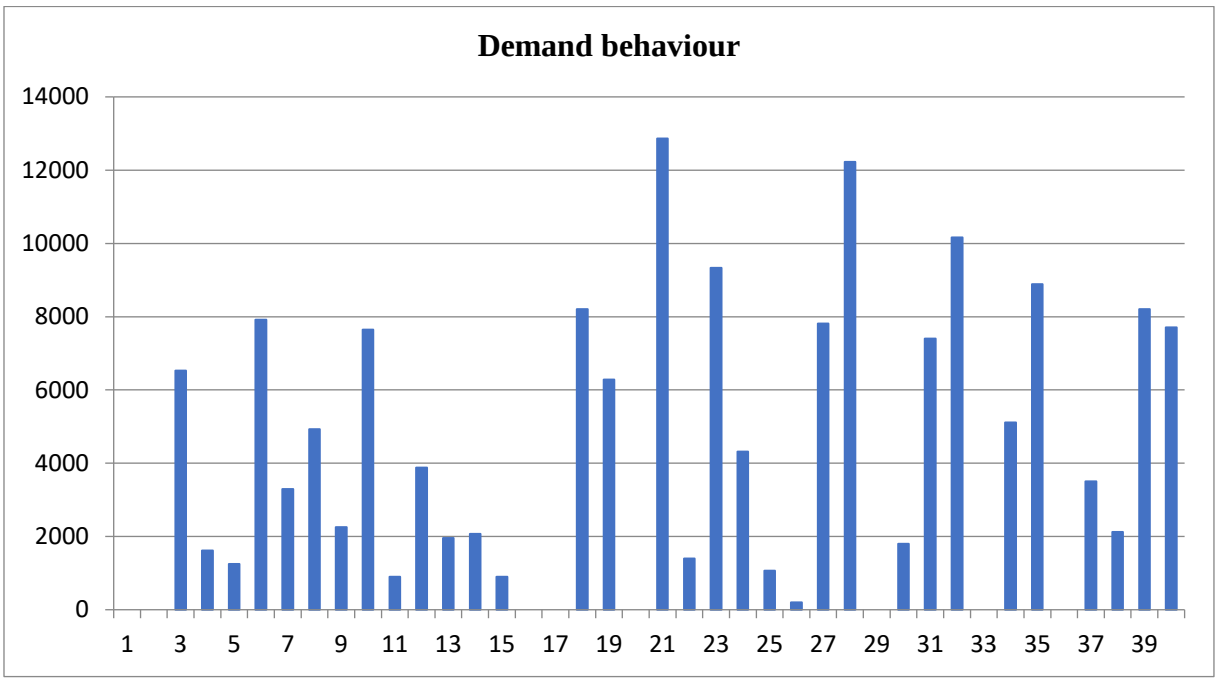

Figure 28. The behaviour of weekly demand

Figure 29. shows how the introduction of the P management model leads to a reduction in average inventory for a service level of 95%.

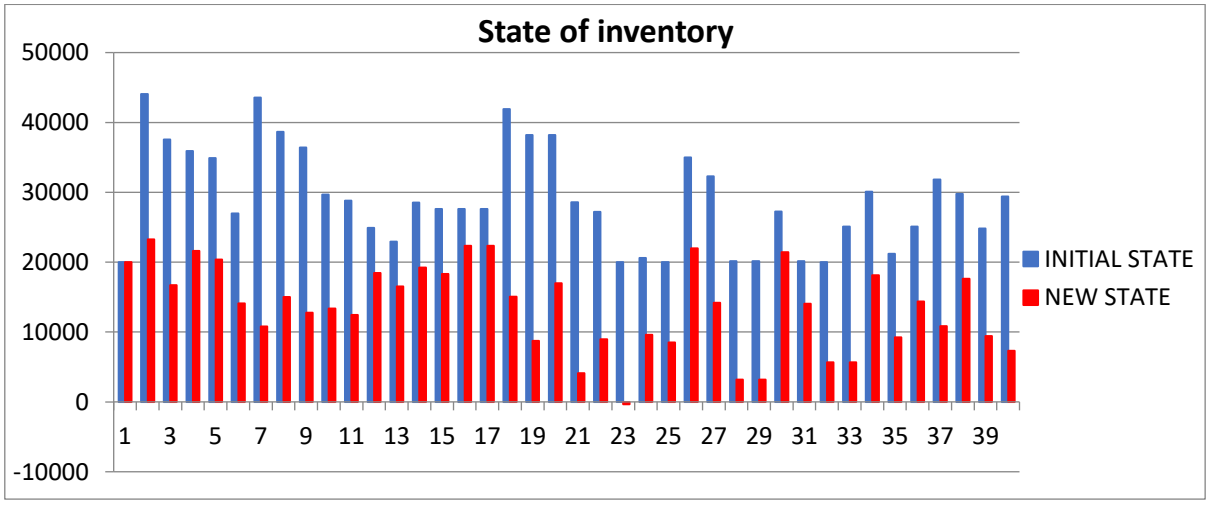

Figure 29. Comparison of the amount of the initial inventory balance and the new balance

It is noticeable that by reducing the service level from 95% to 90%, the average amount of inventory also decreases, as can be seen in Figure 30.

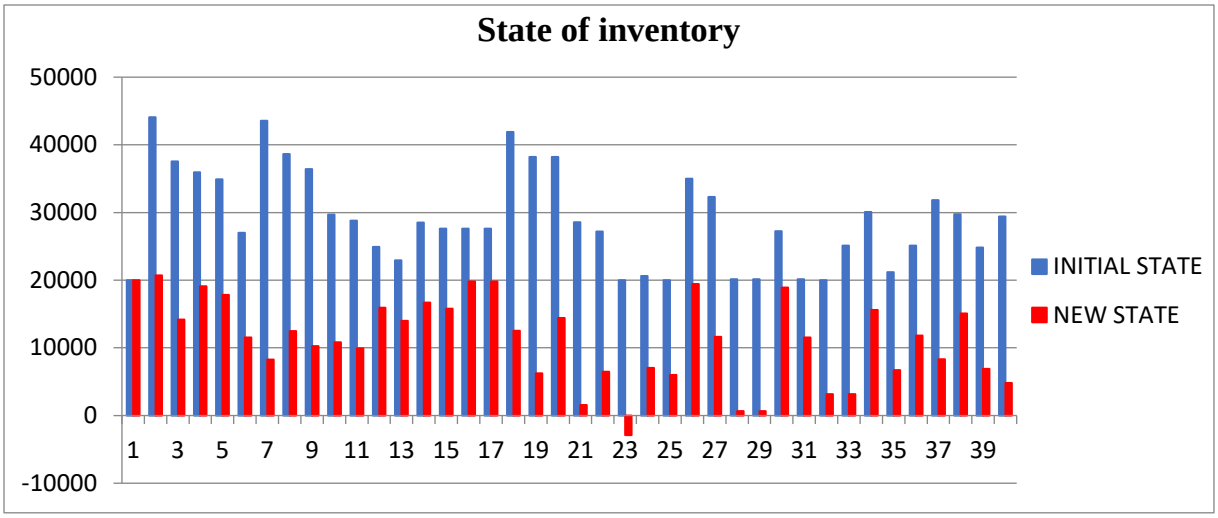

Figure 30. New condition with 90% service level

Table 4. shows a comparison of inventory characteristics for the situation of initial, already established management, and for the situation where the P model was used with two different levels of service, 95%, and 90%. The service level is also shown for the situation of how many times the inventory has been depleted. It can be seen from the table that this level of service is satisfied using the P model, that is, there was no stock depletion of more than 5%.

Table 4. Aimed results

	Initial state	New state, Service level 95%	New state, Service level 90%
Average inventory in the warehouse	29070	13457	11008
How many times the stock ran out	0	1	1
How many supplies were missing in total	0	353	2883
The SERVICE LEVEL for the situation of how much stock was missing in total	100%	>95%	>95%
Inventory turnover ratio	6.76	14.6	17.85

- Second Example – Raw material AT 120 250

A simulation of the P model was performed for the case when LT=1 week, and the review period is every four weeks. The simulation is shown in Appendix 5., with the only difference compared to the previous example actually being the review period.

The first thing to consider during the analysis is the demand, and Figure 31. shows the demand for this raw material. This demand is actually for production in the company, that is, how much raw material is consumed in production.

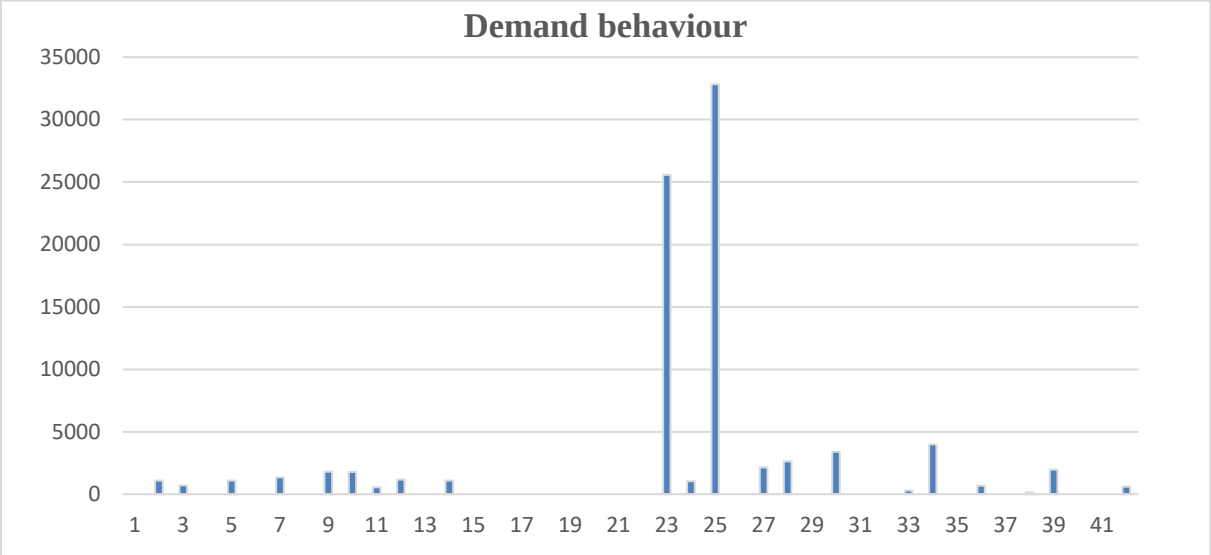

Figure 31. Demand behaviour with two outliers

The situation that happened in this search is unnatural and it is a classic outlier. It was known that the stock would behave like this. The average order for the company is two to three thousand and then the order jumps to 25,000 or 32,000. That is the critical demand that happened, and Figure 32. shows how the inventory management system that used the P model failed. These results of the P model happened because of these two outliers that inflated the mean value, and also inflated the standard deviation. Therefore, the target inventory level is significantly higher.

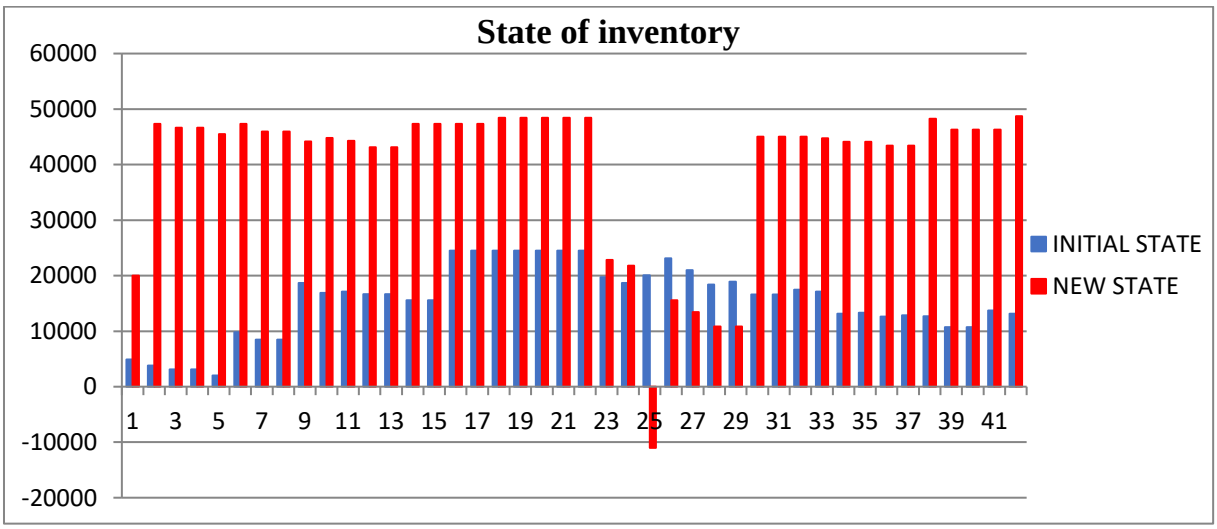

Figure 32. Faulty P model control system

In order to start a real analysis and comparison, the outliers are removed, that is, their value is limited to a maximum of 4000. With the outliers not removed, the mean value is 2046.3 and the value of the standard deviation is 6276.1. When the outliers are removed, the mean value is 846.17 and the value of the standard deviations 1218.1. Now Figure 33. (below) shows a real comparison and analysis.

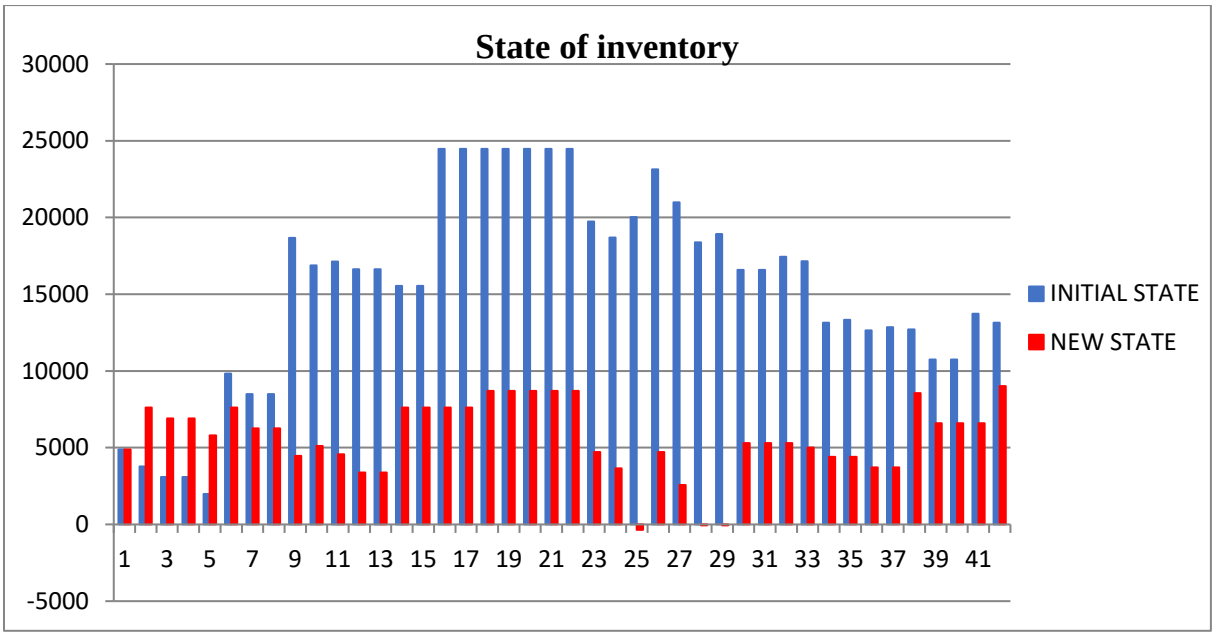

Figure 33. P model with adopted service level of 95%

Analogously to example 1, smaller amounts of stock are obtained, if a service level of 90% is taken in the P model, as it is shown in Figure 34.

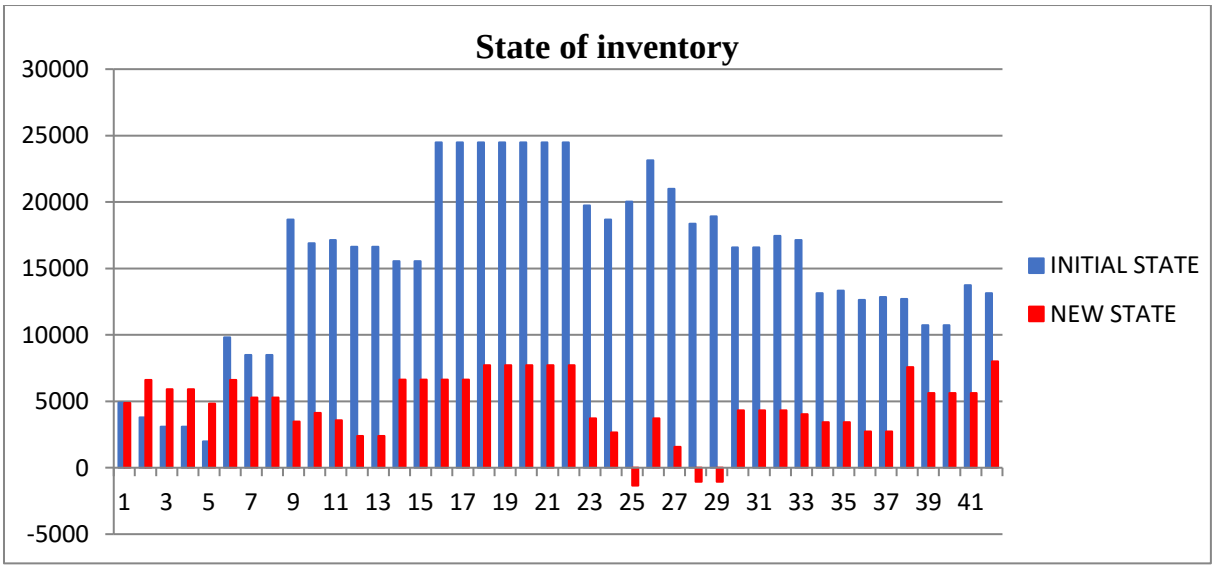

Figure 34. P model with 90% service level

Table 5. shows the inventory parameter for the initial state, as well as for the state if the service level is 90%, i.e., 95%. The service level can be quantitative, but it can also be related to the depletion of supplies, so the service level for missing supplies is met, that is, such supplies are less than 5%.

Table 5. Aimed results

	Initial state	New state, Service level 95%	New state, Service level 90%
Average inventory in the warehouse	15542	5642	4675
How many times the stock ran out	0	3	3
How many supplies were missing in total	0	452	4675
The SERVICE LEVEL for the situation of how much stock was missing in total	100%	>95%	>95%
Inventory turnover ratio	6.63	7.6	9.2

- Third example – Finished goods

In this example, the state of the finished goods is shown. The first thing to do in the analysis is to see what the demand is. Figure 35. shows the demand for this product.

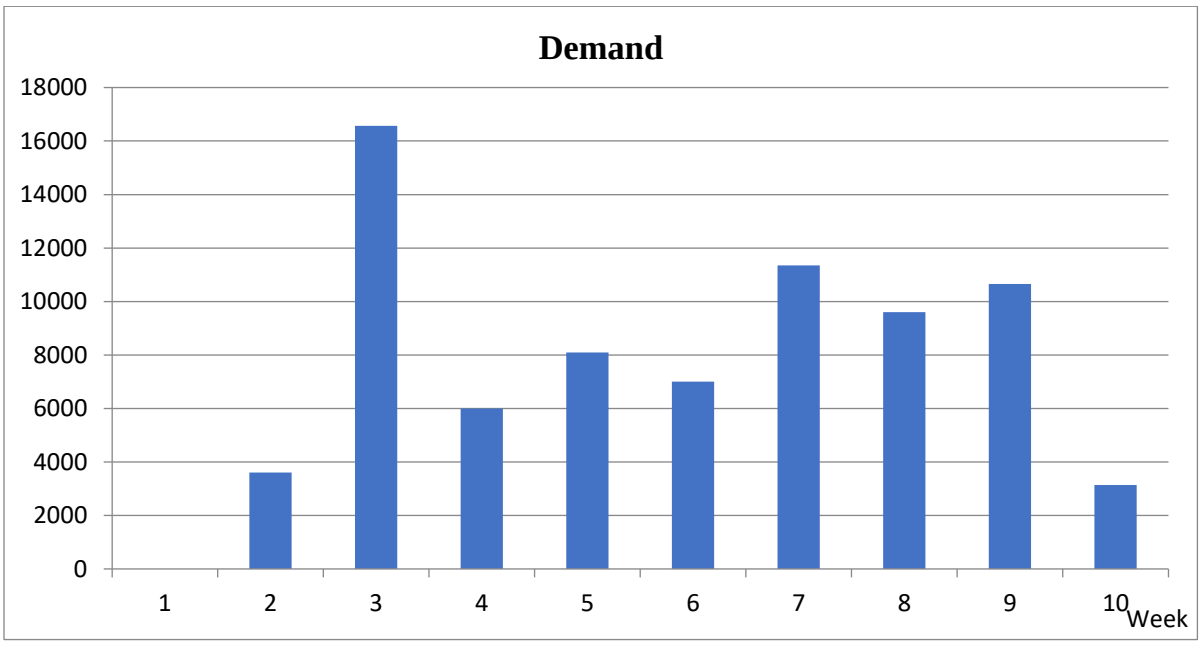

Figure 35. Demand of finished product

From Figure 36., can be seen that the introduction of the P model reduced the level of inventory, but there was no shortage of inventory. Data were collected from a period of ten weeks, where the review period is two weeks, and the lead time is one week.

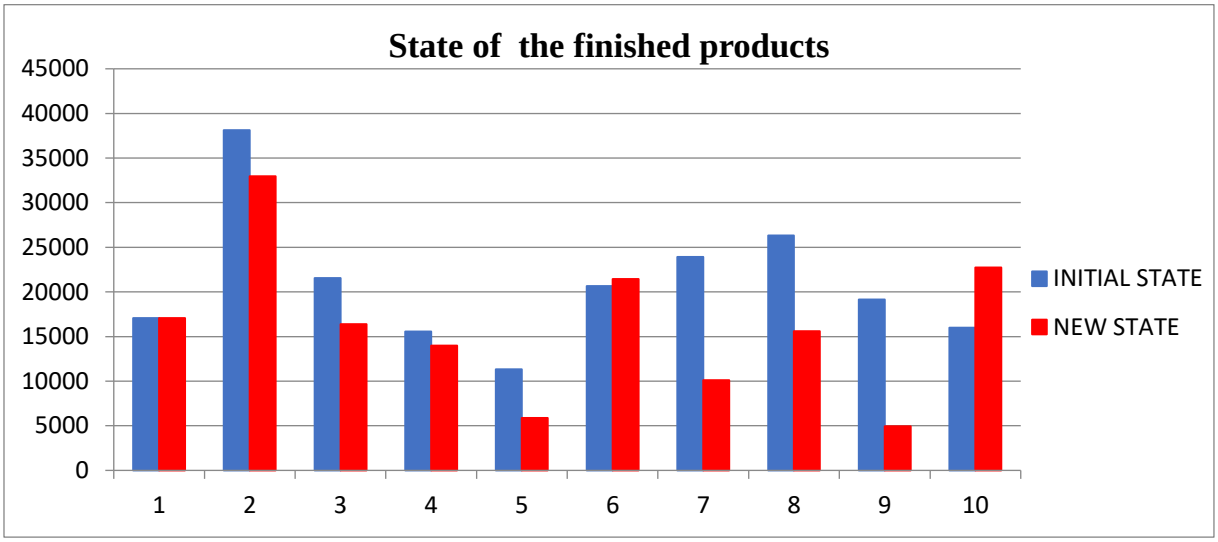

Figure 36. Fixed order period model with a service level of 95%

The real situation of the service level for production is 80% to 90%, so if a service level of 90% is taken, even smaller amounts of inventory are obtained, which leads the company to have less excess and obsolete inventory, as it is shown in Figure 37.

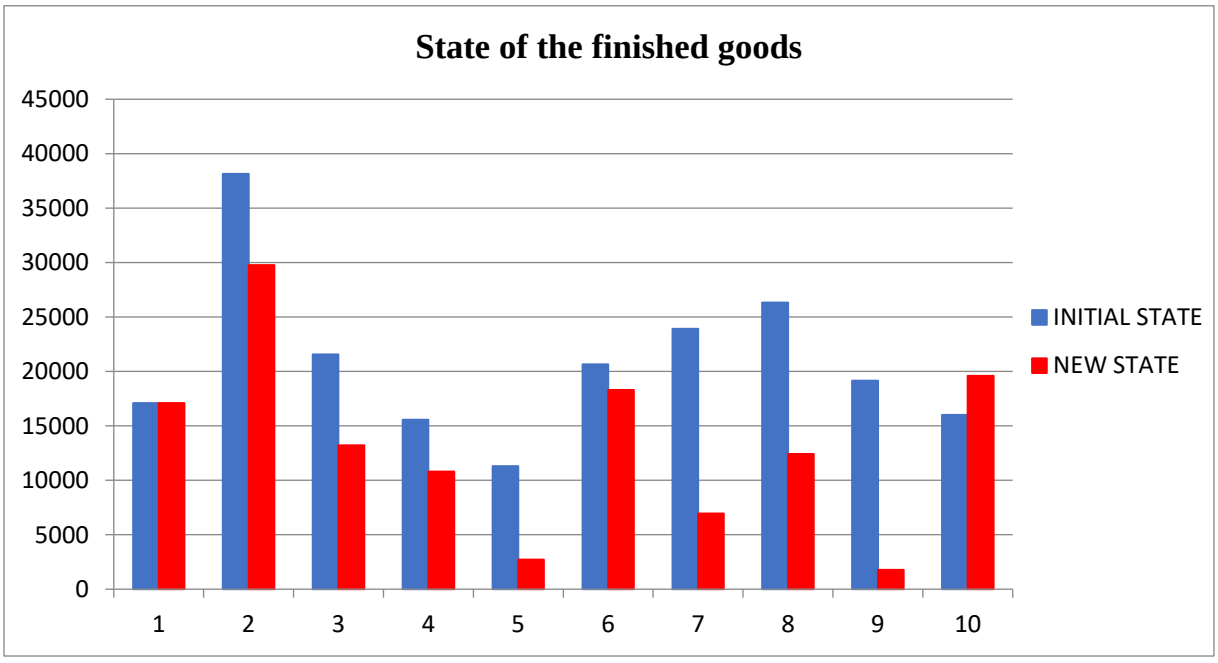

Figure 37. Fixed order period model with a service level of 90%

Table 6. shows the average stock level for previous management and management during the introduction of the P model for service levels of 95% and 90%. It is noticeable that the

average inventory level has decreased, and the inventory turnover ratio has increased, which was the goal of this project.

Table 6. State of finished goods

	Initial state	New state, Service level 95%	New state, Service level 90%
Average inventory in the warehouse	20968	16113	13258
How many times the stock ran out	0	0	0
How many supplies were missing in total	0	0	0
Inventory turnover ratio	18.1	23.6	28.7

- Combined ABC/XYZ analysis

As a preventive measure to reduce excess and obsolete inventory, it is also necessary to pay attention to sorting. Table 7. shows the matrix of the combined ABC-XYZ analysis.

Table 7. Matrix of ABC-XYZ analysis

	X	Y	Z
A	P3	P6	P5
B	P4	P7	P1
C	P8	P9	P2

This analysis was done in such a way that first an ABC analysis was done according to the demand for raw materials, where the raw materials that are used the most in production are distributed in the A group and the raw materials that are in the least use in the C group. After that, an XYZ analysis was performed, where the raw materials were assigned to the X, Y, or Z category depending on the CV demand variation coefficient. CV = Standard Deviation / Average. It is important to note that the coefficient of variation is not an absolute measure in the XYZ analysis, the seasonality of some products must also be taken into account, which is not included in this analysis. CV is a measure of variability but not a measure of

predictability. Otherwise, predictability is taken into account for XYZ analysis, but in this case predictability was not considered. Raw materials in the X group have the smallest demand variation.

After forming the matrix, it is possible to set different priorities for different raw materials. In this regard, for the group of raw materials AX, AY, and BX, a higher level of service will be determined, because they are carrier products, and they should be paid more attention to and checked more often. While for the group of raw materials CY, CZ, and BZ, company should not invest too much time, because they are raw materials that are used less often and have a high coefficient of variation, but still should not be ignored. Through this type of inventory allocation, the amount of excess and obsolete inventory will surely be reduced.

6.3 Dealing with obsolete stocks

All previously done are preventive measures and this will give certain results in reduced obsolete and excess stock. And now there is a situation where the company already has obsolete stocks in finished products, and will certainly have them later. What to do when they happen, how to get rid of them, and how to correct the already existing situation? The solution in the case company takes place through the tactics mentioned in this part.

Sorting

Figure 38. shows five different types of finished products according to the number of days in the warehouse. Why are supplies divided into these five categories? This division was made in order to be able to have an insight into the situation with the stocks, so if the stocks come to a situation where they are in the warehouse for more than 240 days, a decision is made whether to sell them, repackage them or write them off.

Products with more than 240 days in stock amount to 18% of the total number of stocks. The division was also made because if it is noticed that the second or third category is growing, it immediately represents an alarm that in a month or two it will move into the critical fourth or fifth category, which could lead the company to the problem of obsolete or even dead stock. Stocks less than 30 days old are current stocks; no corrective actions are taken there. So, first, it is sorted, and then different management tactics are applied for these different groups of products.

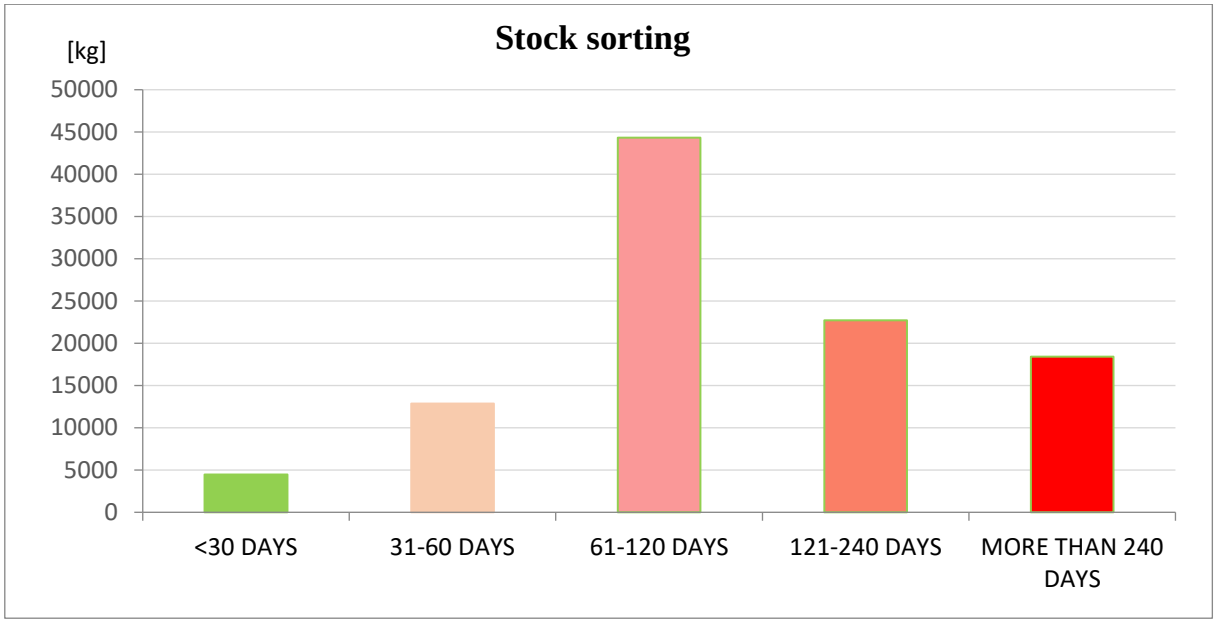

Figure 38. Divisions of warehouse stocks according to how long are there

ABC analysis for finished goods

ABC analysis provides us with a good tool for determining the companies that most cause the emergence of obsolete inventory, that is, inventory that has been in the warehouse for more than 240 days. In category A belong companies 1,2,3 and 4, and that is 18% of the total number of companies, and 80.74% of obsolete stocks refer to them. As for category B, companies 5, 6, 7, 8, and 9 belong there, and such companies are 23% and they cause 14.62% of obsolete stocks. The other 59% of companies belong to the C category. The graph of ABC Analysis is shown in the figure below. Figure 39. shows the percentage of obsolete stocks in companies as a bar graph, and the cumulative percentage is shown by the line with markers.

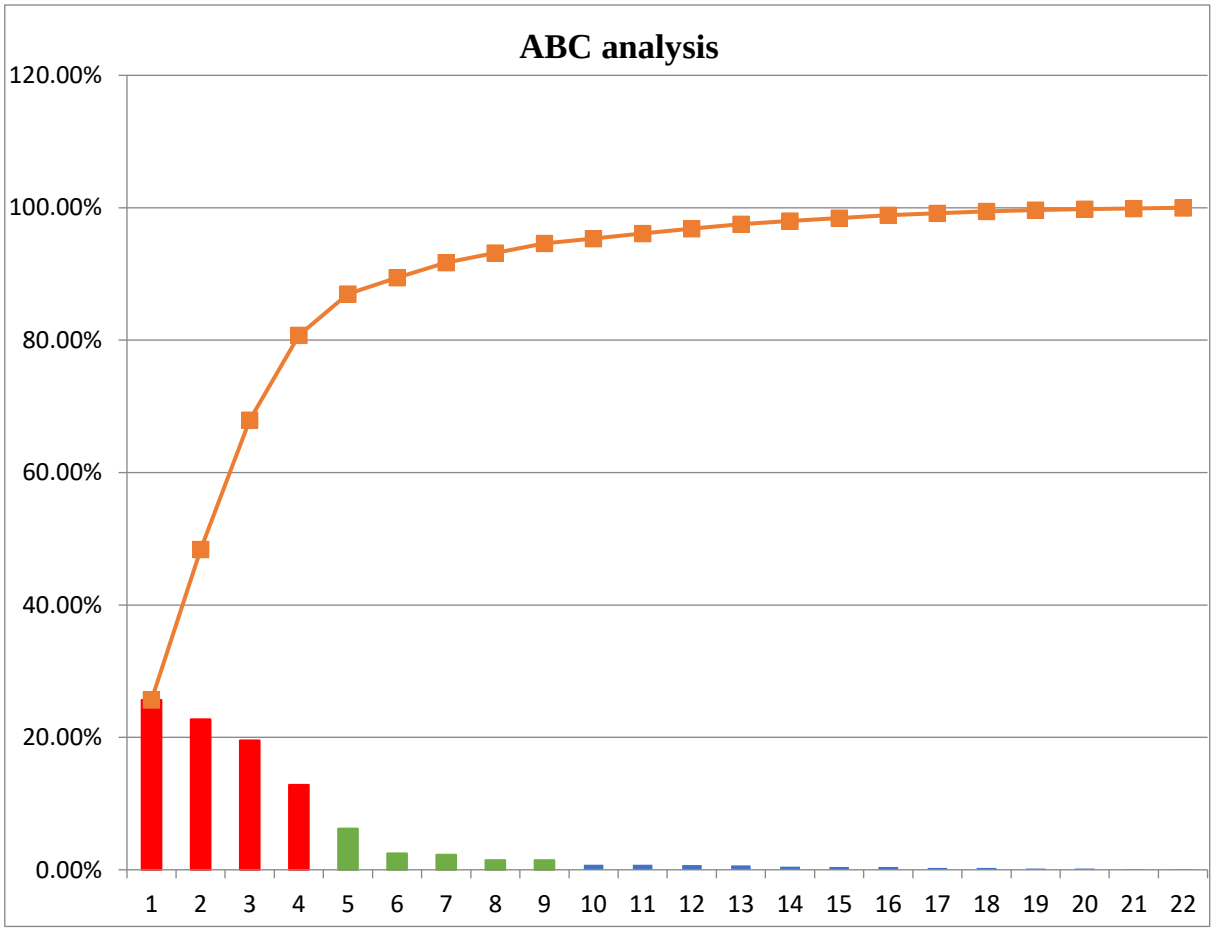

Figure 39. Schedule of companies by ABC analysis

The aforementioned ABC analysis can help determine where the company's biggest threat or biggest problem with obsolete inventory comes from. Which company is it from, and the reasons for that are poor communication, that is, an insufficiently developed type of business. The determination of that company can also be an indication that negotiations with them in a different way, in such a way that the obsolete supplies resulting from cooperation with them, are calculated somewhere in the price. Likewise, for companies that do not make us obsolete stocks, they should be given better business conditions, better prices and so on.

It is also possible to take corrective actions. So, it is possible to set a deadline for the first corrective action, if there is still obsolete stock, then make a second corrective action with a set implementation deadline, and so on. The options during corrective action used in „Neimax d.o.o.“ are as follows:

- Offer products to companies from other industries, such as the meat industry, textile industry, metal industry or express post companies.
- Insertion of obsolete product parts into a more frequent product.

- Sell goods to the same customer with a longer payment option.
- Offer customers a larger quantity discount.
- Finding alternative uses for boxes – using them to make samples, smaller stamped boxes, etc.
- Use as corners when packing pallets in the factory.
- If they are not used anywhere, then in order to free up space in the factory, they are disposed of as waste.

6.4 Effects of the established system

Figure 40. shows the effects of the established system in the case company. It can be seen that the sum of obsolete stocks in the period of 28 weeks has decreased. When it takes the average inventory value from the first 5 weeks and the last 5 weeks, it can be seen that the sum of obsolete inventory has decreased by 64%.

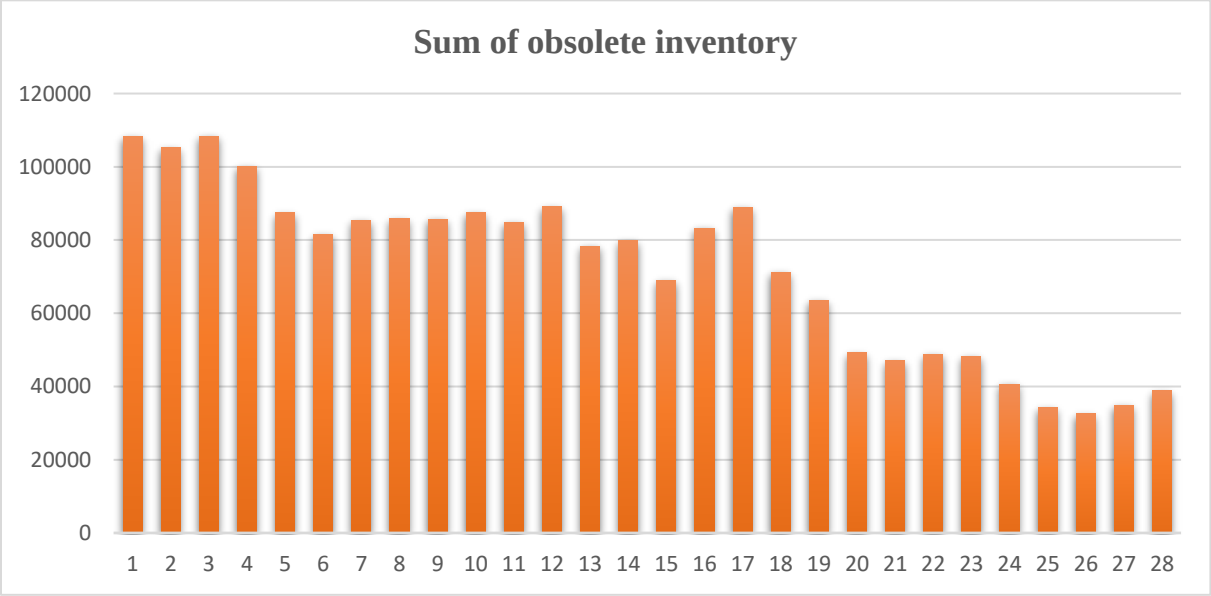

Figure 40. Sum of obsolete inventory

7 CONCLUSION

Stocks enable to have a normal sales flow in sales companies and a normal production flow in production companies. The goal of every company is to improve the production or sales process and to satisfy the needs and demands of customers, i.e. to achieve the highest possible service level. To achieve all this, it is very important to establish an accurate and precise inventory management system. The emphasis in the work is on obsolete and excess stocks.

The goals that were set before the beginning of writing the paper were achieved through the work. The survey described the situation in companies from Bosnia and Herzegovina. The criteria according to which stocks are classified into obsolete and current are listed, and it is shown graphically how often this type of stock is analyzed. Companies also use certain measures to prevent the occurrence of obsolete stocks, so the seven measures that are most often used in prevention are listed. In a situation where there are already obsolete stocks, it is necessary to get rid of them. Also listed are the most common strategies that employers in Bosnia and Herzegovina use when dealing with obsolete inventory. Most companies manage resources through an internally developed system and spreadsheets in excel, about 60% of companies, while a large number of companies (about 30%) make decisions without the support of computer systems, more intuitively by counting inputs and outputs. Only a small percentage of companies use an ERP system. It was concluded that companies that frequently control inventory have 23% of obsolete inventory in total inventory, while companies that control inventory less frequently and companies that do not worry about this type of inventory have 11% of obsolete inventory. This means that employers who do not control stocks or control them less often, do not have a sense of the real state of stocks, since it can be seen from the literature that this type of stock amounts to 20 to 30%.

A case company was also used to fully achieve the goal of the work. Data from the company "Neimax d.o.o." was used. The stocks were monitored for 10 months, and the results of the previous management and management of the newly established model were presented. Also listed are how the company suppresses the existence of obsolete and excess inventory. The graphics show how the implementation of the Fixed order period model leads to a reduction in average inventory and an increase in the inventory turnover ratio, with the service level not being disturbed. It is shown how the implementation of ABC analysis can determine the

companies that generate the highest level of obsolete inventory. And through the use of crossed ABC/XYZ analysis, stocks can be classified into those that are the carriers of processes in the company, and those that are less important. The corrective measures used by the company are also listed, and at the end, a graph of the success of the implementation of strategies to reduce excess inventory is presented.

In the end, it should be pointed out that by implementing lean methods such as SMED (Single Minute Exchange of Die) and Kanban, the optimal batch sizes can be further reduced, which will lead to a drop in inventory, increase flexibility, affect the reduction of WIP (Work-in-process) supplies, etc. Also, more effort should be invested in communication and cooperation within the supply chain, especially in relations with customers, because "Neimax d.o.o." has greater bargaining power there, while in relations with suppliers it does not have great bargaining power, as these are large companies. Forecasting methods could be introduced, which would certainly improve future planning.

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Appendix 1. Example of ABC analysis

Item code	Annual sales (pieces)	Unit Price (€)	Annual turnover (€)	Percentage in total annual turnover	Cumulative share in total annual turnover	Class
7539	35000	24.5	857500	41.1%	41.13%	A
6849	21000	32	672000	32.2%	73.37%	A
2576	24500	6	147000	7.1%	80.42%	B
7891	5250	18.5	97125	4.7%	85.08%	B
1264	21000	4.5	94500	4.5%	89.61%	B
1256	17500	3.5	61250	2.9%	92.55%	C
2136	10500	4.5	47250	2.3%	94.82%	C
1276	15750	3	47250	2.3%	97.08%	C
1579	17500	1.75	30625	1.5%	98.55%	C
2395	26250	1.15	30187.5	1.4%	100.00%	C
SUM:	194250		2084687.5			

Appendix 2. Figures

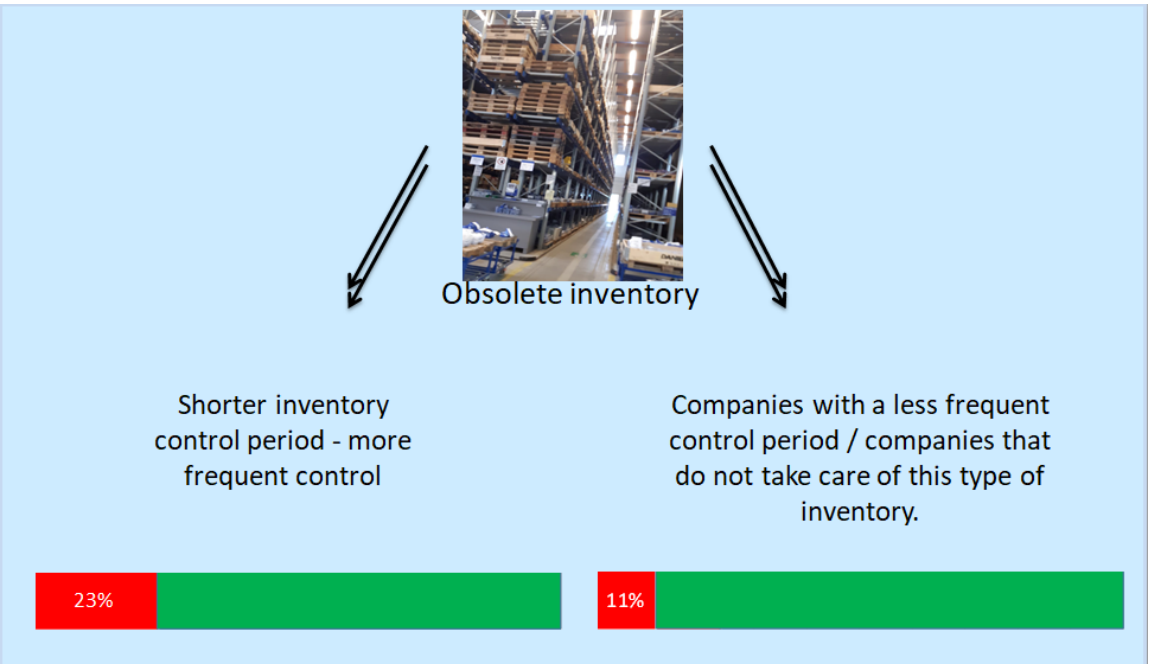


Figure 1. More often control, more realistic state

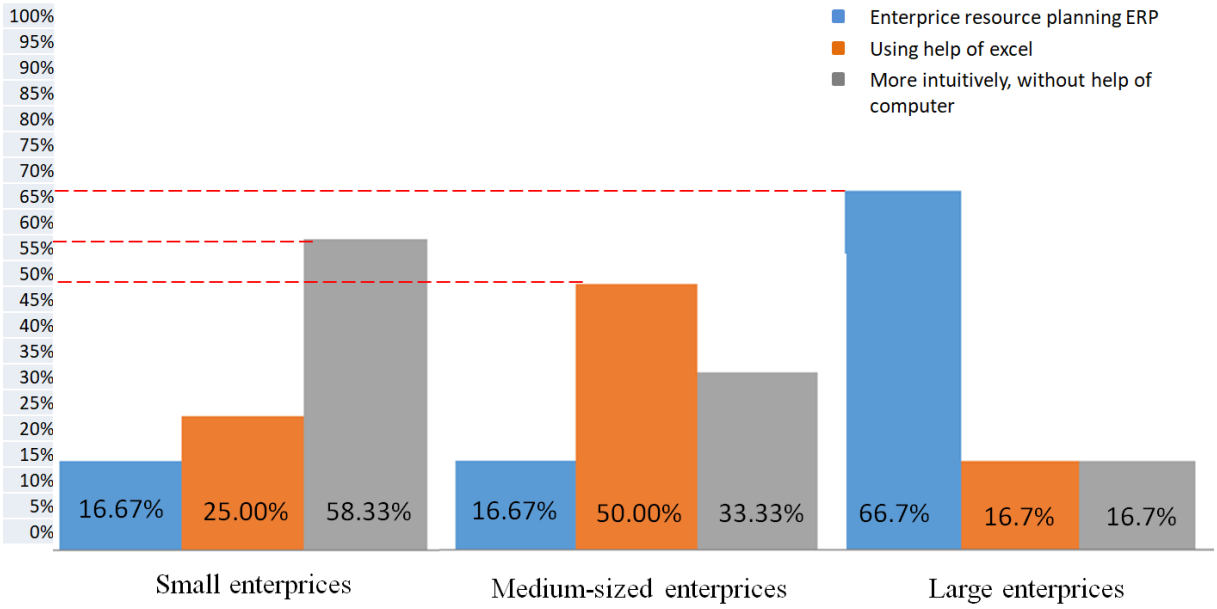


Figure 2. The more employees, the greater the use of computer systems

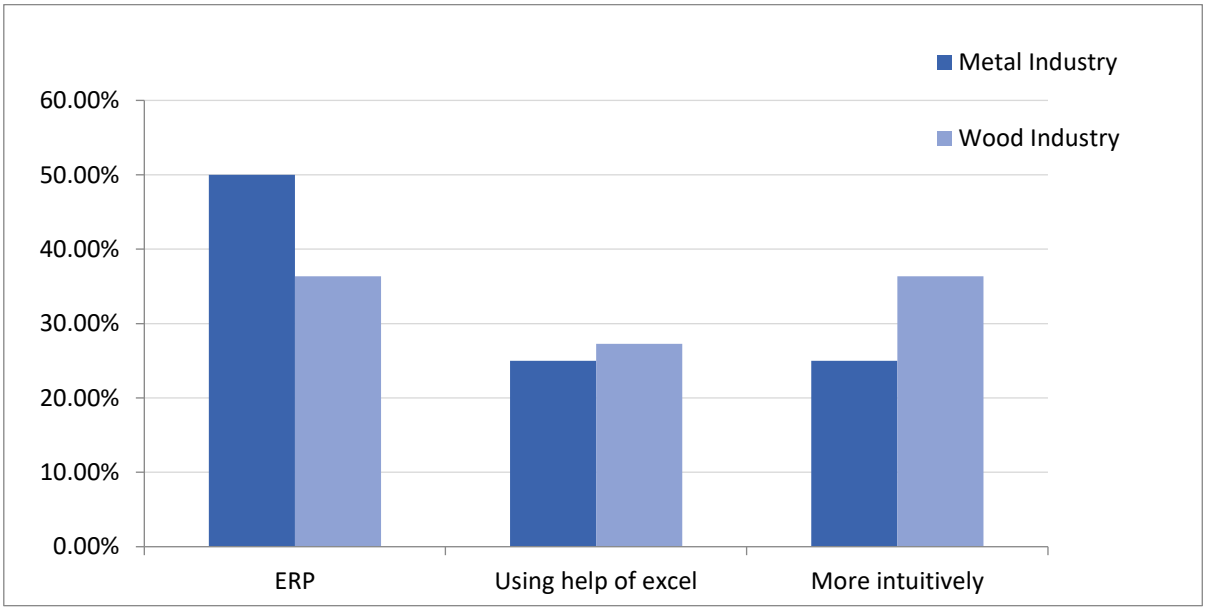


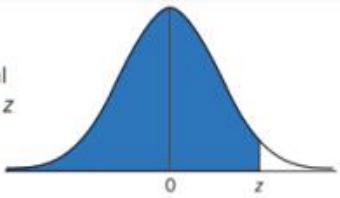
Figure 3. Metal and wood industry

	X	Y	Z
A	• Large participation in total turnover. • Even demand. • High accuracy of forecasts.	• Large participation in total turnover. •Variable but predictable demand. • Average forecast accuracy.	• Large participation in total turnover. • Sporadic and unpredictable demand. • Unreliable forecasts.
B	•Medium participation in total turnover. •Even demand. •High accuracy of forecasts.	•Medium participation in total turnover. •Variable but predictable demand. • Average forecast accuracy.	•Medium participation in total turnover. • Sporadic and unpredictable demand. • Unreliable forecasts.
C	• A small share in the total turnover. •Even demand. •High accuracy of forecasts.	• Small participation in the total turnover. •Variable but predictable demand. • Average forecast accuracy.	• Small participation in the total turnover. • Sporadic and unpredictable demand. • Unreliable forecasts.

Figure 4. Combination of ABC and XYZ Analysis

Appendix 3. Areas under the standardized normal curve, Stevenson (2018)

Table B.2
Areas under the standardized normal curve, from $-\infty$ to $+ z$



z	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
.0	.5000	.5040	.5080	.5120	.5160	.5199	.5239	.5279	.5319	.5359
.1	.5398	.5438	.5478	.5517	.5557	.5596	.5636	.5675	.5714	.5753
.2	.5793	.5832	.5871	.5910	.5948	.5987	.6026	.6064	.6103	.6141
.3	.6179	.6217	.6255	.6293	.6331	.6368	.6406	.6443	.6480	.6517
.4	.6554	.6591	.6628	.6664	.6700	.6736	.6772	.6808	.6844	.6879
.5	.6915	.6950	.6985	.7019	.7054	.7088	.7123	.7157	.7190	.7224
.6	.7257	.7291	.7324	.7357	.7389	.7422	.7454	.7486	.7517	.7549
.7	.7580	.7611	.7642	.7673	.7703	.7734	.7764	.7794	.7823	.7852
.8	.7881	.7910	.7939	.7967	.7995	.8023	.8051	.8078	.8106	.8133
.9	.8159	.8186	.8212	.8238	.8264	.8289	.8315	.8340	.8365	.8389
1.0	.8413	.8438	.8461	.8485	.8508	.8531	.8554	.8577	.8599	.8621
1.1	.8643	.8665	.8686	.8708	.8729	.8749	.8770	.8790	.8810	.8830
1.2	.8849	.8869	.8888	.8907	.8925	.8944	.8962	.8980	.8997	.9015
1.3	.9032	.9049	.9066	.9082	.9099	.9115	.9131	.9147	.9162	.9177
1.4	.9192	.9207	.9222	.9236	.9251	.9265	.9279	.9292	.9306	.9319
1.5	.9332	.9345	.9357	.9370	.9382	.9394	.9406	.9418	.9429	.9441
1.6	.9452	.9463	.9474	.9484	.9495	.9505	.9515	.9525	.9535	.9545
1.7	.9554	.9564	.9573	.9582	.9591	.9599	.9608	.9616	.9625	.9633
1.8	.9641	.9649	.9656	.9664	.9671	.9678	.9686	.9693	.9699	.9706
1.9	.9713	.9719	.9726	.9732	.9738	.9744	.9750	.9756	.9761	.9767
2.0	.9772	.9778	.9783	.9788	.9793	.9798	.9803	.9808	.9812	.9817
2.1	.9821	.9826	.9830	.9834	.9838	.9842	.9846	.9850	.9854	.9857
2.2	.9861	.9864	.9868	.9871	.9875	.9878	.9881	.9884	.9887	.9890
2.3	.9893	.9896	.9898	.9901	.9904	.9906	.9909	.9911	.9913	.9916
2.4	.9918	.9920	.9922	.9925	.9927	.9929	.9931	.9932	.9934	.9936
2.5	.9938	.9940	.9941	.9943	.9945	.9946	.9948	.9949	.9951	.9952
2.6	.9953	.9955	.9956	.9957	.9959	.9960	.9961	.9962	.9963	.9964
2.7	.9965	.9966	.9967	.9968	.9969	.9970	.9971	.9972	.9973	.9974
2.8	.9974	.9975	.9976	.9977	.9977	.9978	.9979	.9979	.9980	.9981
2.9	.9981	.9982	.9982	.9983	.9984	.9984	.9985	.9985	.9986	.9986
3.0	.9987	.9987	.9987	.9988	.9988	.9989	.9989	.9989	.9990	.9990
3.1	.9990	.9991	.9991	.9991	.9992	.9992	.9992	.9992	.9993	.9993
3.2	.9993	.9993	.9994	.9994	.9994	.9994	.9994	.9995	.9995	.9995
3.3	.9995	.9995	.9995	.9996	.9996	.9996	.9996	.9996	.9996	.9997
3.4	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9998

Appendix 4. Simulation of Fixed order period model, the first example

Control week	Demand	State at the beginning of the period	Current + ordered quantities at the beginning of the period	Order quantity	Quantity received	New state
1	0	20000	20000	3243		20000
2	0	23243	23243		3243	23243
3	6524	23243	23243	6524	0	16719
4	1620	23243	16719		6524	21623
5	1246	21623	21623	1620	0	20377
6	7920	21997	21997		1620	14077
7	3290	14077	14077	9166	0	10787
8	4928	19953	19953		9166	15025
9	2250	15025	15025	8218	0	12775
10	7650	20993	20993		8218	13343
11	902	13343	13343	9900	0	12441
12	3880	22341	22341		9900	18461
13	1958	18461	18461	4782	0	16503
14	2068	21285	21285		4782	19217
15	900	19217	19217	4026	0	18317
16	0	22343	22343		4026	22343
17	0	22343	22343	900	0	22343
18	8204	23243	23243		900	15039
19	6285	15039	15039	8204	0	8754
20	0	16958	16958		8204	16958
21	12861	16958	16958	6285	0	4097
22	1400	10382	10382		6285	8982
23	9335	8982	8982	14261	0	-353
24	4320	13908	13908		14261	9588
25	1068	9588	9588	13655	0	8520
26	200	22175	22175		13655	21975
27	7812	21975	21975	1268	0	14163
28	12228	15431	15431		1268	3203
29	0	3203	3203	20040	0	3203
30	1800	23243	23243		20040	21443
31	7398	21443	21443	1800	0	14045
32	10160	15845	15845		1800	5685
33	0	5685	5685	17558	0	5685
34	5110	23243	23243		17558	18133
35	8888	18133	18133	5110	0	9245
36	0	14355	14355		5110	14355
37	3500	14355	14355	8888	0	10855

38	2126	19743	19743		8888	17617
39	8204	17617	17617	5626	0	9413
40	7708	15039	15039		5626	7331

Appendix 5. Simulation of Fixed order period model, the second example

Control week	Demand	State at the beginning of the period	Current + ordered quantities at the beginning of the period	Order quantity	Quantity received	State
1	0	4880	4880	3828		4880
2	1100	8708	8708		3828	7608
3	698	7608	7608		0	6910
4	0	6910	6910		0	6910
5	1100	6910	6910	1798	0	5810
6	0	7608	7608		1798	7608
7	1340	7608	7608		0	6268
8	0	6268	6268		0	6268
9	1806	6268	6268	2440	0	4462
10	1790	6902	6902		2440	5112
11	550	5112	5112		0	4562
12	1170	4562	4562		0	3392
13	0	3392	3392	5316	0	3392
14	1080	8708	8708		5316	7628
15	0	7628	7628		0	7628
16	0	7628	7628		0	7628
17	0	7628	7628	1080	0	7628
18	0	8708	8708		1080	8708
19	0	8708	8708		0	8708
20	0	8708	8708		0	8708
21	0	8708	8708	0	0	8708
22	0	8708	8708		0	8708
23	4000	8708	8708		0	4708
24	1052	4708	4708		0	3656
25	4000	3656	3656	5052	0	-344
26	0	4708	4708		5052	4708
27	2144	4708	4708		0	2564
28	2618	2564	2564		0	-54
29	0	-54	-54	8762	0	-54
30	3398	8708	8708		8762	5310
31	0	5310	5310		0	5310
32	0	5310	5310		0	5310

33	300	5310	5310	3398	0	5010
34	4000	8408	8408		3398	4408
35	0	4408	4408		0	4408
36	693	4408	4408		0	3715
37	0	3715	3715	4993	0	3715
38	144	8708	8708		4993	8564
39	1962	8564	8564		0	6602
40	0	6602	6602		0	6602
41	0	6602	6602	3000	0	6602
42	594	9602	9602	0	3000	9008