LAPPEENRANNAN-LAHDEN TEKNILLINEN YLIOPISTO LUT
School of Business and Management
Supply management

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OPTIMIZING WORKING CAPITAL TIED INTO INVENTORIES BY EFFICIENT INVENTORY MANAGEMENT: CASE STUDY IN A FINNISH MANUFACTURING COMPANY

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Teollisuusyritysten kokonaiskustannuksista 50 prosenttia koostuu materiaalien ostokustannuksista. Materiaaliostot useimmiten näkyvät yrityksissä varastoon sitoutuneena käyttöpääomana. Tehokas käyttöpääoman hallinta on tärkeää yrityksen kannattavuuden ja maksukyvyn näkökulmasta. Tämän pro gradu -tutkielman tarkoituksena on selvittää millä keinoin varastoon sitoutunutta käyttöpääoman määrää voitaisiin optimoida hyödyntämällä tehokasta varastonhallintaa. Tapaustutkimuksen kohteena on monikansallisen teollisuusyrityksen suomalainen liiketoimintayksikkö. Tutkimuksessa keskitytään tutkimaan erityisesti materiaalien osto- ja tilauseräkokoja sekä optimaalista varmuusvaraston tasoa ja niiden vaikutusta sitoutuneeseen käyttöpääomaan. Tutkimuksen teoreettinen viitekehys keskittyy varastonhallintaan ja käyttöpääoman hallintaan.

Tutkimusdata on kerätty kohdeyrityksen toiminnanohjausjärjestelmästä, ja lisäksi on hyödynnetty yrityksen tuottamaa sisäisen laskennan aineistoa sekä havainnointia. Empiirisen tutkimuksen tuloksena voidaan todeta, että pääpiirteissään yrityksen varaston- ja käyttöpääoman hallinta on hyvin toteutettu. Tutkimuksessa löydettiin kuitenkin joitakin parannusehdotuksia liittyen yksittäisten raaka-aineiden osto- ja tilauseräkokoihin, toimittajien kehittämiseen ja toiminnanohjausjärjestelmän hyödyntämiseen.

ABSTRACT

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In manufacturing companies direct purchasing costs consist 50 percent of the total costs. Purchacing and direct materials cost are allocated to inventories which tie up working capital. Efficient working capital management is associated with companies profitability and liquidity. This master's thesis aims at investigating how the working capital tied into inventories could be optimized by efficient inventory management. Thesis is a case study from its nature and the commisioning company is Finnish manufacturing company, which is owned by multinational parent company. Research focuses investigating order and purchasing quantities of raw materials and safety stock levels of raw materials and their influence to working capital. Theoretical framework of the thesis consist of inventory and working capital management.

Research data is collected from the company's ERP system and also company's internal financial reporting data is utilized, in addition, direct observation is used in data collection. Empirical conduction of the research indicate that inventory and working capital management is broadly conducted properly. However, some development suggestions are introduced related to single raw material purchacing and ordering quantities, supplier development and ERP system utilization.

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Laura Tuukkanen 9.12.2019

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1 INTRODUCTION

1.1 Background

In manufacturing companies purchasing consist approximately at least 50 % of the total costs (Baily, Farmer, Jessop & Jones 1994, 7; Dobler & Burt 1996, 26). It can be argued that in purchasing the focus is usually on low purchasing prices whereas financial interests are in good cash flow and low tied-up capital (Jonsson 2008, 17) which usually leads purchasing focusing more on the operative side and the overall financial factors are not complitely predicted. In practise it is common that financial departments focus on cost reduction in terms of inventory value, whereas operations argue for greater inventories (Eakins 2002, 433) which creates challenges for purchasing managers who have to balance between costs and delivery performance. Financial factors in purchasing are referred as company’s ability to manage its working capital. Efficient working capital management increases company’s profitability and liquidity. (Kärri et. al 2016, 277) It can be argued that the existence of a company is dependent on the management of working capital, which is conducted in most cases at the very daily operational level and therefore it requires attention (Barine 2012). Vice versa, it can be also argued that even thought inventories are seen as working capital investments they also enable meeting customer service level and high level of performance. Without inventories customer service level would be decreased, lost revenues would occur, decrease in operational efficiency and profits would occur. (Lawless 2017, 28). As it starts to seems obvious that there is a trade-off between working capital and operational efficiency, the key thing would be to find optimized solution to fulfill both, financial and operational targets.

This thesis focuses on investigating what could be optimized order sizes for raw materials in order to optimize and diminish working capital tied into inventories. Optimized order sizes are calculated with the economic order quantity (EOQ) formula and are compared to actual order sizes. Another research objective is to calculate and illustrate safety stock sizes based on different service level. Safety stock sizes and their purchasing values are compared and illustrated in tables. This study is empirical from its nature and it is commissioned by a company operating in health care industry.

Key results of the thesis indicate that in the company majority of order sizes are optimized in terms of ordering and holding costs. There are no significant room for improvements and possibility to decrease the amount of working capital tied into the inventories of raw materials. EOQ model used for the thesis provides theoretical foundation to build and assess the optimized order sizes, however there are some practical limitations regarding EOQ calculations. Safety stock calculations based on the service level indicate that 95 % safety stock level is not reached in majority of raw materials. In manufacturing company raw material availability is critical, but the research results indicate that if 99,99 % service level is pursued it ties vast amounts of working capital and in practice that significant amounts of working capital tied into inventories can not be held.

1.2 Aim of the study and research questions

Commisioning company of this research is interested in improving their flow of goods in their raw material stock. Company is manufacturing health care products and therefore raw material availability, on-time delivery and right quantity play a significant role in company's performance. Commisioning company is interested in finding out the optimized order quantities and appropriate safety stock levels for certain raw materials in order to diminish the working capital tied into inventories. It is critical for the company that their delivery performance should not be risked, however the stock value should also stay on moderate level. Company is using ABC classification for the raw material items based on their annual purchase value. A and B items value consist majority (80%) of the raw materials and therefore they require more attention in order to keep the stock value at moderate level in terms of working capital tied into inventories.

Working capital amount is dependend of the stock levels and order quantities and therefore the research focuses on answering the following research question:

RQ1: How to determine optimal safety stock level and order sizes in order to avoid excessive tied working capital but at the same time ensure delivery performance?

Subquestions for the research are:

RQ2: What are optimized order sizes for A and B items?

RQ3: What could be the optimal safety stock size for A and B items?

Questions support finding out how the stock levels and order quantities affect the amount of working capital tied into inventories and if there is something that could be improved in the company's operations. The aim of the research is to find out the optimized order size by using economic order quantity (EOQ) formula to optimize warehousing costs and ordering expenses. Results of EOQ calculations are analyzed in the light of actual purchasing prices and the quantities offered by suppliers. EOQ is also analyzed in terms of total cost and the amount of the capital tied into the purchased items.

Another objective is to determine optimal safety stock level in order to ensure delivery performance in case of unexpected distruptions in raw material supply. In determining optimal safety stock, service level approach will be used. Optimal safety stock level is analyzed againts the working capital tied into inventories and the principles of materials management in the company. Eventually by analyzing EOQ and safety stock levels, the research aims at finding improvements to the current purchasing and inventory management practises. Study is focusing on the purchasing managerial perspective as in many cases stock values are interests of the managers.

1.3 Theoretical framework

This chapter introduces conceptual framework of the thesis. Based on the research questions, the chosen concepts for the thesis are inventory management and working capital management. Inventory management influences the amount of working capital, but working capital management can also influence inventory management practises if the financial aspects are underlined in a company.

Figure 2. below illustrates inventory and working capital management relations.

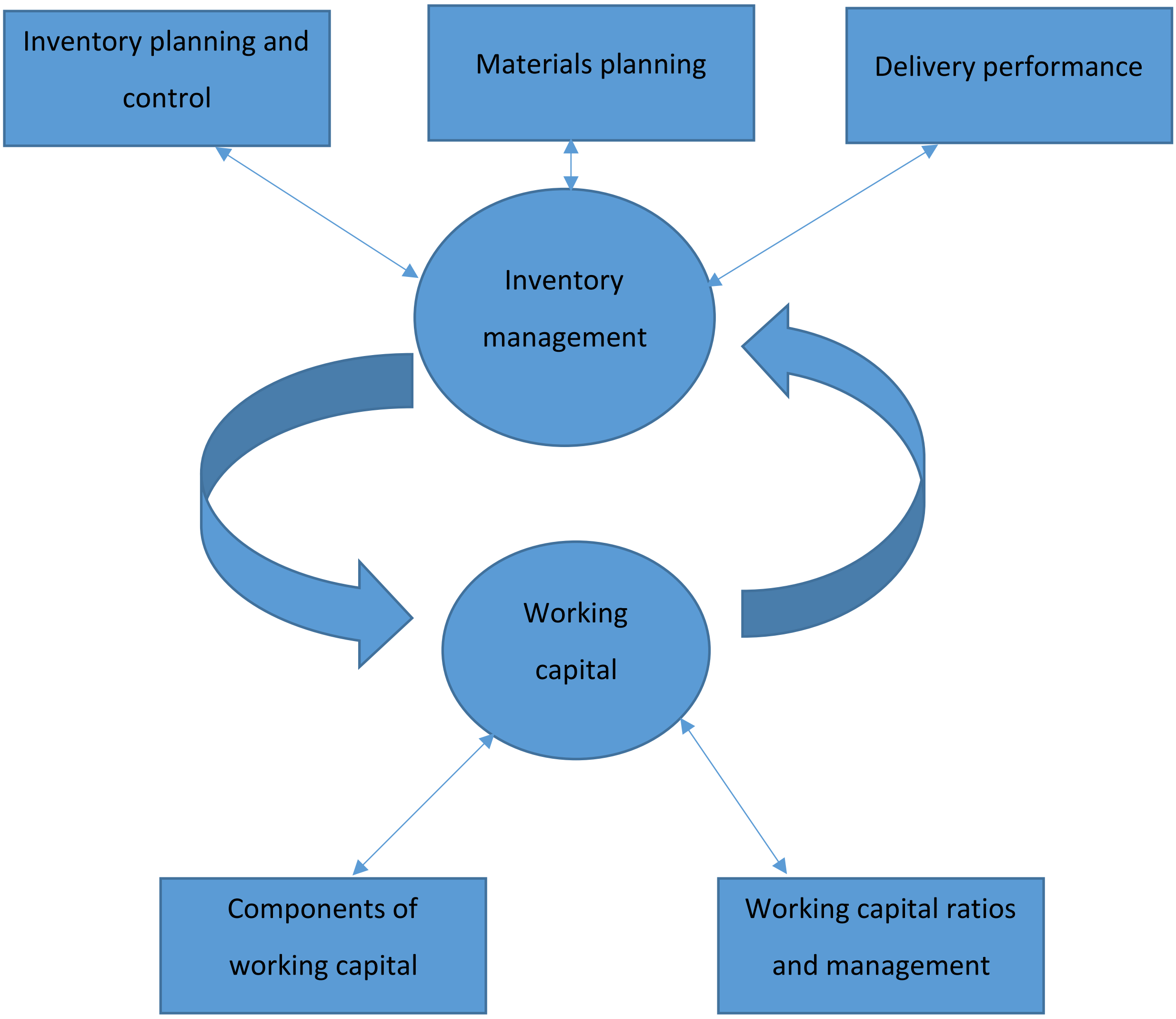

Figure 2. Conceptual framework of the thesis

Topics concerning inventory management are inventory planning and control, materials planning and delivery performance. In practice inventory management is conducted by inventory planning and materials planning. Delivery performance is included to the theoretical framework as it is important for the commissioning company to ensure raw material availability, which is associated with inventory levels and timing of order arrival. Concerning working capital management key components of working capital are introduced, working capital ratios and management tools. Inventories are one key component of working capital, known as current assets of the company. Working capital ratios express the financial performance of the inventory management in a company. Working management tools are included to the theoretical framework as the research focuses on finding development suggestions how to optimize working capital tied into inventories. Chosen context for the thesis is purchasing management, because as earlier stated the operations managers sometimes fail to see the overall financial perspective and they focus solely on prices.

1.4 Outline of the study

Research consist of three main chapters, which are introduction, theoretical framework and empirical conduction of the research. Figure 1. below visualises the structure of the research.

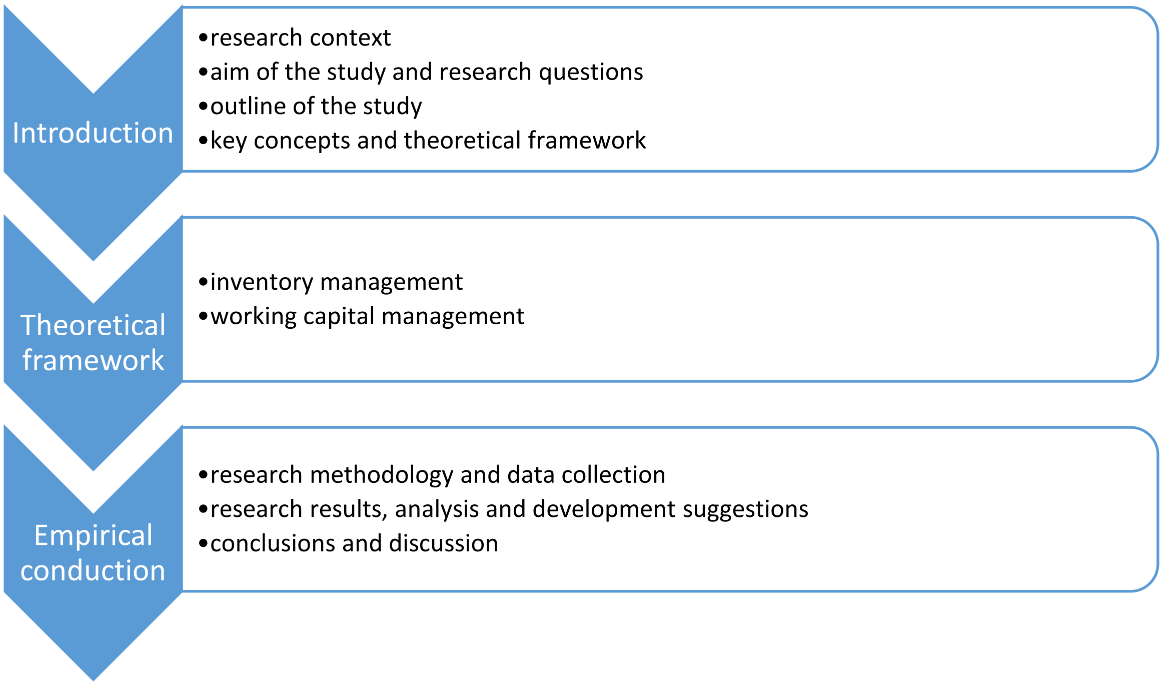

Figure 1. Structure of the research

Introduction chapter describes the research context, aim of the study and research questions. Key concepts of the study are defined and theoretical framework and their relations are introduced. In the following chapter theoretical framework of inventory and working capital management are introduced. Third chapter introduces the empirical conduction of the research. In empirical chapter, research methodology and data collection and research results and analysis are drawn. Lastly, development suggestions and conclusions are introduced.

1.5 Key concepts of the study

This section provides some important definitions related to the thesis. Definitions are provided for inventory, working capital, EOQ, safety stock and delivery performance.

Inventory

Inventory can be described as ”accumulations of materials, customers or information as they flow through processes or networks”. (Slack & Brandon-Jones 2018, 312). Inventories are used to compensate the uneveness in supply and demand. (Slack & Brandon-Jones 2018, 312-313; Slack, Chambers & Johnston 2010, 343).

Working capital

Working capital refers to the company's capital available to run its daily operations. Working capital can be divided into three different categories such as net working capital, operating working capital and financial working capital (Kärri et. al 2016, 277). Networking capital consists of excess capital available from the current assets over the current liabilities and it is known as net current assets of the company.

EOQ

Economic order quantity (EOQ) model is one the simpliest models to use when calculating the economic order quantities (Eakins 2002, 436). EOQ model aims at finding the best balance between advantages and disadvantages of holding inventories and minimize the annual total costs (Slack & Brandon-Jones 2018, 322; Leenders & Fearon 1993, 196).

Safety stock

Safety stocks are used to balance demand and costs. There are several safety stock methods that can be used in determining safety stock level. Methods can be for example manually estimated safety stock, safety stock as a percentage of leadtime demand or safety stocks calculated by desired service level. (Jonsson 2018, 287-288)

Delivery performance

Delivery performance or delivery service takes place during phases of order to delivery and delivery itself. Delivery service elements consist of inventory service level, delivery precision and reliability, delivery time and flexibility (Jonsson 2008, 85).

2 INVENTORY MANAGEMENT

It can be argued that in the operations management inventory should be allowed to accumulate when the advantages of having it competes its disadvantages. Inventories should be avoided as they tie up working capital and may be associated with high administrative and insurance costs. Physical inventories also require space which may be limited. In addition, inventories can hide quality and organizational problems. (Slack, Brandon-Jones & Johnson 2016, 437-438) Inventories can consist of materials, people or information. Inventories are also associated with risk as items or information held can deteriorate, however, they provide security for the operations by stabilizing supply and demand. There are different types of inventory depending on the stage of operations. Types of inventories include buffer inventory, cycle inventory, de-coupling inventory, anticipation inventory and pipeline inventory. (Slack, Chambers & Johnston 2010, 343-344).

Despite the several reasons to avoid inventories, they do have their benefits. Key benefit of holding inventories is that they provide security against uncertainty i.e. fluctuation of supply and demand. In the inventory management literature demand is commonly seen as deterministic or stochastic. Deterministic demand has the assumption that demand rate is known and constant, whereas stochastic demand is associated with changing demand rate over time. (Williams & Tokar 2008, 222). Inventories are used to compensate lack of flexibility for example if the operations are sometimes tied into some others activities than that operations which would needed to be supplied. Inventories that are used for compensating are called cycle inventories. Related to unpredictable demand, anticipation stock can be utilized if goods are produced on stock for demand in the future. If the goods can not be moved immediately from the point of supply to demand companies can use pipeline inventories to fill the processing pipeline, which is important especially if the geographical distances cause challenges. Inventories allow operations, in this case the purchasing department take the iniative of certain special supplier discount for materials even if they would not be needed immediately, if accumulation of stocks is allowed. Lastly holding inventories can reduce overall costs in terms of bulk buying prices or balancing ordering and administrative costs of purchasing enabled by economic order quantity. (Slack, Brandon-Jones & Johnson 2016, 437-438)

Inventories can be also generalized into input and output inventories. Input inventories consist of raw materials and work-in-progress materials and output inventories consist of finished products. (Tsoukalas 2011, 460) In manufacturing company input inventories represent a value adding factor in the production. Input inventory is also characterized as facilation of production by minimizing costs associated procurement of raw and work-in-process materials, protect againts stockouts. Output inventories are used to facilitate sales or avoid lost sales and stockouts. (Iacoviello, Schiantarelli & Schuh 2011, 1180) According to Sakki (2009, 103) in Finland the overall value of stock is quite evenly divided among raw material, work-in-progress and finished products stocks.

Common reason for holding stock is distance and transportation of materials. Long distance requires more time for transportation, which decreases agility of materials handling. Transportation is expensive and therefore it is suggested to deliver larger quantitites at once in order to diminish transportation costs. Companies also try to cope with uneven demand by increasing buffer inventories. Uneven demand usually leads to excess inventory levels as purchased amount rarely matches with the actual consumption. Even though safety stocks bring added value to the company's delivery performance they are often overestimated and not completely controlled. Excess inventories result from insufficient planning in terms of arriving and outgoing goods or lack of knowledge of demand in purchasing meaning that production planning might have better knowledge of demand. Other reasons are lack of target setting in terms of what should be the optimum stock level and lack of computer based MRP planning. Also, wide assortment of items increases stock levels. (Sakki 2009, 103-106)

2.1 Inventory and materials management

Inventory management is about planning and controlling of resources which transform as they move through supply chains, operations and processes. (Slack & Brandon-Jones 2018, 309-310) *Planning* can be determined being something that it is intended to happen in the future in a formalized way. If the operations do not go as planned, controlling of sequences comes in. *Controlling* is moreover about coping with the changes in planned process. However, planning and control can be seen as mutual processes and they balance each other. Concerning both, planning and control, the time horizon can be in long-term, medium-term and short-term horizon and the significance of each is dependent of time horizon. (Slack, Chambers & Johnson 2010, 270-271) Inventory management is operative from its nature and it is related to order quantities, placement of order and timing and the level of control of stocked items (Slack & Brandon-Jones 2018, 311). Inventory management is in practice conducted by materials management.

Materials management aims at ensuring raw materials and components availability and also ensure delivery performance of finished products. Materials management is operative from its nature and it aims at efficient inventory control in terms of working hours, working capital profitability and warehousing of materials. (Sakki 2009, 115) Objectives of materials management are “to optimize the input of materials according to potential sales and capacity of the manufacturing plant” and “to ensure that the maximum value is obtained per unit of expenditure” (Carter & Price 1995, 26).

Materials can be divided into four different categories based on their type and usage as table 1. below suggests.

Table 1. Types of materials and their characteristics (Muhlemann, Oakland & Lockyer 1992, 364)

Material	Type	Usage
Raw materials	Direct materials, processed further in manufacturing	Material for finished products
Work-in-progress	Direct materials, processed partly in previous manufacturing process	Material for finished products
Finished products	Finished products	Products for customers
Service materials	Indirect materials	Used in service and maintenance operations

Raw materials are used to produce finished products and their value is added in the manufacturing of finished items. *Work-in-progress* materials have been partly processed when they arrive, or they have been processed in the receiving organization, however they are not yet finished products. *Finished products* are ready products that can be dispatched and used by customers. *Service materials* are those materials that are required in the service and/or maintenance operations in manufacturing. Service materials can be for example cleaning service and materials associated with cleaning. Materials can be categorized based on the costs they represent. Usually raw-materials and work-in-progress materials are used directly to manufacture finished products and their costs can be directly allocated into finished products. Service materials represent indirect material and indirect cost as they can not be directly allocated to certain finished product. (Muhlemann, Oakland & Lockyer 1992, 364)

Despite the type of the materials they all are managed somehow. Most commonly used management approaches are continuous and periodic review approaches. In continuos review approach the timing of the order placement varies, but the order quantity remains fixed (Çomez & Kiessling 2012). New order is placed when the stocked item reaches its re-order point. Even though using continuos approach can be time consuming, it has its advantage as the order size can be set to the economic order quantity especially if computerized inventory system is utilized properly and the data is accurate. (Slack, Brandon-Jones & Johnston 2016, 455-456)

Periodic review approach is based on fixed and regular order placement timewise. In practice periodic review is conducted by placing an order for example once a month to bring the stock to predetermined level (Chiang 2006). Level is calculated to cover demand between the replenishment order being placed and the following replenishment order arriving. (Slack, Brandon-Jones & Johnston 2016, 455-456) Periodic review approach is commonly used when multiple items are bought from one supplier where order and transportation coordination is important (Silver et. al 1998).

In addition to continuous and periodic review approaches, the two-bin or three-bin system can be used. At simplest the two-bin system includes storing of re-order point quantity and the safety stock quantity in the second bin and allows using materials in the first bin. New order is placed whenever the first bin is consumed. In three-bin system the activily used materials are in first bin, re-order level materials are in second bin and in the third bin safety stocks are kept. (Slack, Brandon-Jones & Johnston 2016, 455-456)

Vendor managed inventory (VMI) approach can be also used to balance supply and demand. In vendor managed inventory vendor takes the responsibility for replenishment of inventories based on the agreed limits. VMI is characterized by centralized decision making and constant information sharing between vendor and customer. (Govindan 2013) Centralized decision making aims at reducing total supply chain inventory costs and increasing inventory turnover (Yu et al. 2012). VMIs can be used for decrease demand variability, inventory holding cost and distribution costs (Borade & Sweeney 2015). VMIs are associated with electronic data interchange (EDI) systems where information shared between supplier and buyer. Advantage of EDIs is that they enchance Just-in-Time inventory management practices (Banerjee & Banerjee 1992; Nath & Hendon 1998). Despite the inventory management approach still, at the heart of efficient inventory management models and approaches is to find balance between trade-off of customer satisfaction and cost of service (Bendavid, Herer & Yucesan 2017, 62).

2.2 Optimizing inventory costs

Costs associated with inventories can be divided into ordering costs and holdings costs. Holding costs consist of opportunity cost of investment in stocks, incremental ordering cost, incremental warehouse and storage costs, incremental material handling costs and cost of obsolescence and deterioration of stocks. Ordering costs consist of preparing a purchase order, receiving deliveries and handling invoices. (Drury 1996, 704-705) In practise cost management of inventories is a trade-off between holding and ordering costs. If the the ordered quantity is large it requires less purchase orders and ordering costs are decreased, but holding costs will increase. Vice versa, if the ordered quantity is small, it will decrease holding costs of the material, but frequent order placement increases ordering expences. (Drury 1996, 704-705; Leenders & Fearon 1993, 196)

Figure 3. below illustrates the relationship between ordering and inventory carrying costs.

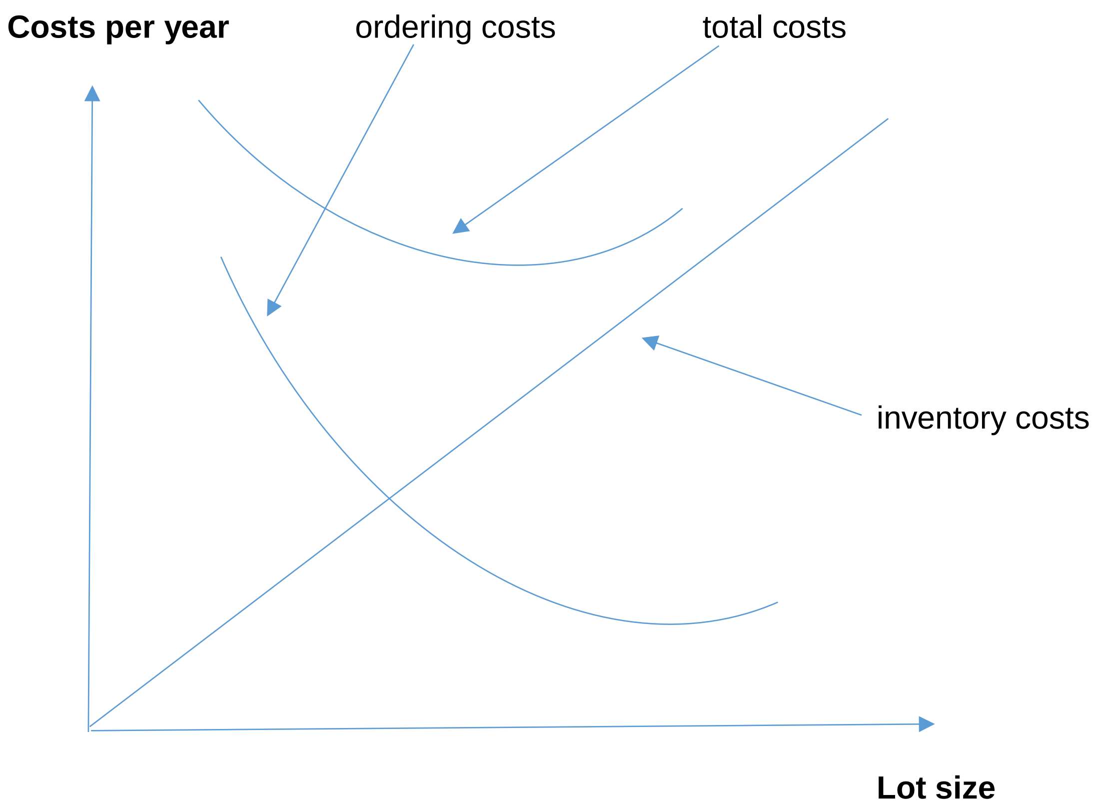

Figure 3. Relationship between ordering costs and incremental inventory carrying costs (adapted from Jonsson 2008, 280)

As described earlier inventories can be costly for the companies and therefore companies need to consider quantities they order, in order to cope with the costs. Economic order quantity (EOQ) model is one the simpliest models to use when calculating the economic order quantities (Eakins 2002, 436). EOQ model is invented by Harris in the beginning of 1900s and it has been foundation for modern inventory models since (Khan et al. 2011).

2.3 EOQ model

EOQ model aims at finding the best balance between advantages and disadvantages of holding inventories and minimize the annual total costs (Slack & Brandon-Jones 2018, 322; Leenders & Fearon 1993, 196).

EOQ can be calculated with following formula:

EOQ = $\sqrt{\frac{2\times D\times O}{i\times c}}$

Where:

D= demand per time unit
O= incremental ordering or set-up cost per order event
i= incremental inventory carrying cost in % per time and time unit
c= unit cost/goods value per item

(Jonsson 2008, 281)

EOQ model can provide basic information for companies what should be their order quantities, but it has also some pitfalls in terms of applicability in practise. The EOQ formula is based on several assumptions: the ordered quantities arrive at once, unit price is equal to every ordered quantity and shortages do not occur and there is no safety stock. EOQ formula also assumes that demand is stable, which is not realistic presumption. (Jonsson 2008, 281; Relph & Newton 2014) Some errors may also occur in determining the ordering and inventory carrying costs (Slack & Brandon-Jones 2018, 322). EOQ model is applicable for cost perspective in decision making concerning purhased items as it balances ordering and inventory carrying cost. Limitations of EOQ model are identified by the researchers and model has further been developed to overcome its limitations. Limitations are related to supply chain coordination, quality improvement and yield management, and the impact of human error on production and inventory systems (Khan et al. 2011).

2.4 Safety stocks

Other approach to balance ordering and inventory carrying costs is to use safety stock method. Safety stocks are used to balance demand and costs. There are several safety stock methods that can be used in determining safety stock level. Methods can be for example, manually estimated safety stock, safety stock as a percentage of lead time demand or safety stocks calculated by desired service level. (Jonsson 2018, 287-288)

Manually estimated safety stock are based on the experience of how the demand of items fluctuates, or how the suppliers perform. Manually estimated safety stock is labour intensive and therefore it is not the best method to use. Safety stocks as a percentage of lead time demand is calculated safety stock being the percentage of lead time demand. This method does not consider possible forecasting errors or demand fluctuation, which can be considered as disadvantage. Most applicable safety stock calculation method is safety stocks calculated by desired service level. (Jonsson 2018, 287-288) Service level describes to what extent the items are available in stock when they are needed (Donselaar & Broekmeulen 2013). Service level can be referred to cycle service level, which is determined as ”the probability of not having a stockout in a replenishment cycle” (Chopra & Meindl 2001). According to Bivjank (2013) service level approach can be divided into three definitions and possibilities to control inventories. First is the is the possibility of not being stocked out in certain time period, second is the possibility of fulfilling demand directly from stock on hand and third option is to allow back-orders in certain time period to cover demand. (Bivjank 2013, 1853)

One formula for calculating safety stock by desired service level is following:

$$B = ks \times \sqrt{L}$$

Where
B = safety stock
k = safety factor
s = standard deviation of demand
L = lead time

Desired service level %	50	75	90	95	97	98	99	99,5	99,9	99,99
Safety factor k	0	0,67	1,28	1,64	1,88	2,05	2,33	2,57	3,09	3,72

Figure 4. Desired service level and safety factors (Tersine 1994)

Advantage of using this safety stock calculations method is that it considers demand variations and set desirable service level. Method also allows to set-up different service level requirements for different items (Jonsson 2008, 288) for example based on their ABC-classification.

Figure 5. below illustrates the service level and safety stock size correlation.

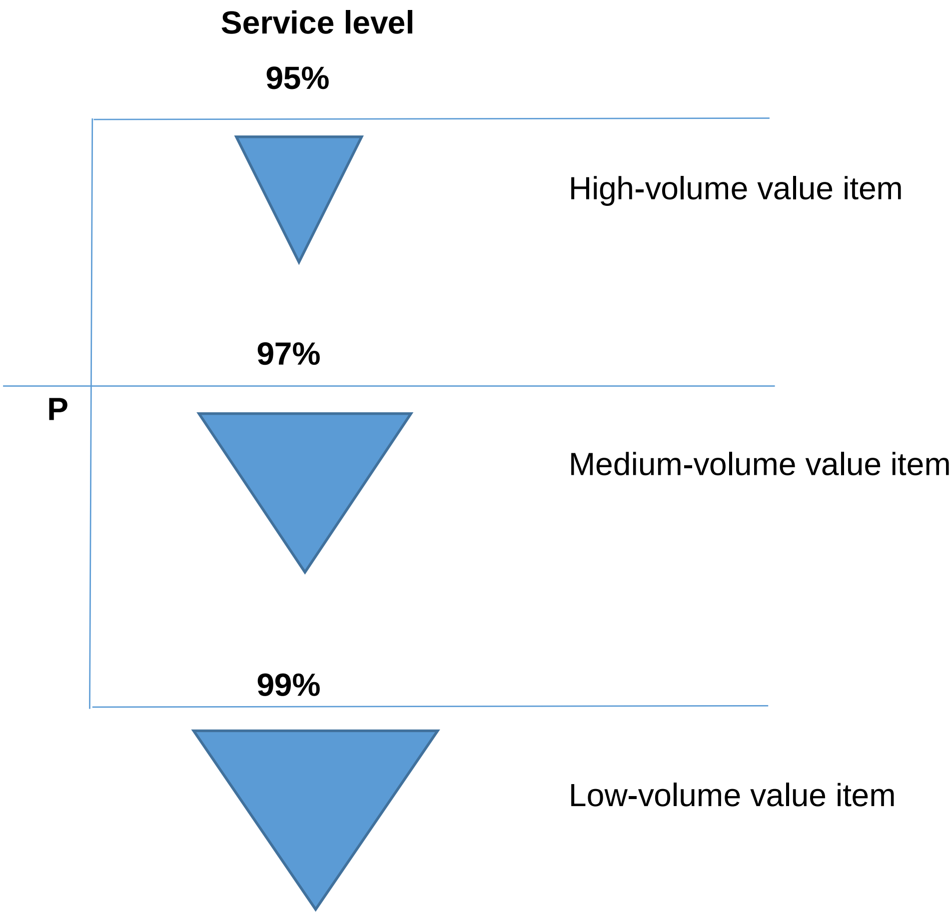

Figure 5. Service level and safety stock size correlation (adapted from Jonsson 2008, 287)

P stands for product which in this case consist of three different items. Items are classified based on their value. If the item is high-volume value item the service level could be at 95 % as they are more expensive and vice versa if the item is low-volume value item the service level should be at 99 %. Triangles illustrate the size of the safety stocks in different service levels. (Jonsson 2008, 287) Different service levels have their impact on delivery performance in a company.

2.5 Delivery performance

Delivery performance or delivery service takes place during phases of order to delivery and delivery itself. Delivery service elements consist of inventory service level, delivery precision and reliability, delivery time and flexibility. Inventory service level is associated with the orders that can be delivered directly from the stock to the customers. Delivery precision and reliability are related to the timing and quality as well as quantity of agreed with the customer. Delivery time or lead time is associated with the time elapsed from order to delivery, whereas flexibility illustrates the agility to respond to changes in order process. (Jonsson 2008, 85) If company is not agile enough to respond changes in process it is likely face problems in delivery performance.

Problems associated with delivery performance can be determined as supply chain risks. Supply chain risks occur when there are unexpected events that disturb the flow of materials from suppliers to final customers. (Waters 2007, 7) Risks can be classified many ways, but one way of categorizing risk is to observe it based on how it moves along in the supply chain. Based on this perspective supply risks can be divided into internal risks, supply chain risks and external risks. Internal risks refers to operational risks, such as accidents, equipment and system reliability, human errors or quality issues. Internal risks are also associated with managerial decisions related to order quantity and batch sizes, safety stock levels or financial issues. Supply chain risks are caused by external operators within the supply chain. Usually supply chain risks occur from the interaction between members of the supply chain. Examples of supply chain risks are supplier related such as reliability, material availablity, capacity, lead times or delivery problems. Also customers cause supply chain risks as their demand varies, customized requirements or problems with payments or order processing. Supply chain risks are caused because of inadequate cooperation between members and lack of visibility. External risks are those that are not dependent of supply chain members and are related to the environment is which supply chain is operating. Examples of external risks are accidents, extreme weather, natural disasters, legislation or wars. (Waters 2007, 98-99) According to Chopra and Sunil (2004) supply chain risks can be categorized and risk drivers identified. Table 2. below concludes risk gategories and risk drivers.

Table 2. Supply chain risks and risk drivers (Chopra & Sunil 2004, 54)

Risk Gategory	**Risk driver**
Distruptions	Natural disaster, labor dispute, supplier bankruptcy, war and terrorism and dependency of on a single source of supply as well as capacity and responsiveness of alternative suppliers
Delays	High capacity utilization at supply source, inflexibility of supply source, poor quality or yield at supply source, excessive handling (border crossing, change of transportation mode etc.)
Systems	IT infrastructure breakdown, system integration or extensive system networking, E-commerce
Forecast	Inaccurate forecasts due to long lead times, seasonality, product variety, short life cycles, small customer base. Bullwhip effect or information distortion due to sales promotions, incentives, lack of supply chain visibility, and exaggeration of demand in times of product shortage
Intellectual property	Vertical integration of supply chain, global outsourcing and markets
Procurement	Exchange rate risk, percentage of a key component or raw material procured from a single source, industry wide capacity utilization, long-term versus short-term contracts

Receivables	Number of customers and their financial abilities
Inventory	Rate of product obsolence, inventory holding cost, product value, demand and supply uncertainty
Capacity	Cost of capacity and capacity flexibility

Risk categories include distruptions, delays, systems, forecast, intellectual property, procurement, receivables, inventory and capacity. Each category has its own risk drivers which are described in the table 2. There are multiple possible risks that companies are facing in their operations. Risks influence companies delivery performance and it is important that they are identified.

2.6 Manufacturing approaches and inventories

It can be argued that different manufacturing approaches create some challenges to manufacturing, which can lead to supply risks. Especially Pull type manufacturing creates challenges as demand fluctuates based on the customer need. Common manufacturing approaches in industrial companies are Push and Pull strategies. Based on the selection, companies coordinate their flow of materials differentially. Push strategy, in practice, is based on material requirements planning (MRP) calculations and Pull strategy’s foundations lie in Just-In-Time manufacturing associated with Lean management. (Sakki 2009, 128-129)

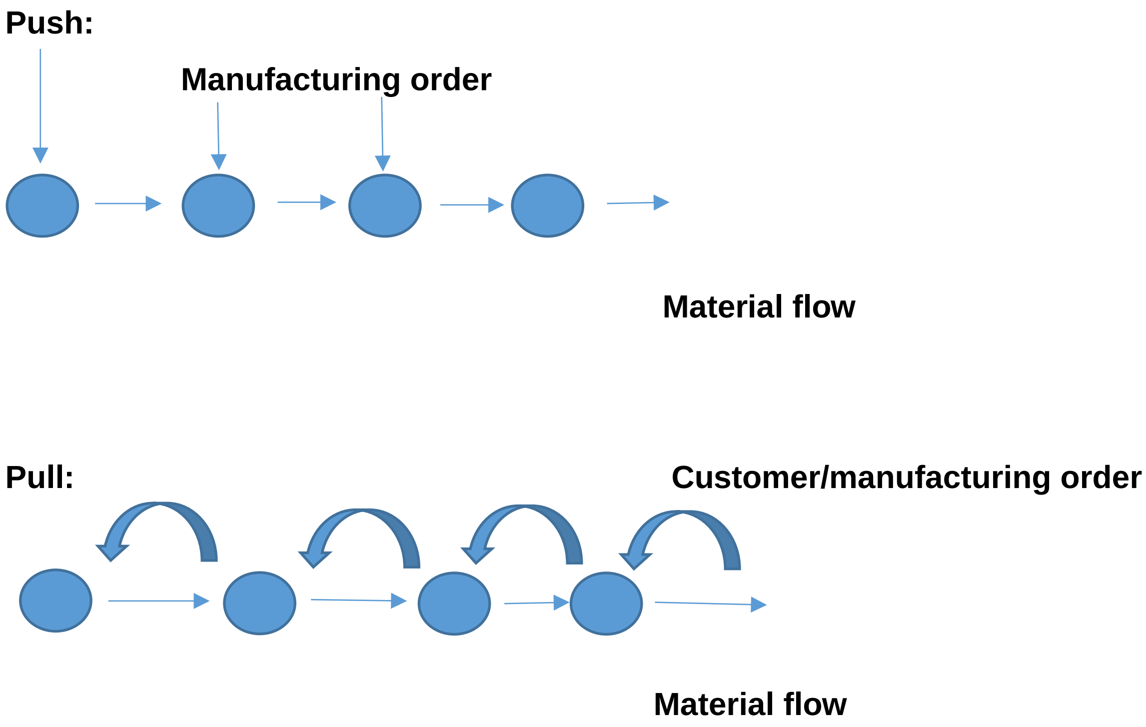

Figure 6. Illustration of push- and pull-based management (adapted from Jonsson 2008, 269)

Figure 6. illustrates the distinction between push- and pull- based management in materials management. Push type is initiazed "by the supplying unit itself or by a central planning unit in the form of plans or direct orders," without the actual consuming unit. (Jonsson 2008, 268). Pull type is initiazed by "what is really needed, when it is needed, and in the amount needed" (Lyonnet & Toscano 2014). Push and pull strategies are commonly used as combined approaches and their characteristics are explained in more details next.

Push strategy

Push strategy is applied as its simpliest by using materials requirements planning (MRP) approach. MRP approach calculates how many parts or materials are needed and what times to manufacture a product. (Slack, Brandon-Jones & Johnston 2016, 491). MRP systems are usually integrated into enterprise resource planning (ERP) systems. ERP systems can be defined as system consisting of software support modules between different functions of a company that are integrated. (Slack, Brandon-Jones & Johnston 2016, 477).

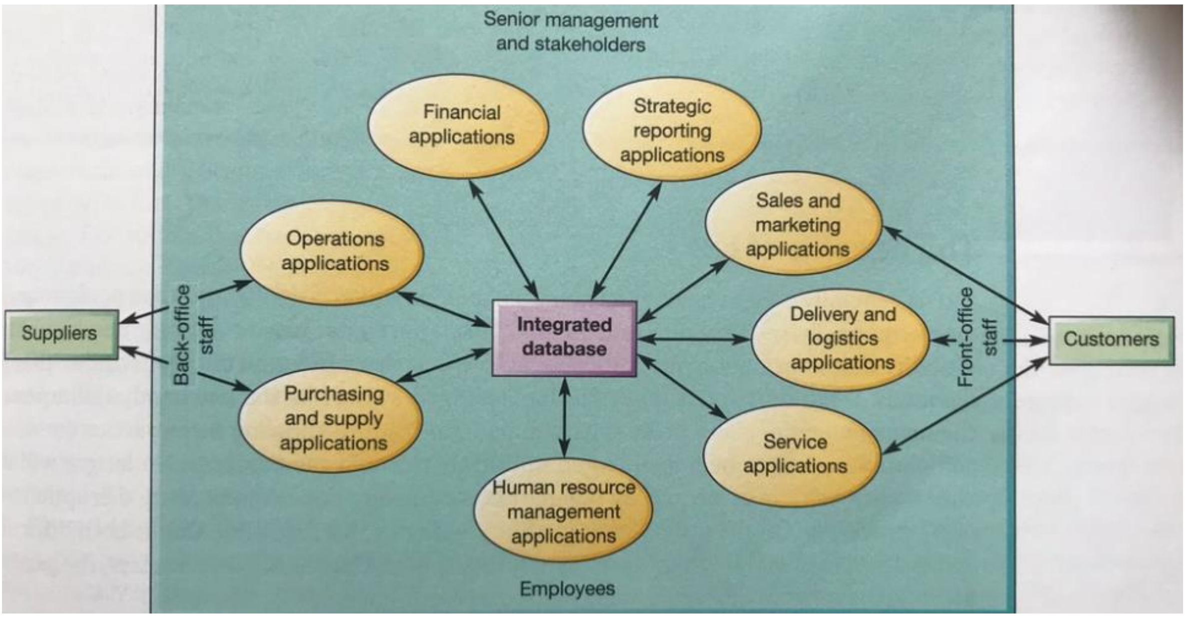

Figure 7. Example of ERP illustration (Slack, Brandon-Jones & Johnston 2016, 477)

Figure 7. illustrates actors around the integrated database and how the information flows between actors.

In MRP the Master production schedule (MPS) creates the input into MRP which consists of information regarding the volume and timing concerning the manufacturing of products. MPS is based on the customer orders and forecasted demand, it also considers current stock level of each finished item. In order to produce the required products MRP calculates the raw materials required for manufacturing based on the bills of material. MRP also suggest schedule when to place purchase orders and other activities to perform.

Figure 8. below illustrates the information flow in the MRP.

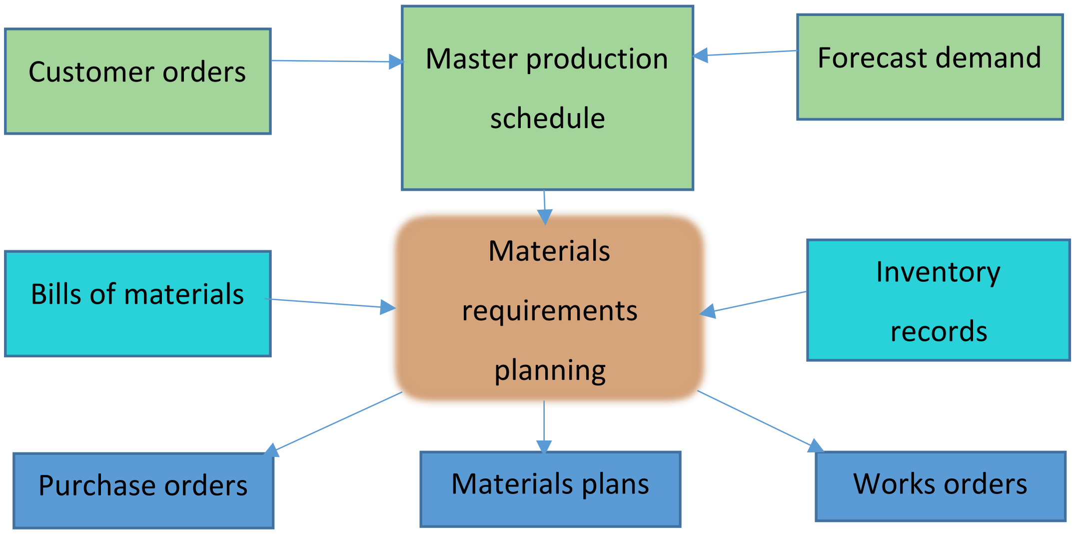

Figure 8. Materials requirements planning (MRP) schematic (adapted from Slack, Brandon-Jones & Johnston 2016, 491)

In conclusion MRP is set of logical calculations that are used to determine volumes and timing for demand in the future. (Slack, Brandon-Jones & Johnston 2016, 491-497)

Pull strategy and Lean

The foundation of Lean thinking lies at the consequences after the Second World War. After the war car manufacturer Toyota was forced to eliminate all the possible waste due to lack of resources and capital. The concept was originally known as the Toyota Production System (TPS) before it became known as Lean. After Toyota successfully implemented their new philosophy, others such as US and European car manufacturers started to imitate Japanese manufacturers by using Just-In-Time (JIT) concept, which has similarities to original TPS concept. (Pepper & Spedding 2010)

In Toyota waste was defined according to Russell & Taylor (2000) “anything other than the minimum amount of equipment, materials, parts, space and time which are absolutely essential to add value to the product”. Waste reduction is essential in lean and waste is known as *“muda”* in the lean philosophy. Lean aims at reducing waste and seven different types of wastes or “mudas” can be identified: over-production, defects, unnecessary inventory, inappropriate processing, excessive transportation, waiting and unnecessary motion. (Pepper & Spedding 2010)

In addition to “Muda” Lean has also another well-known focus, called “Kaizen”. Kaizen is a Lean approach, which aims at constant development enabled by employee engagement in organization. Kaizen is usually conducted in certain processes of the company at a time, not in overall process improvement. Kaizen improvement process usually has four development stages. Stages are plan, do, check and act, also known as “PDCA” which is a scientific approach to process development. (Lean Production 2018) Kaizen is associated with standardization of processes in order to avoid variance. Standardization can be applied in part standardization, employee training standardization or process standardization (Jayaram, Ajay & Nicolae 2010)

Toyota has made the foundation for Lean thinking, but others have extended the Toyota production philosophy into five different elements concentrating on the whole company level. According to Holweg (2007) those elements are: product development process, supplier and customer management process and the policy focusing on the whole company. Lean focus is in individual products and product value-streams. Value-stream can be described as sequence of activities that are needed “to design, produce, and provide a specific good or service, and along which information, materials, and worth flows” (Business Dictionary 2017). At the core of Lean thinking is the capability to identify which factors are creating value to the customers and which phases are diminishing the value creation.

Lean focuses on maximizing customer value and at the same time minimize waste. At the core of Lean thinking is creating more value to the customers with less internal resources. Lean can be utilized in improving quality, increasing output, meeting customer needs or provide innovations in production or processes to perform better than competitors. (Howell 2013)

The most commonly known Lean practices are use of Just-In-Time (JIT) and Kanban practices in manufacturing. As stated earlier manufacturing approaches influence the flow of materials in the process and have their influence on stock levels. In JIT approach suppliers provide raw materials in small quantities frequently to buying company and the Kanban system aims at stricter control over the inventories by utilizing cards in coordinating the flow of goods in manufacturing (Muhlemann, Oakland & Lockyer 1992, 391-393). If production of goods or services is made with Lean principles the buffering costs are minimized. The most obvious source of excess buffer is obvious waste meaning the waste, which is not needed in the operations. Second, less obvious source of excess buffer is variability. Variability is something that is not absolutely regular and predictable, such as delivery times or demand rates. Sources of variability can be divided into internal and external variability. Internal variability consists for example of set-ups, downtime, fluctuation in production rates, rework etc. External variability consists of for example irregular demand, product variety to meet market needs, change of orders etc. The fundamental aspect of variability is that it will be buffered in the production, which leads to three different variability buffers: inventory, capacity and time. Inventory and capacity buffers are to provide protection for variability in demand or in production, whereas lead times provide protection for production variability. In order to cope with above mentioned variability, Lean principles, suggest that:

1. obvious waste should be eliminated in order to be competitive in global economy
2. buffers should be balanced
3. reduce variability as it necessitates buffering
4. continual improvement regarding variability reduction enables reduction of capacity buffer and keeping inventory buffer low

(Hopp & Spearman 2004, 144-146)

Lean management techniques have been recognized as most effective tools for improvement in manufacturing companies (Saha et al. 2015) and Lean inventory management principles are something to consider also in support activities of manufacturing.

3 WORKING CAPITAL

Working capital refers to the “capital available for conducting day-to-day operations of an entity, normally the excess of current assets over the current liabilities” (CIMA 2005). According to Talonpoika (2016), net working capital aims at ensuring business continuity and ability to meet its short-term liabilities. Networking capital consists of excess capital available from the current assets over the current liabilities and it is known as net current assets of the company. However, the ratio can be also negative if the liabilities exceed assets - then the company has net current liabilities. (Templar et al. 2016, 47-48) Table below concludes company’s current liabilities and current assets.

Table 3. Current assets and liabilities of a company (Templar et al. 2016)

current assets	current liabilities
inventories	trade and other payables
trade and other accounts receivables	short-term borrowings
other current assets	current portion of long-term borrowings
cash and cash equivalents	current tax payable
	short-term provisions

Current assets of a company consist of inventory, trade and other accounts receivables, other current assets and cash and cash equivalents. Current liabilities consist of trade and other payables, borrowings, taxes payables and short-term provisions. The net working capital is calculated by subtracting current liabilities from current assets. (Templar et al. 2016, 51-52)

Working capital can be also divided into three different categories such as net working capital, operating working capital and financial working capital. Key components of operational working capital are inventories, accounts receivable and accounts payables. (Kärri et al. 2016, 277)

3.1 Working capital ratios

Turnover ratios are financial ratios that measure assets' activity or efficiency in generating cash by turnover. Turnover ratios show how many times the possible inventory, accounts receivable or accounts payable are turned into cash for example in a fiscal year (Business Dictionary 2019). Turnover ratios can be calculated by dividing 365 days by the days of inventory, accounts receivable or accounts payable.

Inventory turnover measures how efficiently the company is able to manage its warehousing of goods. Inventory turnover measures how many times in a year the average inventory is sold. Inventory turnover is calculated by dividing the cost of goods sold by average inventory. (Horngren & Oliver 2010, 699) As the inventory turnover ratio is calculated costs of goods sold to its average inventory (Lee, Zhou & Hsu 2015, 38) the changes in costs of goods sold have influence in turnover rate. High inventory turnover is desirable as it decreases the working capital tied into inventory (Alma Talent 2018).

Accounts receivable refers to companies' investment in inventory and accounts receivable such as credit sales to the customers (Alma Talent 2019). Accounts receivable turnover measures company's ability to collect cash from customers during certain period. Accounts receivable turnover is calculated net credit sales divided by average net accounts receivable. (Horngren & Oliver 2010, 699) Capital tied into inventories and accounts receivable can be significant especially in manufacturing companies and that is why efficient management concerning minimization of inventory and accounts receivable is important. (Atrill & McLaney 2012, 434-435) In addition, reduction of working capital may increase the return on investment. The average rate for accounts receivable turnover depends heavily on the industry, but in general the quicker the cycle the better, as it decreases the amount of capital tied into the company. However too tight collection of receivables may indicate problems in the credit sales terms to the customer, which may lead to losses in sales. However, the situation should be evaluated based on the overall performance. (Alma Talent 2019)

Accounts payable refers to obligations that the company has to fulfil to its creditors. Accounts payable is usually short-term debt to the suppliers or other creditors. Accounts payable turnover ratio shows how many times the company pays its accounts payable in a year. (Newstex 2015) The suggested ratio for accounts payable turnover is varies between industries, but in general the shorter the accounts payable turnover the better is the company's liquidity. Commonly used ratios to measure company's liquidity are current ratio and quick ratio. (Alma Talent 2019)

3.2 Managing working capital

Working capital management has a significant impact on company's profitability, risk propensity and eventually to the value of the firm (Erasmus 2010, 2). Excessive working capital may lead to unnecessary accumulation of inventories, which results to inventory mishandling and wastage and overly speculative profit of held inventories (Barine 2012). In addition over investment in working capital increases holding and financial costs (Panda & Nanda 2018). Therefore it is suggested that companies should have aggressive strategy to manage their working capital by shortening cycle times for inventory and accounts receivables and increasing cycle times for accounts payables (Marttonen et al. 2013, 430). Working capital management focuses on optimizing the trade off between profitability and liquitidy. (Bendavid, Herer & Yucesan 2017, 62). Working capital management is measured by the efficiency of working capital cycle.

Working capital cycle (WCC) can be determined as "the period of time which elapses between the point at which cash begins to be expanded on the production of a product and the collection of cash from the purchaser" (CIMA 2005, 98).

Working capital cycle measurement includes company's inventory, accounts receivable and accounts payable days. Working capital cycle measures the efficiency of working capital management and it can be calculated as follows:

inventory days + receivable days - payable days = WCC.

The shorter or even negative the cycle is, the more efficiently the company is performing. A negative working capital cycle indicates that the working capital is efficiently utilized within the company and thus it can be assumed that value is being created. Erasmus (2010, 9) argues that efficient management of working capital could result in increased firm profitability and ultimately result in the creation of shareholder wealth.

The common working capital management practices of a company are selling of inventory quickly, collecting payments from customers quickly and expanding the debt payments to collectors (Erasmus 2010, 2). Influencing accounts payable and accounts receivable conditions are dependent on the power relations of the supplier and buyer. It is common that the power distance is not equal and the one with more power can dominate contractual i.e. payment terms caused by information asymmetry between the buyer and supplier. (Lonsdale 2001; Habib et al. 2015). However there are some techniques that can be applied to influence payment terms. From the suppliers point of view receivables days can be improved by trading on cash only or reduce credit time offered to customer and by offering discount if invoice is settled earlier. From the purchasing perspective opposite techniques can be applied by increasing credit time and decreasing cash payment.

Payables days can be improved by expanding payment terms to the suppliers as it improve working capital cycle and enhance cash flow. However this decision will have negative impact on company’s current and acid test ratios, which measure liquitidy. Inside the company working capital management can be improved by shortening production cycles to reduce inventory days of supply by combining manufacturing and inventory management strategies. (Templar et al. 2016; Theodore and Hutchison 2002)

4 EMPIRICAL CONDUCTION OF THE STUDY

This chapter briefly introduces case company and reminds of the objectives of the research. Research methodology and data collection methods are explained, and research reliability and validity are assessed. Research limitations and practicality of the research are also included.

4.1 Case company and research background

Research is made for manufacturing company operating in healthcare industry. Company is one of the 15 manufacturing companies of the parent company. Parent company is operating globally, and it has over 550 suppliers and contract manufacturers around the world. (Company website 2019) Study is initiated by company's intention to improve its operations regarding efficient inventory management of incoming raw materials. Based on this aim the economic order quantities (EOQs) and safety stock levels based on desired service level for raw materials are calculated and analyzed in respect to working capital tied into inventories. Research started as of practical training in the company in order to get insight of its operations first and then expanded into research, which was conducted during 2019.

4.2 Research methodology and data collection

Chosen methodology for the research is quantitive case study. Quantitive research is used to investigate numerical questions (Heikkilä 2014, 15) and therefore it is the most suitable research method for this research. In quantitive research the results are usually illustrated with figures and tables. Quantitive research is also suitable for investigating dependencies between different variables and determining the current situation in the researched phenomeon. (Heikkilä 2014, 15) Case studies are characterized by desire to derive ”a(n) (up)-close or otherwise in-depth understanding of a single or small number of cases” in real-life context. (Yin 2012, 4).

Collected data can consist of multiple sources such as documentation, archival records, interviews, direct observation, participant-observation and physical artifacts (Yin 1994, 78). Research uses archival records as secondary data for the research and in addition direct observation was used. Secondary data consist of company's internal reporting data. In addition, direct observation was used to collect information for the research by working in the research environment.

Research data is merely produced by utilizing company's SAP system. In addition company's budgeting information is used in the calculations of economic order quantities. Assistance from the company's financial controlling was required in order to make the research calculations as reliable as possible. Financial controlling provided the information concerning warehousing cost and labour cost associated with EOQ calculation. It was decided that warehousing cost are 15 % of each item and labour costs 120 euros per order. Other additional data such as inventory turnover ratios are provided by the company's financial controlling.

Concerning second research objective, safety stock levels, the information for calculations was collected from company's SAP system. Company's SAP system provide information of the consumption of materials of 2018 and the standard deviation was calculated from 53 weeks as lead time for materials is in weeks. In research, the desired service level related to safety stock is determined based on the literature. Safety stock levels were calculated with 95 %, 99 %, 99,9 % and 99,99 % service level and analyzed in theoretical level in terms of working capital tied into safety stocks. Different service level selection is to illustrate the distinction between different service levels and amount of inventory required to fulfill the set service level. Data collection for the thesis has been conducted during spring 2019. Final calculations for EOQ and safety stock calculations were made during 2019. Data sample consisted of 39 raw materials selected based on their annual purchase value of 70 percent of the total annual purchase budget.

Results from the EOQ and safety stock calculations are compared with the actual value of raw materials. Results are illustrated with visual graphs and each are analyzed against real life context. Lastly development suggestions are drawn from the results and conclusion are made.

4.3 Research reliability and validity

Reliability of the study is associated with the iterativess of the research results. Research can be considered being reliable if two or more researchers end up in similar result or if the research is repeated and the same result is got from both research occasions. (Hirsjärvi, Remes & Sajavaara 2007, 226) Reliability of this research is related to the accuracy of the EOQ calculations. It was decided that for EOQ calculations fixed ordering cost per each item would be 120 euros, even though there might be some differences in ordering costs depending on the item in practice. Concerning holding costs it was decided that annual holding cost per each item would be 15 % including warehousing costs and return on investment. Determined fixed values for ordering and holding costs are based to some extent, on the best assumptions of reality and therefore results of EOQ calculations must be critically evaluated.

Validity of the study is related to the performance of the set measure or research method to deliver the answer to the research question. Concerning validity of research, it should be mentioned that quite often the researcher has its own subjective approach to the topic which might have an affect to the validity of the study. (Hirsjärvi, Remes & Sajavaara 2007, 226-227) Research method selection is considered being valid as the research is focused on numerical analysis. However, some other calculation methods, could have taken into consideration in determining the appropriate safety stock levels and EOQ to make the research more valid. However, in conclusion it can be argued that research is valid as it answers the set research questions and draws development suggestions from the results.

4.4 Research limitations

Limitation of the study is that focuses only on the A class materials and 25 materials of B class materials. However, sample includes 70 percent of the annual purchasing value and therefore it is sufficient data sample. Including all raw material in the research would not have been worth of investigating as their value is marginal in the overall raw material budget. Study is limited to purchasing and materials planning perspective and it does not consider production planning, which has significant role in manufacturing company. Another limitation is that the study focuses in the raw materials warehouse and it does not consider the whole material flow in the company or in the supply chain. Limitation is also concerned with the fact that EOQ model used for calculating optimal order size has presumption that demand is stable and in reality demand fluctuates. EOQ calculation results do not consider order quantity discounts, which is a limitation to the research. Also some of the materials are in vendor managed inventory, which does not cause working capital being tied into inventory, but it is excluded from the research. Limitation concerning safety stock level is that it is based on the set service level and it is hard to determine what could be the best managerial decision concerning approved service level or moreover the service loss rate. Service loss calculations are excluded from the research, as research focuses on raw materials, not on actual products. Service loss calculations would be too complex as raw materials are used for multiple end-products.

4.5 Research practicality

Research results indicate that economic order quantity calculations can be applied to reality. Commissioning company is interested in optimizing their order quantities based on the calculations made in the research. Determining safety stock levels based on desired service level is not applicable in reality. Safety stock sizes based on calculation require a lot of physical space which is limited. Also regarding working capital it is not possible or profitable keep that much capital in inventories.

5 RESEARCH FINDINGS AND ANALYSIS

This chapter introduces the current situation of the inventory management principles of the company related to research objectives, the optimized order quantities and level of safety stocks held. Chapter also represents calculations made in the research. First, it illustrates the results from economic order quantity (EOQ) calculations. Secondly, the results from safety stock calculations are presented. Each result is analyzed and commented against the research objective. The sample for the research consisted of 39 raw materials which were chosen based on their ABC classification in the company. Sample includes 14 raw materials of A class items and 25 raw materials from B class items. A class items consist 50 percent of the annual purchasing value. A and B class items together consist 70 percent of purchase value in the company.

5.1 Current status of inventory management in the company

Purchasing department is responsible of negoating raw material pricing and order quantities with the suppliers. Materials planning department is responsible of making operative purchasing orders according to the need of production. Order quantities of the materials are merely determined based on the common sense and budget estimation, also suppliers influence the decision making regarding order quantities. Suppliers have determined their minimum order quantities and pricing, which are often influenced by their capacity and production approach. For volume materials purchasing quantity is large which enables having price advantages. Total annual purchasing budget of the company is approximately 65 million euros. Raw material inventory includes 1160 materials and they are ABC classified based on their value. Materials are used for manufacturing health care products and many of them are custom made for the company. Raw materials inventory turnover target is less than 44 days in inventory and the turnover of A and B class materials is followed monthly in the company. Principle of the company is to have minimum amount of safety stocks held. For safety stock determination company is using multiple approaches such as manually estimated safety stocks, and also utilizing SAP system. SAP is utilized by holding static safety stocks to cover for example few production order needs and by determining dynamic coverage profiles for example of 10 or 15 days which equals two to three weeks safety stock. Also the two-bin approach is used and VMI's where suppliers hold inventory for the company. Total raw material inventory target value is less than 8,2 million euros. Raw material inventory value is followed in the company on a weekly basis. Raw material inventory performance and the overall delivery performance of the company is followed by the rate of back orders. In practice back orders are not allowed. Back orders are measured by company order line availability (OLA) rate, which target is less than 25 days lasting back orders for finished goods.

5.2 EOQ calculations

EOQ calculations for the research were made with the following formula:

$$EOQ = \sqrt{\frac{2 \times D \times O}{i \times c}}$$

Where

D= demand per time unit
O= incremental ordering or set-up cost per order event
i= incremental inventory carrying cost in % per time and time unit
c= unit cost/goods value per item

(Jonsson 2008, 281)

D factor – demand per time unit was taken from the company's budget of raw materials consumption for 2019. C factor – unit cost/goods value per item was also taken from the company's budget for 2019 where the actual prices of the materials were expressed as cost per 100 units. The price for one item was calculated by dividing the budget value by 100. O factor – incremental ordering or set-up cost per order event for the EOQ calculations was determined to be 120 euros per order. I factor - incremental inventory carrying cost in % per time and time unit was determined to be 15 %. O and I factor values were discussed with the company's purchasing manager and financial controlling and it was decided that for the calculations the values would be same for each item. Calculations were made with excel (appendix 1.) in order to get graphs to illustrate the results.

Ordering and holding costs were calculated with the following formulas:

Ordering costs = $D/Q \times O$

Holding costs = $Q/2 \times i \times c$

Total costs were calculated by summing ordering and holding cost together with the following formula:

TC = $\frac{Q}{2} \times i \times c + \frac{D}{Q} \times O$

In above formulas Q equals to order quantity.

(Jonsson 2008)

Results of the EOQ calculations are summed up in tables and analyzed against the actual order sizes. Figures, tables below and appendices illustrate the results from EOQ calculations of materials and their actual order quantities and their ordering and holding costs in euros. Also inventory turnover is discussed as it is associated with order quantities. Inventory turnover figures are provided by the company's financial accounting. Inventory turnover figures are based on the situation in the end of October 2019. Company target for inventory turnover is less than 44 days in inventory.

5.2.1 EOQ calculation analysis and development suggestions A class materials

This section illustrates and analyzes calculated economic order quantity (EOQ) for each A class materials. Figure 9. below illustrates the EOQ for material A1 in terms of ordering and holding cost as well as total costs. Other materials EOQ figures are included in appendices, but analysis is included in the text. After each analysis possible development suggestions are given and inventory turnover of the material is commented. Lastly comparison is made between calculated EOQs and actual order quantities of the materials and they are visualized in tables.

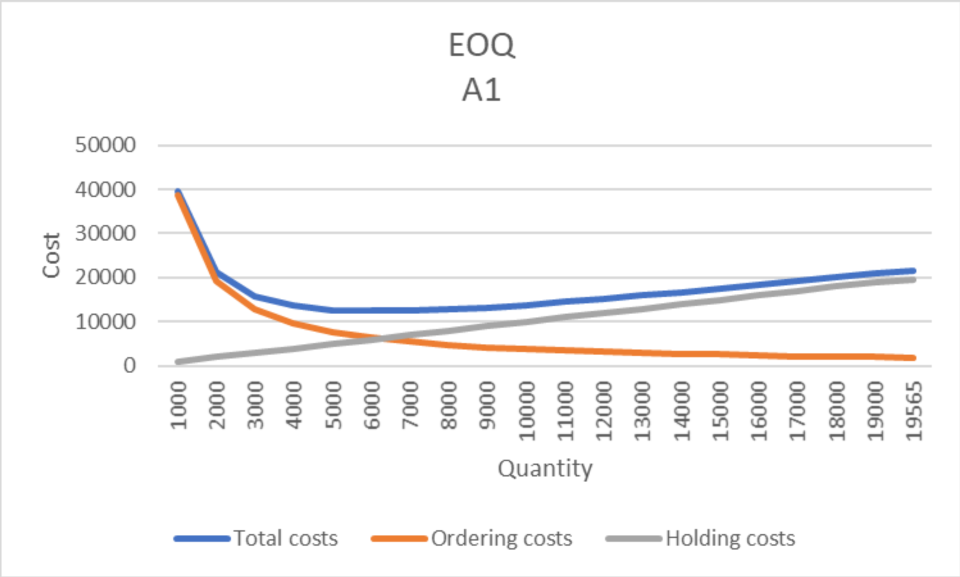

Figure 9. Material A1 economic order quantity

A1: EOQ (6215m) is lower than the actual order quantity(19565m). As the figure 9. shows holding costs increase significantly when ordered quantity is larger as the material is expensive. Material is shipped from other continent in a container. Due to transportation mode it suggested to order larger quantities than suggested EOQ to optimize transportation costs. Material inventory turnover is 18 days, which is below target of 44 days which is good result in terms of working capital management.

A2: EOQ (22720m) is lower than the actual order quantity (89100m). As the figure shows holding costs increase significantly when ordered quantity is high as the material is expensive. Order size could be reduced however it might be so that supplier is not willing or capable of delivering smaller quantities. Regarding order size it should be also considered that one truck load consist of 29700 meters. Ordering smaller quantities would increase transportation costs. Current inventory turnover of this material is 47 days, which is over target of 44 days. Smaller order quantities would improve inventory turnover.

A3 & A4: Materials A3 and A4 are practically one material which consists of two different components and therefore they can be analyzed as one material. EOQ (5496 kg) for these materials is quite high. There was variation in actual order quantities from 900 kg to 5400 kg for these items. There is also deviation of 22647 euros in total costs between EOQ and smallest actual order quantity. Order size could be revised with the supplier, but it should be considered that A3 and A4 materials have certain shelf live so the recommended optimized order size should be evaluated based on that. Actually materials A3 and A4 are changing to other material where the order quantity is 5400 kgs which is a good decision to improve order quantity and decrease total costs. Inventory turnover of these materials is 13 days, which is below target of 44 days.

A5: EOQ (19684m) is smaller than the actual order quantity (30434m). Order quantity could be revised with the supplier. However as the figure shows there are no significant difference in total costs between EOQ and actual order quantity. Material is shipped from other continent so the actual order size is convenient. Inventory turnover of this material is 12 days, which is below target of 44 days

A6: EOQ (17333m) is smaller than the actual order quantity (26000m). Even though there is difference between suggested EOQ and actual order size, total costs still remain quite similar despite the order quantity. As the figure shows total costs start to increase after the EOQ point is reached and therefore it is suggested to keep order quantities around 20000 meters in order to balance ordering and holding costs. One truck load of this material is 26000 meters and ordering costs are optimized as full loads are ordered. Inventory turnover of this material is 44 days, which is equal to target of 44 days, which might be a result of decreased demand for this material.

A7: EOQ (6665m) is smaller than the actual order quantity (13260m). There are difference of 2657 euros in total costs between the EOQ and actual order size. As the figure shows total costs start to increase after EOQ point is reached, so the order quantity could be revised with the supplier. However concerning this material, decreasing order quantity is not convinient as it shipped from another continent. Inventory turnover of this material is 20 days, which is clearly below the target inventory days of 44 days.

A8: EOQ (25200m) is slightly smaller than the actual order quantity (36000m). 36 000 meters is the minimum order quantity that the supplier is able to provide with fixed price. There is only marginal difference of 470 euros in total costs between EOQ and actual order quantity. Taking earlier mentioned issues into consideration, changing order size would not make any great impact on the tied working capital, even though the material is expensive. However order quantities should be kept close to EOQ as the figure shows total costs start to increase after the EOQ point is reached. Inventory turnover of this material is 39 days, which is below target of 44 days.

A9: EOQ (145851 m) is slightly smaller than the actual order quantity (195072 m). Order size could be revised with the supplier in order to better balance ordering and holding costs. However there is only marginal difference of 310 euros in total costs of EOQ and actual order quantity. Based on the total cost estimation, changing order quantity would not make any great impact on the working capital. As the figure illustrates total costs do not increase significantly after the EOQ point is reached. Material is shipped from another continent and one container equals the actual order quantity, and in respect to transportation it is suggested to keep order quantity as it is. Inventory turnover of this material is 28 days, which is below target of 44 days.

A10: EOQ (14997 kg) is smaller than the actual order quantity (20000 kg). Order quantity for this material is 20000 kgs which could be decreased. As the figure shows, there is not significant difference in total costs between actual order quantity and EOQ, however this material has certain shelf live and by decreasing the order quantity the risk of deterioration could be decreased. Actually, it is agreed with supplier that order quantity will be 18000 kg in the future, which improves inventory turnover. Inventory turnover of this material is 29 days, which is below target of 44 days.

A11: EOQ (63326 m) is larger than the actual order quantity (36000 m). Budgeted annual demand of 1 837 982 meters is quite high. Considering the budgeted annual demand, the order quantity could be revised with the supplier in order to decrease ordering costs. However the order quantity should be kept around 50000 to 80000 meters to balance ordering and holding costs and minimize total costs. This material is produced in large batches and is delivered in four different call-offs so order size can not be influenced. Total quantity consisting of four call-offs is the largest and cheapest way of ordering materials. Inventory turnover for this material is 20 days, which is below target of 44 days.

A12: EOQ (40715 m) is slightly larger than the actual order quantity (36000 m). Order quantity could be increased, to balance better ordering and holding costs, however there is only marginal difference of 53 euros in total costs. As the figure shows after EOQ point is reached holding costs start to increase and therefore it is suggested to keep order size around 30000-50000 meters. This material is produced in large batches and is delivered in four different call-offs so order size can not be influenced. Total quantity consisting of four call-offs is the largest and cheapest way of ordering materials. Inventory turnover of this material is 40 days, which is slightly below the target of 44 days.

A13&A14: Materials A13 and A14 are practically one material which consists of two different components and therefore they can be analyzed as one material. EOQ (2582 kg) is slightly smaller than the actual order quantity (3000 kg). There is only marginal difference of 71 euros in total costs between EOQ and actual order quantity, so changing order quantity would not make great impact on the working capital tied into inventories. However as the figure shows there are quite significant changes in total costs depending on the order size and therefore the order size in suggested to keep around 3000 kgs. This material is in consignment stock, and therefore it does not influence stock value. Inventory turnover for this material is 3 days, which is clearly below target of 44 days.

Table 4. below concludes A class materials calculated economic order quantities and actual order quantities and their total costs of ordering and holding costs.

Table 4. Comparison of economic order quantities and actual order quanties of A class materials

Material	EOQ M/PCS	Total cost €	Actual quantity M/PCS	Actual cost €
A1	6215	12430	19565	21539
A2	22720	11587	89100	24189
A3	5496	10607	900-5400	33254-10609
A4	5496	10607	900-5400	33254-10609
A5	19684	11023	30434	12086
A6	17333	9533	26000	10328
A7	6665	10797	13260	13454
A8	25200	7308	36000	7778
A9	145851	7293	195072	7603
A10	14997	7048	20000	7343
A11	63326	6966	36000	8107
A12	40715	6921	36000	6974
A13	2582	6327	3000	6398
A14	2582	6327	3000	6398

Comparison between calculated economic order quantities and actual order quantities indicate that there is not significant differences between them. Differences are mostly explained by transportation unit size, maximum price advantage and/or supplier capacity. In terms of total costs the economic order quantity is worth of 124 774 euros of all A class materials. The actual order quantity total cost value is 198 705 or 153 415 euros, depending on the order size of materials A3 and A4. Deviation in total costs between EOQ quantity and actual order size is between 28641-73931 euros. Potential development possibility is associated with internal suppliers and those suppliers who are supplying multiple materials where transportation costs could be optimized at the same time.

5.2.2 EOQ calculation analysis and development suggestions B class materials

This section illustrates and analyzes calculated economic order quantity (EOQ) for each B class materials. Figure 10. below illustrates the EOQ for material B1 in terms of ordering and holding cost as well as total costs. Other B class materials figures are included in appendices, but analysis is included in the text. After each analysis possible development suggestions are given and inventory turnover of the material is commented. Lastly comparison is made between calculated EOQs and actual order quantities of the materials and they are visualized in tables.

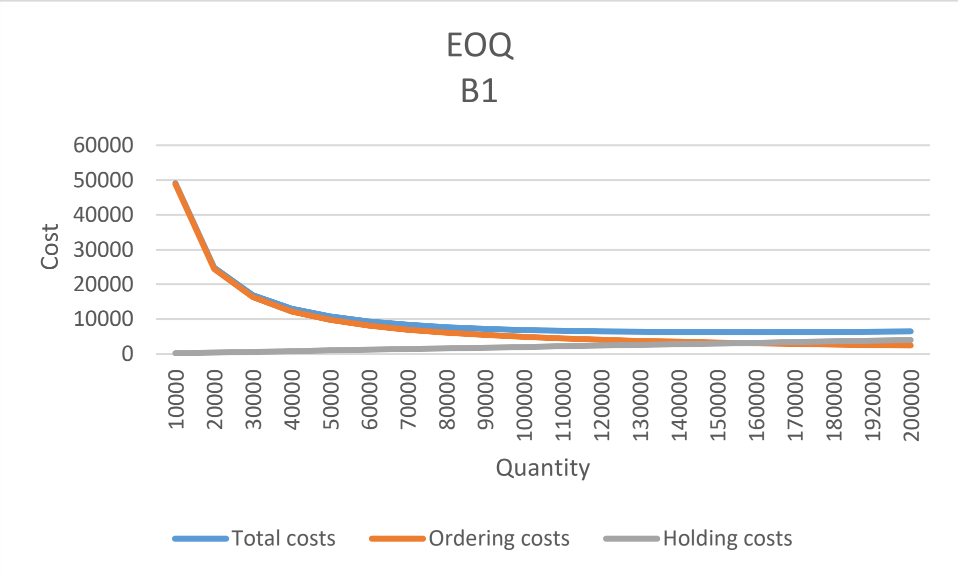

Figure 10. Material B1 economic order quantity

For material B1 EOQ (156340m) is slighly smaller than actual order quantity (192000m). However there are no significant difference between total costs between EOQ and actual order quantity. If order quantity is smaller total costs mainly consists of ordering costs where as holding costs remain at minimum. Holding costs of this item are low due to low unit price (0,25 €). Budgeted demand for this item is 4 073 709 meters, and therefore large order quantities are suggested in order to decrease ordering costs. However order size is one full truck load and decreasing of order size is not convenient in respect to transportation costs. As the figure 10. shows there are no significant differences in total costs after the EOQ of 156 340 meters is rearched. Inventory turnover for this material is 26 days which is below target of 44 days.

B2: EOQ (12114 pcs) is larger than the actual order quantity (6400 pcs). Order quantity could be increased to balance ordering and holding costs. However as the figure shows, total costs remain quite similar after the EOQ point is rearched. There has been change in the component actual consumption, in comparison to budgeted demand and actual consumption is smaller than budgeted. Inventory turnover for this material is 55 days, which is over target of 44 days. Poor inventory turnover is a result of decreased demand for the material.

B3: EOQ (31921m) is almost equal to actual order quantity (30000m). As the figure shows 30000 meters is the optimized order quantity. However the order quantity could be also something between 20000-50000 meters as the total costs remain below 6000 euros and after that costs start to increase. Inventory turnover for this material is 47 days, which is above target of 44 days.

B4: EOQ (13978 kg) is smaller than the actual order quantity (20000kg). Holding costs start to increase when the order quantity is larger, but the total cost do not differentiate between EOQ and actual order quantity. Material is dispatched in a container from another continent, and therefore the actual order quantity is convenient as one transportation unit is 20000 kg. Inventory turnover for this material is 27 days, which is below target of 44 days.

B5: EOQ (145222m) is smaller than actual order quantity (240000m). As the figure shows optimized order quantity is rearched between 140000 and 150000 meters, and after that holding costs start to increase. Order quantity could be revised with the supplier to check if any optimization could be done. Especially as supplier is producing other materials as well. Inventory turnover for this material is 33 days, which is below target of 44 days.

B6: EOQ (115305m) is almost equal to actual order quantity (118852m). Total costs between EOQ and actual order quantity are also almost equal and therefore current order quantity is suggested. Material is dispatched from another continent and therefore full containers are suggested in respect to transportation costs. Inventory turnover for this material is 36 days, which is below target of 44 days.

B7: EOQ (17048m) is smaller than the actual order quantity (36000m). Total costs are 1297 euros higher with actual order quantity than with the EOQ. I could be revised with the supplier if the order quantity could be optimized, however according to observation 36 000 meters is minimum quantity provided by the supplier. Inventory turnover for this material is 33 days, which is below target of 44 days.

B8: EOQ (187438m) is larger than the actual order quantity (125000m). There is only little difference of 311 euros in terms of total costs between EOQ and actual order quantity. Budgeted demand for this material is 2 927 439 meters and by increasing order quantity ordering costs could be optimized. However order size is limited by the production process of the supplier and order quantity is therefore fixed. Also based on the close location of the supplier there is no need to order larger quantities at once. Inventory turnover for this material is 31 days, which is below target of 44 days.

B9: EOQ (130581m) is almost equal to actual order quantity (132000m). As the figure shows optimized order quantity is reached at 130000 meters and before and after that ordering and holding costs are not balanced. Inventory turnover for this material is 48 days, which is over target of 44 days.

B10: EOQ (219980m) is larger than the actual order quantity (66000m). Budgeted annual demand for this material is 4 032 587 meters and by increasing order quantity ordering expences could be reduced. There is difference of 3592 euros in total costs between the EOQ and actual order quantity. However supplier is delivering also other materials weekly and by taking this into consideration increasing of order quantity is not necessary. Increased order quantity would not decrease total costs as 66 000 meters is the largest and cheapest order quantity. Inventory turnover for this material is 15 days, which is below target of 44 days. By ordering smaller quantities than suggested EOQ inventory turnover is more efficient.

B11: EOQ (15027m) is smaller than the actual order quantity (36000m). EOQ suggests smaller order quantity because of the unit price (1,74 €) which raises holding costs of the material. There is difference of 1588 euros in total costs between EOQ and actual order quantity. Order quantity could be revised with the supplier, but it is so that the actual order quantity of 36000 meters is the minimum production quantity that supplier is providing. Inventory turnover for this material is 42 days, which is slighly below target of 44 days.

B12: EOQ (58615m) is almost equal to actual order quantity (54000m). Total costs are also almost equal between EOQ and actual order quantity. As the figure shows total costs increase when order quantity is smaller or larger than EOQ or actual order quantity and therefore it is suggested to keep order quantity around 50000 meters. Inventory turnover for this material is 31 days, which is below target of 44 days.

B13: EOQ (7311 kg) is smaller than the actual order quantity (20000kg). There is deviation of 1892 euros in total costs between EOQ and actual order quantity costs. Holding costs increase after EOQ is rearched due to material unit price (3,16€). Actual order quantity is one transportation unit and therefore change in order quantity is not possible due to nature of the material. Inventory turnover for this material is 46 days, which is slightly over target of 44 days.

B14: EOQ (11047 pcs) is smaller than the actual order quantity (19200 pcs). Order quantity could be revised with the supplier in order to balance better ordering and holding costs. Actually this component is discontinued and therefore there is no need for improvement. Inventory turnover for this material is 40 days, which is slighly below target of 44 days.

B15: EOQ (28146pcs) is smaller than the actual order quantity (54000 pcs). Deviation in total costs is 805 euros between EOQ and actual order quantity. As the figure shows the difference is quite marginal and therefore changing of order quantity would make great impact in total costs. Actually this component is discontinued and therefore there is no need for improvement. Inventory turnover for this material is 215 days, which is clearly above target of 44 days, resulting of decreased demand.

B16: EOQ (6371 kg) is almost equal to actual order quantity (6160 kg). As the figure shows order quanitity is optimized in terms of total cost, and both ordering and holding costs. It is suggested to keep the order quantity around 6000 kgs. Inventory turnover for this material is 25 days, which is below target of 44 days.

B17: EOQ (430063m) is larger than the actual order quantity (288000m). Order quantity could be revised with the supplier, especially as the budgeted demand for this material is 7 352 190 meters, so by increasing order size ordering expenses could be minimized. On the other hand though, bigger order quantities require more storage space and increase holding costs. As the figure shows, there are no significant differences in total cost after the EOQ point is rearched. Minor changes are result of low unit price (0,05 €). Increasing order quantity might have negative impact on inventory turnover especially as no price advantages are achieved by ordering more than actual order quantity. Inventory turnover for this material is 27 days, which is below target of 44 days.

B18: EOQ (182605m) is larger than the actual order quantity (99000m). EOQ is quite high compared to the actual order quantity, which can be explained by the low unit price (0,14 €). Budgeted demand for the material is 2 778 721 meters and therefore larger quantities could be suggested to revise with the supplier if cost benefits are achieved by ordering larger quantities. Larger order quantities might have negative impact on inventory turnover so increasing order quantity might not be that beneficial. However, material is in consignment stock and therefore having large order quantities does not tie working capital. Inventory turnover for this material is 34 days, which is below target of 44 days.

B19: EOQ (36719m) is smaller than the actual order quantity (120000m). After EOQ point is rearched holding costs start to increase. Holding costs increase due to material unit price (0,67 €) and because the budgeted annual demand is 561 799 meters. As the annual demand is quite moderate EOQ suggests smaller order quantities to cope with the holding costs. However supplier production process does not allow smaller order quantities. Material is in consignment stock and therefore having large order quantities does not tie working capital. Inventory turnover for this material is 7 days, which is clearly below target of 44 days.

B20: EOQ (369367pcs) is larger than the actual order quantity (230000pcs). Order quantity could be revised with the supplier. Annual budgeted demand for this material is quite high 5 684 656 pieces and by increasing order quantity ordering costs could be decreased. However as the figure shows total costs do not rise significantly after EOQ point is rearched. Price of this material does not decrease, if order quantity is larger than actual order quantity. Therefore increasing order quantity to the suggested EOQ is not beneficial in respect to inventory turnover. Supplier is located close and therefore smaller quantities can be ordered as transportation can be organized more flexible. Inventory turnover for this material is 23 days, which is below target of 44 days.

B21: EOQ (154060m) is slighly smaller than the actual order quantity (216480m). As the figure shows after the EOQ point is rearched holding cost start to increase, and they consist majority of total costs. As the annual budgeted demand for this material is quite high 1 977 878 meters the actual order quantity is convinient in comparison to suggested EOQ which decreases ordering costs. Actual order size is minimun order quantity offered by the supplier and changes are not possible. Inventory turnover for this material is 37 days, which is below target of 44 days.

B22: EOQ (254336m) is large than the actual order quantity (108000m). Annual budgeted demand for this material is 2 695 287 meters and considering that it could be revised with supplier if the order size could be increased. However as the figure shows total costs do not decrease significantly by increasing order size. Ordering larger quantities could have negative impact on inventory turnover, especially as this supplier is delivering other materials as well weekly. Inventory turnover for this material is 87 days, which is clearly above target of 44 days.

B23: EOQ (45880m) is almost equal to the actual order quantity (48000m). As the figure shows, total costs start to increase after the EOQ point is rearched. It is suggested to keep order quantities around 40000-50000 meters. Inventory turnover for this material is 42 days, which is slighly below target of 44 days.

B24: EOQ (269300 m) is larger than the actual order quantity (144000m). EOQ is quite high due to low unit price (0,07 €) and therefore holding costs are lower as well. Budgeted annual demand of 3 021 769 meters is quite high and therefore larger order quantities could be revised with the supplier in order to balance total costs. However the actual order size is economic as the price would not decrease even if suggested EOQ would be ordered. Inventory turnover for this material is 20 days, which is below target of 44 days.

B25: EOQ (135351m) is larger than the actual order quantity (80000m). Order quantity could be revised with the supplier in order to balance ordering and holding costs. Increasing order quantities would decrease ordering costs, especially as the budgeted annual demand of 1 526 649 meters is quite high. However supplier is delivering also other materials weekly and therefore actual order quantity is convinient in respect to transportation costs and holding costs. Also the actual order quantity is economic as increasing of order size to suggested EOQ would not decrease price of the material.
Inventory turnover for this material is 31 days, which is below target of 44 days.

Table 5. below concludes B class materials calculated economic order quantity and actual quantities and their value in euros.

Table 5. Comparison of economic order quantities and actual order quanties of B class materials

Material	EOQ M/PCS	Total cost €	Actual quantity M/PCS	Actual cost €
B1	156340	6254	192000	6386
B2	12114	5572	6400	6745
B3	31921	5427	30000	5437
B4	13978	4473	20000	4763
B5	145222	4357	240000	4918
B6	115305	4612	118852	4614
B7	17048	4432	36000	5729
B8	187428	3749	125000	4060
B9	130581	3917	132000	3918
B10	219980	4400	66000	7992
B11	15027	3907	36000	5495
B12	58615	4103	54000	4117
B13	7311	3436	20000	5328
B14	11047	3867	19200	4472
B15	28146	3659	54000	4464
B16	6371	3759	6160	3761
B17	420063	4201	288000	4503
B18	182605	3652	99000	4358
B19	36719	3672	192000	9951
B20	369367	3694	230400	4113
B21	154060	3081	216480	3261
B22	254336	2543	108000	3535
B23	45880	2753	48000	2756
B24	269300	2693	144000	3238
B25	135351	2707	80000	3090

Comparison between calculated economic order quantities and actual order quantities indicate that the is no significant differences between them. Differences are mostly explained by transportation unit size, maximum price advantage and/or supplier capacity. In terms of total costs the economic order quantity is worth of 98920 euros of selected B class materials. The actual order quantity total cost value is 121004 euros. Deviation in total costs between EOQ quantity and actual order size is between 22084 euros.

5.3 Concluding findings of EOQ calculations and development suggestions

Based on the comparison made between calculated EOQ and actual order quantity the differences in order quantities and total costs consisting of ordering and holding costs are marginal and inventory turnover ratios of the materials are mostly below target of 44 days, which indicates that working capital is efficiently utilized. Working capital management is dependent of other variables than just optimized order quantities such as suppliers production capacity and pricing, which can be considered as external factors. Another external factor is demand fluctuation, which can not be controlled by the manufacturing company due to pull type manufacturing strategy.

Internal factors have also influence in the inventory and working capital management. In this case internal factors are referred to order quantities, which are based on the budget estimation. Internal factor is also associated with the flow of materials. It is suggested that flow of raw materials should be kept as stable as possible, in terms of right order quantities ordered and delivered at right time. Internal variation should be minimized as it might cause buffer. Variation is in close relation to external demand variability which in practice occurs in the production planning of the company. It is identified in the company that there is a gap between purchasing, materials planning and production planning. Gap is related to the difference in planning cycle of materials and production planning. Planning time horizon for exact production orders is only 1-2 weeks and for materials planning it might be as long as six months. Materials planning is based on the forecasted demand of finished goods where the raw materials requirement is based. Sometimes different planning cycle is creating challenges as if there is need for urgent and unplanned changes in the production planning. From materials planning perspective these situations cause challenges, for example during six month period demand for certain materials may change many times, and in some cases demand may disappear completely. These challenges may result as excess working capital and poor inventory turnovers for certain materials. Working capital cycle and demand fluctuations could be better controlled in the company if supplier lead times could be decreased by further supplier development. Simple example of supplier development could be adjusting order sizes with the suppliers who are supplying multiple materials to balance better ordering and holding costs. Supplier development could be also excellent communication with the suppliers about their performance and expectations regarding cooperation, and also about the demand fluctuations and forecasts.

Supplier development is important as poor supplier performance may cause supply chain risks, which are usually caused by inadequate cooperation between members and lack of visibility. Related to supplier development and order quantities and timing it could be assessed if EDIs could be used to improve information flow with suppliers. Automation would free labour resources for other activities and by utilizing automated system, occurance of human errors could be minimized. However, automation can not replace the cooperation, which is done within the company between different departments.

Research results and analysis indicate that maximum price advantages in volume items are achieved by ordering largest order quantities suppliers offer. This means that even though EOQ model might suggest to order larger quantities than actual order quantities, it is not that convenient as larger order quantities require more storage space and tie working capital into inventories. Many of the suppliers are delivering materials weekly and by taking this into consideration, it does not make sense to order larger quantities at once. It must be also mentioned that larger than actual order quantities i.e. suggested EOQ calculations, are limited by transportation, meaning that actual order quantity equals one truck or container load. It must be also mentioned that commissioning company of the research is operating in specific and regulated business environment, which requires custom made materials for the company. Regulated business environment and asset specificity is creating challenges for the company as it is has chosen to use single sourcing and there is not or only little possibility to use dual or pararrel sourcing. In addition to sourcing strategies it must be noted that the sourcing decisions are not controlled by the manufacturing company. However company could try to influence the strategic sourcing decision whether to "make" or "buy" raw materials. Lastly, related to sourcing and all above mentioned issues and potential in further development in company's materials and inventory management it is obvious that supplier performance is important.

5.4 Safety stock calculations

Safety stock levels for the research were calculated with the following formula:

$$\boldsymbol{B = ks} \times \sqrt{\boldsymbol{L}}$$

Where

B = safety stock

k = safety factor

s = standard deviation of demand

L = lead time

Safety factors were determined to be 95 %, 99 %, 99,9 % and 99,99 % for each raw material. Safety factors are based on the table 6. below. Safety factor is based on the normal standard distribution table and each service level has their own value. (Tersine 1994)

Table 6. Desired service level and safety factors (Tersine 1994)

Desired service level %	50	75	90	95	97	98	99	99,5	99,9	99,99
Safety factor k	0	0,67	1,28	1,64	1,88	2,05	2,33	2,57	3,09	3,72

Data for standard deviation of demand was collected from the company's SAP system. Data consisted of the actual demand per week (53) of raw materials in 2018. Lead time information is based on the actual lead times of the suppliers of raw materials. Information of supplier lead times was collected from material planners of the company. Safety stock levels are illustrated with tables and 95, 99,00, 99,9 and 99,99 percent service levels are compared with each other in terms of their size and value. In this section theoretical maximum and average inventory level calculations are analyzed. Maximum inventory value is calculated by summing up replenishment order value and safety stock value for different service levels together. Average inventory is calculated by dividing replenishment order quantity by two and summing up that with safety stock value for different service levels. Also actual average inventory calculations are included in this section. Actual average inventory calculations are calculated as follows: actual safety stock level + order quantity /2. Actual safety stock is based on the actual average inventory level, before replenishment order arrives. Actual average inventory calculations are calculated by summing up actual inventory level before replenishment orders arrive and dividing them by the amount of order arrival times. Actual average stock data was collected from company's SAP system, from previous six months period of 1.4.-30.9.2019.

5.5 A class safety stock calculations

This chapter represents the results of A class materials safety stock calculations. Chapter analyses the required safety stock amount and safety stock value in euros for different service levels. Analysis includes theoretical maximum and theoretical average inventory amount and value for A class materials. Theoretical maximum and average inventories are compared to calculated actual average inventory of the company. As a result from the analysis the service level of raw material inventory for each A class material can be determined.

5.5.1 A class maximum inventory calculations

This chapter introduces the maximum inventory calculation results and their value in euros. Maximum inventory calculations are chosen to the research to illustrate what could be the inventory value at its highest in terms of tied working capital. Maximum inventory calculation gives results of certain time period inventory level, thus it is not the best inventory measurement practice. However, as the company is using periodic inventory management approach it is suitable and complimentary data for the research. In this chapter each A class material is analyzed and supplier lead times are mentioned as they have influence on the amount of safety stocks required. Figure 11. below illustrates material A1 maximum inventory value for different service levels. For other A class materials figures are illustrated in appendices section, but analysis is included in the text. Safety stocks are calculated with the formula and order quantity of each material is summed up with the safety stock amount, which gives maximum inventory value for the material.

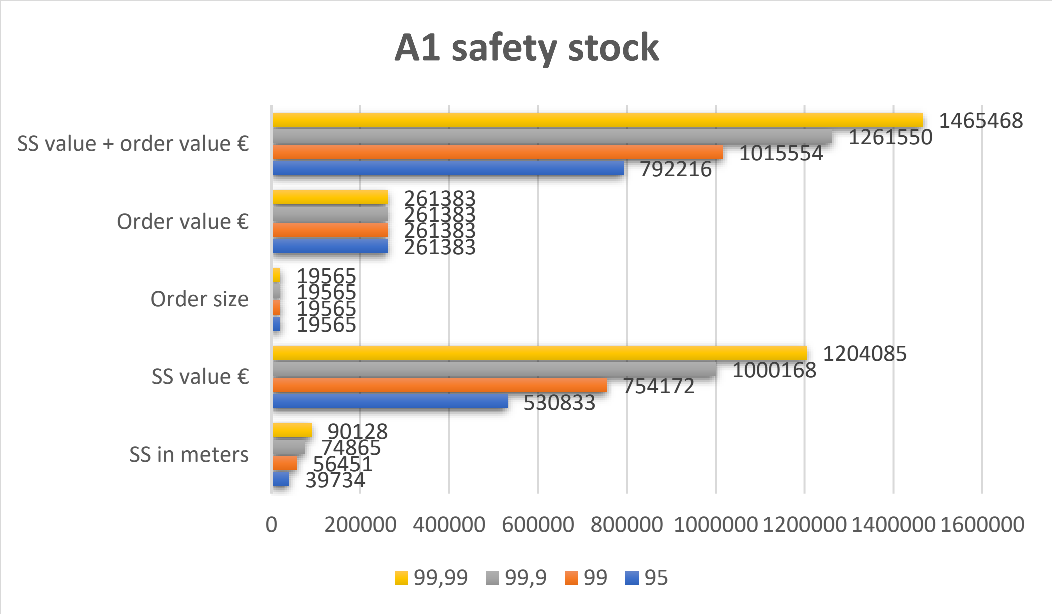

Figure 11. Maximum inventory value of material A1 for different service levels

Lead time for material A1 is 16 weeks and standard deviation of demand in 2018 was 6057 meters. Based on the service level calculation 95 % service level is reached by 39734 meters safety stock which value is 580833 euros. Service level of 99 % is reached with 56451 meters safety stock which value is 754172 euros. Service level of 99,9 % is reached with 74865 meters safety stock which is value of 1000168 euros. Service level of 99,99 % safety stock is 90128 meters and value of 1204085 euros. There is a significant difference in terms of safety stock size between calculated service levels. Comparison between 95 % and 99,99 % service level indicate 44,1 percent difference in safety stock size. Safety stock value and order value deviation between 99,99 and 95 percent service level is 673 270 euros. Based on the calculation the actual safety stock of material A1 is 17193 meters, which indicates that 95,00 percent service level is not reached.

Lead time for material A2 is 12 weeks and standard deviation of demand in 2018 was 9962 meters. Based on the service level calculation 95 % service level is reached by 56595 meters safety stock which value is 194196 euros. Service level of 99 % is reached with 80407 meters safety stock which value is 275900 euros. Service level of

99,9 % is reached with 106634 meters safety stock which is value of 365893 euros. Service level of 99,99 % safety stock is 128375 meters and value of 440493 euros. There is a significant difference in terms of safety stock size between calculated service levels. Comparison between 95 % and 99,99 % service level indicate 44,1 percent difference in safety stock size. Safety stock value and order value deviation between 99,99 and 95 percent service level is 246 297 euros. Based on the calculation the actual safety stock of material A2 is 152190 meters, which indicates that 99,99 percent service level is reached.

Lead time for material A3 and A4 is 12 weeks and standard deviation of demand in 2018 was 972 kgs. Based on the service level calculation 95 % service level is reached by 6376 kgs safety stock which value is 81939 euros. Service level of 99 % is reached with 9059 kgs safety stock which value is 116413 euros. Service level of 99,9 % is reached with 12014 kgs safety stock which is value of 154385 euros. Service level of 99,99 % safety stock is 144635 kgs and value of 185861 euros. There is a significant difference in terms of safety stock size between calculated service levels. Comparison between 95 % and 99,99 % service level indicate 44,1 percent difference in safety stock size. Safety stock value and order value deviation between 99,99 and 95 percent service level is 103922 euros. Based on the calculation the actual safety stock of material A3 and A4 5553 kgs, which indicates that 95,00 percent service level is not reached.

Lead time for material A5 is 16 weeks and standard deviation of demand in 2018 was 7429 meters. Based on the service level calculation 95 % service level is reached by 48734 meters safety stock which value is 180682 euros. Service level of 99 % is reached with 69238 meters safety stock which value is 256701 euros. Service level of 99,9 % is reached with 91822 meters safety stock which is value of 340432 euros. Service level of 99,99 % safety stock is 110544 meters and value of 409840 euros. There is a significant difference in terms of safety stock size between calculated service levels. Comparison between 95 % and 99,99 % service level indicate 44,1 percent difference in safety stock size. Safety stock value and order value deviation between 99,99 and 95 percent service level is 229158 euros. Based on the calculation the actual safety stock of material A5 is 25939 meters, which indicates that 95,00 percent service level is not reached.

Lead time for material A6 is 12 weeks and standard deviation of demand in 2018 was 4977 meters. Based on the service level calculation 95 % service level is reached by 28275 meters safety stock which value is 103481 euros. Service level of 99 % is reached with 40171 meters safety stock which value is 147018 euros. Service level of 99,9 % is reached with 53274 meters safety stock which is value of 194973 euros. Service level of 99,99 % safety stock is 64136 meters and value of 234725 euros. There is a significant difference in terms of safety stock size between calculated service levels. Comparison between 95 % and 99,99 % service level indicate 44,1 percent difference in safety stock size. Safety stock value and order value deviation between 99,99 and 95 percent service level is 131243 euros. Based on the calculation the actual safety stock of material A6 is 84286 meters, which indicates that 99,99 percent service level is reached.

Lead time for material A7 is 26 weeks and standard deviation of demand in 2018 was 3899 meters. Based on the service level calculation 95 % service level is reached by 32605 meters safety stock which value is 352140 euros. Service level of 99 % is reached with 46323 meters safety stock which value is 500297 euros. Service level of 99,9 % is reached with 61433 meters safety stock which is value of 663484 euros. Service level of 99,99 % safety stock is 73958 meters and value of 798757 euros. There is a significant difference in terms of safety stock size between calculated service levels. Comparison between 95 % and 99,99 % service level indicate 44,1 percent difference in safety stock size. Safety stock value and order value deviation between 99,99 and 95 percent service level is 446617 euros. Based on the calculation the actual safety stock of material A7 is 17279 meters, which indicates that 95 percent service level is not reached.

Lead time for material A8 is 19 weeks and standard deviation of demand in 2018 was 12424 meters. Based on the service level calculation 95 % service level is reached by 88820 meters safety stock which value is 171290 euros. Service level of 99 % is reached with 126190 meters safety stock which value is 243357 euros. Service level of 99,9 % is reached with 167339 meters safety stock which is value of 322713 euros. Service level of 99,99 % safety stock is 201456 meters and value of 388509 euros. There is a significant difference in terms of safety stock size between calculated service levels. Comparison between 95 % and 99,99 % service level indicate 44,1 percent difference in safety stock size. Safety stock value and order value deviation between 99,99 and 95 percent service level is 217219 euros. Based on the calculation the actual safety stock of material A8 is 50908 meters, which indicates that 95 percent service level is not reached.

Lead time for material A9 is 16 weeks and standard deviation of demand in 2018 was 22208 meters. Based on the service level calculation 95 % service level is reached by 145684 meters safety stock which value is 44958 euros. Service level of 99 % is reached with 206979 meters safety stock which value is 63874 euros. Service level of 99,9 % is reached with 274491 meters safety stock which is value of 84708 euros. Service level of 99,99 % safety stock is 330455 meters and value of 101978 euros. There is a significant difference in terms of safety stock size between calculated service levels. Comparison between 95 % and 99,99 % service level indicate 44,1 percent difference in safety stock size. Safety stock value and order value deviation between 99,99 and 95 percent service level is 57021 euros. Based on the calculation the actual safety stock of material A9 is 311772 meters, which indicates that 99,9 percent service level is reached.

Lead time for material A10 is 12 weeks and standard deviation of demand in 2018 was 3426 kgs. Based on the service level calculation 95 % service level is reached by 19646 kgs safety stock which value is 61536 euros. Service level of 99 % is reached with 27652 kgs safety stock which value is 87426 euros. Service level of 99,9 % is reached with 36672 kgs safety stock which is value of 115943 euros. Service level of 99,99 % safety stock is 44149 kgs and value of 139581 euros. There is a significant difference in terms of safety stock size between calculated service levels. Comparison between 95 % and 99,99 % service level indicate 44,1 percent difference in safety stock size. Safety stock value and order value deviation between 99,99 and 95 percent service level is 78045 euros. Based on the calculation the actual safety stock of material A10 is 23259 kgs, which indicates that 95 percent service level is reached.

Lead time for material A11 is 12 weeks and standard deviation of demand in 2018 was 15835 meters. Based on the service level calculation 95 % service level is reached by 89961 meters safety stock which value is 66013 euros. Service level of 99 % is reached with 127810 meters safety stock which value is 93787 euros. Service level of 99,9 % is reached with 169499 meters safety stock which is value of 124378 euros. Service level of 99,99 % safety stock is 204057 meters and value of 149737 euros. There is a significant difference in terms of safety stock size between calculated service levels. Comparison between 95 % and 99,99 % service level indicate 44,1 percent difference in safety stock size. Safety stock value and order value deviation between 99,99 and 95 percent service level is 83724 euros. Based on the calculation the actual safety stock of material A11 is 74081 meters, which indicates that 95 percent service level is not reached.

Lead time for material A12 is 12 weeks and standard deviation of demand in 2018 was 12665 meters. Based on the service level calculation 95 % service level is reached by 71951 meters safety stock which value is 83133 euros. Service level of 99 % is reached with 102224 meters safety stock which value is 118109 euros. Service level of 99,9 % is reached with 135567 meters safety stock which is value of 156634 euros. Service level of 99,99 % safety stock is 163207 meters and value of 188569 euros. There is a significant difference in terms of safety stock size between calculated service levels. Comparison between 95 % and 99,99 % service level indicate 44,1 percent difference in safety stock size. Safety stock value and order value deviation between 99,99 and 95 percent service level is 105419 euros. Based on the calculation the actual safety stock of material A12 is 84402 meters, which indicate that over 95 percent service level is reached.

Lead time for material A13 and A14 is 16 weeks and standard deviation of demand in 2018 was 3426 meters. Based on the service level calculation 95 % service level is reached by 2572 kgs safety stock which value is 42038 euros. Service level of 99 % is reached with 3653 kgs safety stock which value is 59725 euros. Service level of 99,9 % is reached with 4845 kgs safety stock which is value of 79207 euros. Service level of 99,99 % safety stock is 5833 kgs and value of 95355 euros. There is a significant difference in terms of safety stock size between calculated service levels. Comparison between 95 % and 99,99 % service level indicate 44,1 percent difference in safety stock size. Safety stock value and order value deviation between 99,99 and 95 percent service level is 53317 euros. Based on the calculation the actual safety stock of each material A13 and A14 is 724 kgs, which indicate that 95 percent service level is not reached.

Table 7. below concludes the safety stock value for each A class materials with desired service level.

Table 7. A class materials safety stock value in euros (€) for desired service level in percent (%)

Material	95 %	99 %	99,90 %	99,99 %
A1	530833	754172	1000168	1204085
A2	194196	275900	365893	440493
A3	81939	116413	154385	185861
A4	81939	116413	154385	185861
A5	180682	256701	340432	409840
A6	103481	147018	194973	234725
A7	352140	500297	663484	798757
A8	171290	243357	322713	388509
A9	44958	63874	84708	101978
A10	61536	87426	115943	139581
A11	66013	93787	124378	149737
A12	83133	118109	156634	188569
A13	42038	59725	79207	95355
A14	42038	59725	79207	95355
Total (€)	**2036216**	**2892917**	**3836508**	**4618708**

In order to have 95 percent safety stock for all A class materials it would cost 2036216 euros. 99 percent service level value is 2892917 euros, for 99,90 percent the value of safety stock is 3836508 euros and 4618708 euros for 99,99 percent service level. Table shows in theory the lowest value inventory value that can be reached by using service level in determining safety stock size.

Table 8. below illustrates the safety stock value and value of single order. In theory table illustrates the maximum inventory value for desired service level and for the time replenishment of inventory occurs.

Table 8. A class materials maximum inventory value in euros (€) for desired service level in percent (%)

Material	95 %	99 %	99,90 %	99,99 %
A1	792216	1015554	1261550	1465468
A2	499925	581629	671622	746222
A3	151332	185806	223778	255254
A4	151332	185806	223778	255254
A5	293516	369535	453266	522674
A6	198636	242173	290128	329879
A7	495351	643507	806694	941968
A8	240716	312783	392139	457935
A9	105157	124073	144907	162178
A10	124768	150658	179175	202813
A11	92430	120204	150795	176154
A12	124727	159704	198229	230164
A13	91082	108768	128250	144399
A14	91082	108768	128250	144399
Total (€)	**3452268**	**4308969**	**5252559**	**6034760**

Safety stock and order arrival would rise the value of inventory to 3452268 euros with 95 percent service level. 99 percent service level would be worth of 4308969 euros, 99,9 percent would cost 5252558 and 99,99 service level 6034760 euros. In practice the value of inventory would not rise that high as materials have different delivery schedule and materials are transferred to work-in-process inventory as they are used in manufacturing.

5.5.2 A class theoretical average inventory calculations

In this section theoretical average inventory calculations for A class materials are analyzed. Theoretical average inventory value is calculated as follows: safety stock per desired safety stock + order quantity / 2 = theoretical average stock.

Figure 12. below illustrates the theoretical average inventory value for material A1. Other A class material theoretical average inventory figures are included in the appendices.

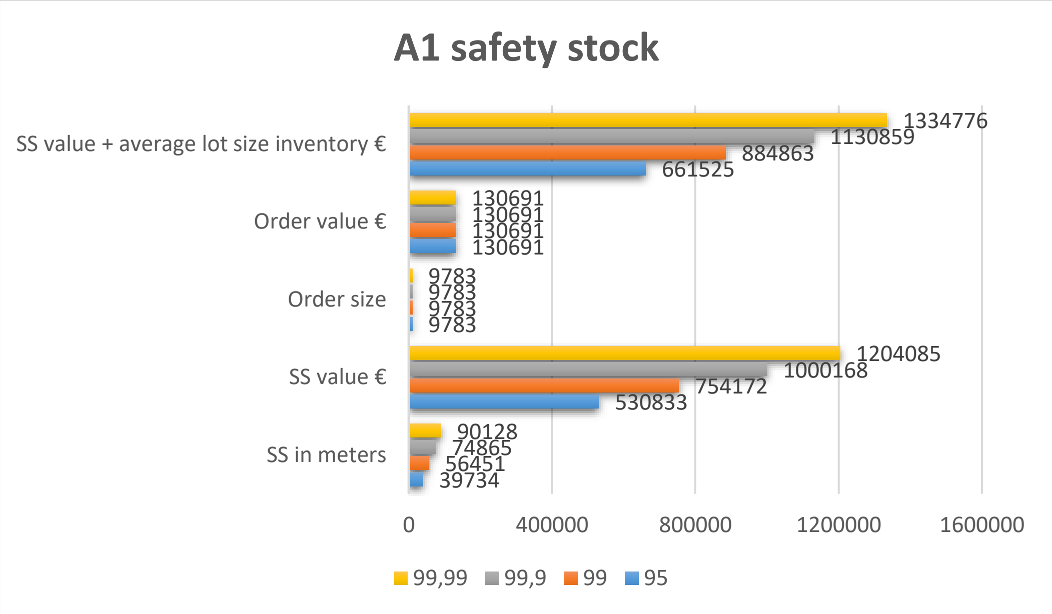

Figure 12. Theoretical average inventory value of material A1 for different service levels

As the figure 12. illustrates, theoretical average inventory value for material A1 for 95 percent service level is 661525 euros, for 99 percent 884863 euros, for 99,9 percent 1130859 euros and for 99,99 percent 1334776 euros.

Table 9. below concludes A class materials theoretical average inventory value in euros for desired service level of the inventory.

Table 9. A class materials theoretical average inventory value in euros (€) for desired service level in percent (%)

Material	95 %	99 %	99,90 %	99,99 %
A1	661525	884863	1130859	1334776
A2	347060	428764	518758	593357
A3	116635	151110	189081	220558
A4	116635	151110	189081	220558
A5	237099	313118	396849	466257
A6	151058	194596	242550	282302
A7	423745	571902	735089	870362
A8	206003	278070	357426	423222
A9	75058	93973	114807	132078
A10	93152	119042	147559	171197
A11	79222	106995	137587	162945
A12	103930	138907	177431	209367
A13	66560	84247	103728	119877
A14	66560	84247	103728	119877
Total (€)	**2744242**	**3600943**	**4544533**	**5326734**

For 95 percent service level the inventory value would be worth of 2744242 euros. 99 percent service level would cost 3600943 euros. 99,90 percent service level would be worth of 4544533 euros and for 99,99 percent inventory value would be 5326734 euros. In comparison to inventory target value of 8,2 million having 95 percent service level for the inventory would tie up approximately 33 % of the working capital. For 99 percent service level inventory would require 43 % of the working capital. For 99,9 percent and 99,99 percent service level the working capital requirement would be 55 % and 64 %.

5.5.3 A class actual average inventory calculations

Chapter concludes the results of actual average inventory calculations of A class materials. Table 10. below illustrates the actual safety stock quantity of materials in the inventory during previous six months period of 1.4.-30.9.2019. Actual average stock is calculated by summing actual inventory level before replenishment order arrive and dividing that by the amount of order arrivals. Actual safety stock value is calculated by multiplying safety stock quantity with unit price of the material. Actual total average inventory value is calculated by dividing actual order quantity by two and summing up that to actual safety stock value.

Table 10. A class materials actual safety stock quantity, actual safety stock value and the actual average inventory value

Material	Actual safety stock quantity	Actual safety stock value (€)	Actual total average inventory value (€)
A1	17193 m	226467	355325
A2	152190m	157141	536820
A3	5553kg	67876	87125
A4	5553kg	67876	87125
A5	25939m	85988	136432
A6	84286m	322927	372734
A7	17279m	156186	216114
A8	50908m	35226	99627
A9	311772m	109601	148137
A10	23259kg	74879	107072
A11	74081m	55227	68646
A12	84402m	97510	118305
A13	724 kg	12595	64718
A14	724 kg	12595	64718
total €		**1482094**	**2462898**

As the table 10. illustrates the actual safety stock value for A class materials is 1482094 euros. Actual total average inventory value is worth of 2462898 euros. Comparison between actual total average inventory value and raw material inventory total target value (8,2 million) indicates that with current inventory management practices, approximately 30 percent of the working capital is tied into A class materials inventory.

5.6 B class safety stock calculations

This chapter represent the results of B class materials safety stock calculations. Chapter analyses the required safety stock amount and safety stock value in euros for different service levels. Analysis includes theoretical maximum and theoretical average inventory amount and value for B class materials. Theoretical maximum and average inventories are compared to calculated actual average inventory of the company. As a result from the analysis the service level of raw material inventory for each B class material can be determined.

5.6.1 B class maximum inventory calculations

This chapter introduces the maximum inventory calculation results and their value in euros. Maximum inventory calculations are chosen to the research to illustrate what could be the inventory value at its highest in terms of tied working capital. Maximum inventory calculation gives results of certain time period inventory level, thus it is not the best inventory measurement practice. However, as the company is using periodic inventory management approach it is suitable and complimentary data for the research. In this chapter each B class material is analyzed and supplier lead times are mentioned as they have influence on the amount of safety stocks required. Figure 13. below illustrates material B1 maximum inventory value for different service levels. For other B class materials figures are illustrated in appendices section, but analysis is included in the text. Safety stocks are calculated with the formula and order quantity of each material is summed up with the safety stock amount, which gives maximum inventory value for the material.

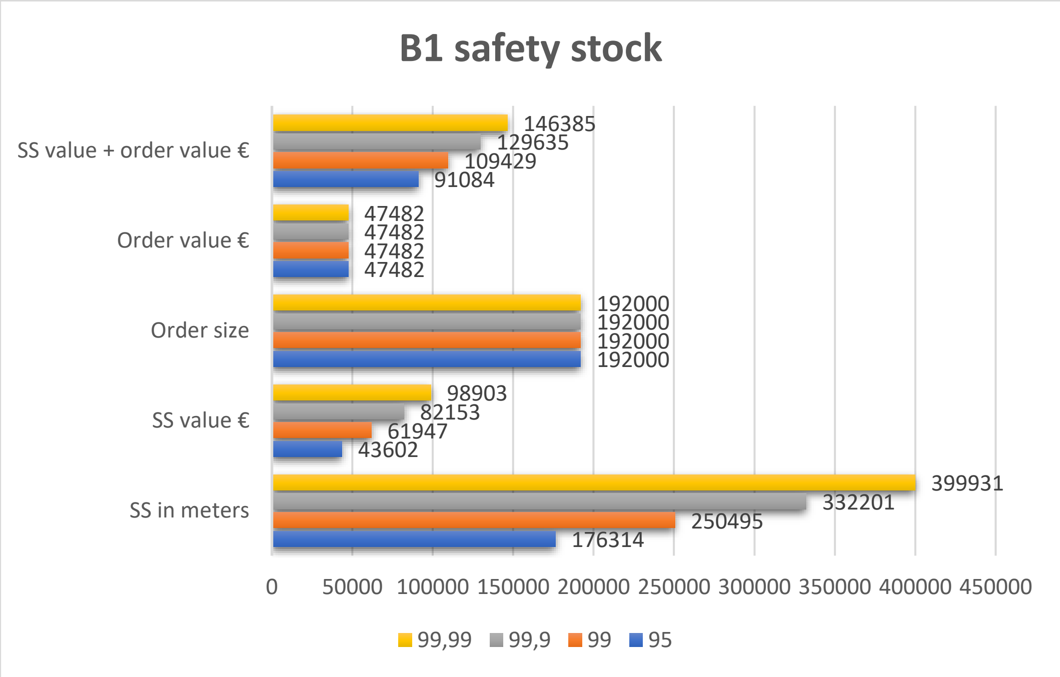

Figure 13. Maximum inventory value of material B1 for different service levels

Lead time for material B1 is 12 weeks and standard deviation of demand in 2018 was 31035 meters. As the figure 13 illustrates, based on the service level calculation 95 % service level is reached by 176314 meters safety stock which value is 43602 euros. Service level of 99 % is reached with 250495 meters safety stock which value is 61947 euros. Service level of 99,9 % is reached with 332201 meters safety stock which is value of 82153 euros. Service level of 99,99 % safety stock is 399931 meters and value of 98903 euros. There is a significant difference in terms of safety stock size between calculated service levels. Comparison between 95 % and 99,99 % service level indicate 44,1 percent difference in safety stock size. Safety stock value and order value deviation between 99,99 and 95 percent service level is 55301 euros. Based on the calculation the actual safety stock of material B1 is 128084 meters, which indicates that 95,00 percent service level is not reached.

Lead time for material B2 is 8 weeks and standard deviation of demand in 2018 was 4824 meters. Based on the service level calculation 95 % service level is reached by 22377 pieces safety stock which value is 68943 euros. Service level of 99 % is reached with 31791 pieces safety stock which value is 97949 euros. Service level of 99,9 % is reached with 42161 pieces safety stock which is value of 129898 euros. Service level of 99,99 % safety stock is 50757 meters and value of 156382 euros.

There is a significant difference in terms of safety stock size between calculated service levels. Comparison between 95 % and 99,99 % service level indicate 44,1 percent difference in safety stock size. Safety stock value and order value deviation between 99,99 and 95 percent service level is 87439 euros. For material B2 actual safety stock was not determined as there were no order arrivals during data collection period.

Lead time for material B3 is 12 weeks and standard deviation of demand in 2018 was 31035 meters. Based on the service level calculation 95 % service level is reached by 176314 meters safety stock which value is 196272 euros. Service level of 99 % is reached with 250495 meters safety stock which value is 278851 euros. Service level of 99,9 % is reached with 332201 meters safety stock which is value of 369806 euros. Service level of 99,99 % safety stock is 399931 meters and value of 445203 euros. There is a significant difference in terms of safety stock size between calculated service levels. Comparison between 95 % and 99,99 % service level indicate 44,1 percent difference in safety stock size. Safety stock value and order value deviation between 99,99 and 95 percent service level is 248931 euros. Based on the calculation the actual safety stock of material B3 is 30506 meters, which indicates that 95,00 percent service level is not reached.

Lead time for material B4 is 16 weeks and standard deviation of demand in 2018 was 2234 kgs. Based on the service level calculation 95 % service level is reached by 14665 kgs safety stock which value is 31508 euros. Service level of 99 % is reached with 20821 kgs safety stock which value is 44765 euros. Service level of 99,9 % is reached with 27612 kgs safety stock which is value of 59366 euros. Service level of 99,99 % safety stock is 33242 kgs and value of 71470 euros. There is a significant difference in terms of safety stock size between calculated service levels. Comparison between 95 % and 99,99 % service level indicate 44,1 percent difference in safety stock size. Safety stock value and order value deviation between 99,99 and 95 percent service level is 39962 euros. Based on the calculation the actual safety stock of material B4 is 11646 kgs, which indicates that 95,00 percent service level is not reached.

Lead time for material B5 is 16 weeks and standard deviation of demand in 2018 was 23771 meters. Based on the service level calculation 95 % service level is reached by 155938 meters safety stock which value is 35320 euros. Service level of 99 % is reached with 221546 meters safety stock which value is 50180 euros. Service level of 99,9 % is reached with 293810 meters safety stock which is value of 66548 euros. Service level of 99,99 % safety stock is 353712 meters and value of 80116 euros. There is a significant difference in terms of safety stock size between calculated service levels. Comparison between 95 % and 99,99 % service level indicate 44,1 percent difference in safety stock size. Safety stock value and order value deviation between 99,99 and 95 percent service level is 44796 euros. Based on the calculation the actual safety stock of material B5 is 116408 meters, which indicates that 95,00 percent service level is not reached.

Lead time for material B6 is 16 weeks and standard deviation of demand in 2018 was 40092 meters. Based on the service level calculation 95 % service level is reached by 263004 meters safety stock which value is 74009 euros. Service level of 99 % is reached with 373657 meters safety stock which value is 105147 euros. Service level of 99,9 % is reached with 373657 meters safety stock which is value of 139444 euros. Service level of 99,99 % safety stock is 596569 meters and value of 167875 euros. There is a significant difference in terms of safety stock size between calculated service levels. Comparison between 95 % and 99,99 % service level indicate 44,1 percent difference in safety stock size. Safety stock value and order value deviation between 99,99 and 95 percent service level is 93865 euros. Based on the calculation the actual safety stock of material B6 is 123026 meters, which indicates that 95,00 percent service level is not reached.

Lead time for material B7 is 19 weeks and standard deviation of demand in 2018 was 3776 meters. Based on the service level calculation 95 % service level is reached by 26993 meters safety stock which value is 46919 euros. Service level of 99 % is reached with 38350 meters safety stock which value is 66660 euros. Service level of 99,9 % is reached with 50859 meters safety stock which is value of 88403 euros. Service level of 99,99 % safety stock is 61228 meters and value of 106427 euros. There is a significant difference in terms of safety stock size between calculated service levels. Comparison between 95 % and 99,99 % service level indicate 44,1 percent difference in safety stock size. Safety stock value and order value deviation between 99,99 and 95 percent service level is 59508 euros. Based on the calculation the actual safety stock of material B7 is 21849 meters, which indicates that 95,00 percent service level is not reached.

Lead time for material B8 is 12 weeks and standard deviation of demand in 2018 was 13580 meters. Based on the service level calculation 95 % service level is reached by 77150 meters safety stock which value is 12221 euros. Service level of 99 % is reached with 109609 meters safety stock which value is 17362 euros. Service level of 99,9 % is reached with 145361 meters safety stock which is value of 23025 euros. Service level of 99,99 % safety stock is 174998 meters and value of 27720 euros. There is a significant difference in terms of safety stock size between calculated service levels. Comparison between 95 % and 99,99 % service level indicate 44,1 percent difference in safety stock size. Safety stock value and order value deviation between 99,99 and 95 percent service level is 15499 euros. Based on the calculation the actual safety stock of material B8 is 255557 meters, which indicates that 99,99 percent service level is reached.

Lead time for material B9 is 16 weeks and standard deviation of demand in 2018 was 39381 meters. Based on the service level calculation 95 % service level is reached by 258339 meters safety stock which value is 59909 euros. Service level of 99 % is reached with 367031 meters safety stock which value is 85114 euros. Service level of 99,9 % is reached with 486749 meters safety stock which is value of 112877 euros. Service level of 99,99 % safety stock is 585989 meters and value of 135891 euros. There is a significant difference in terms of safety stock size between calculated service levels. Comparison between 95 % and 99,99 % service level indicate 44,1 percent difference in safety stock size. Safety stock value and order value deviation between 99,99 and 95 percent service level is 75982 euros. Based on the calculation the actual safety stock of material B9 is 151131 meters, which indicates that 95,00 percent service level is not reached.

Lead time for material B10 is 19 weeks and standard deviation of demand in 2018 was 14588 meters. Based on the service level calculation 95 % service level is reached by 104284 meters safety stock which value is 12670 euros. Service level of 99 % is reached with 148159 meters safety stock which value is 18001 euros. Service level of 99,9 % is reached with 196486 meters safety stock which is value of 23873 euros. Service level of 99,99 % safety stock is 236546 meters and value of 28740 euros. There is a significant difference in terms of safety stock size between calculated service levels. Comparison between 95 % and 99,99 % service level indicate 44,1 percent difference in safety stock size. Safety stock value and order value deviation between 99,99 and 95 percent service level is 16070 euros. Based on the calculation the actual safety stock of material B10 is 68578 meters, which indicates that 95,00 percent service level is not reached.

Lead time for material B11 is 19 weeks and standard deviation of demand in 2018 was 2978 meters. Based on the service level calculation 95 % service level is reached by 21289 meters safety stock which value is 37004 euros. Service level of 99 % is reached with 30245 meters safety stock which value is 52572 euros. Service level of 99,9 % is reached with 40111 meters safety stock which is value of 69720 euros. Service level of 99,99 % safety stock is 48289 meters and value of 83935 euros. There is a significant difference in terms of safety stock size between calculated service levels. Comparison between 95 % and 99,99 % service level indicate 44,1 percent difference in safety stock size. Safety stock value and order value deviation between 99,99 and 95 percent service level is 46932 euros. Based on the calculation the actual safety stock of material B11 is 29763 meters, which indicates that 95,00 percent service level is reached.

Lead time for material B12 is 12 weeks and standard deviation of demand in 2018 was 9833 meters. Based on the service level calculation 95 % service level is reached by 55863 meters safety stock which value is 25691 euros. Service level of 99 % is reached with 79366 meters safety stock which value is 36500 euros. Service level of 99,9 % is reached with 105253 meters safety stock which is value of 48406 euros. Service level of 99,99 % safety stock is 126713 meters and value of 58275 euros. There is a significant difference in terms of safety stock size between calculated service levels. Comparison between 95 % and 99,99 % service level indicate 44,1 percent difference in safety stock size. Safety stock value and order value deviation between 99,99 and 95 percent service level is 32584 euros. Based on the calculation the actual safety stock of material B12 is 78259 meters, which indicates that 95,00 percent service level is reached.

Lead time for material B13 is 12 weeks and standard deviation of demand in 2018 was 945 kgs. Based on the service level calculation 95 % service level is reached by 5369 kgs safety stock which value is 16965 euros. Service level of 99 % is reached with 7627 kgs safety stock which value is 24103 euros. Service level of 99,9 % is reached with 10115 kgs safety stock which is value of 31965 euros. Service level of 99,99 % safety stock is 12178 kgs and value of 38482 euros. There is a significant difference in terms of safety stock size between calculated service levels. Comparison between 95 % and 99,99 % service level indicate 44,1 percent difference in safety stock size. Safety stock value and order value deviation between 99,99 and 95 percent service level is 21517 euros. Based on the calculation the actual safety stock of material B13 is 4423 kgs, which indicates that 95,00 percent service level is not reached.

Lead time for material B14 is 8 weeks and standard deviation of demand in 2018 was 3705 pieces. Based on the service level calculation 95 % service level is reached by 17186 pieces safety stock which value is 39700 euros. Service level of 99 % is reached with 24417 pieces safety stock which value is 56403 euros. Service level of 99,9 % is reached with 32381 pieces safety stock which is value of 74800 euros. Service level of 99,99 % safety stock is 38983 pieces and value of 90051 euros. There is a significant difference in terms of safety stock size between calculated service levels. Comparison between 95 % and 99,99 % service level indicate 44,1 percent difference in safety stock size. Safety stock value and order value deviation between 99,99 and 95 percent service level is 21517 euros. For material A14 actual safety stock was not determined as there were no order arrivals during data collection period.

Lead time for material B15 is 8 weeks and standard deviation of demand in 2018 was 9692 meters. Based on the service level calculation 95 % service level is reached by 44958 meters safety stock which value is 39909 euros. Service level of 99 % is reached with 63873 meters safety stock which value is 56700 euros. Service level of 99,9 % is reached with 84707 meters safety stock which is value of 75194 euros. Service level of 99,99 % safety stock is 101977 meters and value of 90525 euros. There is a significant difference in terms of safety stock size between calculated service levels. Comparison between 95 % and 99,99 % service level indicate 44,1 percent difference in safety stock size. Safety stock value and order value deviation between 99,99 and 95 percent service level is 50616 euros. For material A15 actual safety stock was not determined as there were no order arrivals during data collection period.

Lead time for material B16 is 8 weeks and standard deviation of demand in 2018 was 2978 kgs. Based on the service level calculation 95 % service level is reached by 13814 kgs safety stock which value is 54334 euros. Service level of 99 % is reached with 19626 kgs safety stock which value is 102373 euros. Service level of 99,9 % is reached with 26027 kgs safety stock which is value of 102373 euros. Service level of 99,99 % safety stock is 31334 kgs and value of 123245 euros. There is a significant difference in terms of safety stock size between calculated service levels. Comparison between 95 % and 99,99 % service level indicate 44,1 percent difference in safety stock size. Safety stock value and order value deviation between 99,99 and 95 percent service level is 68911 euros. Based on the calculation the actual safety stock of material B16 is 4201 kgs, which indicates that 95,00 percent service level is not reached.

Lead time for material B17 is 16 weeks and standard deviation of demand in 2018 was 39248 meters. Based on the service level calculation 95 % service level is reached by 257467 meters safety stock which value is 13105 euros. Service level of 99 % is reached with 365791 meters safety stock which value is 18619 euros. Service level of 99,9 % is reached with 485105 meters safety stock which is value of 24692 euros. Service level of 99,99 % safety stock is 584010 meters and value of 29726 euros. There is a significant difference in terms of safety stock size between calculated service levels. Comparison between 95 % and 99,99 % service level indicate 44,1 percent difference in safety stock size. Safety stock value and order value deviation between 99,99 and 95 percent service level is 16621 euros. Based on the calculation the actual safety stock of material B17 is 497298 meters, which indicates that 99,9 percent service level is reached.

Lead time for material B18 is 6 weeks and standard deviation of demand in 2018 was 27289 meters. Based on the service level calculation 95 % service level is reached by 109624 meters safety stock which value is 14953 euros. Service level of 99 % is reached with 155747 meters safety stock which value is 21244 euros. Service level of 99,9 % is reached with 297065 meters safety stock which is value of 40520 euros. Service level of 99,99 % safety stock is 357631 meters and value of 48781 euros. There is a significant difference in terms of safety stock size between calculated service levels. Comparison between 95 % and 99,99 % service level indicate 44,1 percent difference in safety stock size. Safety stock value and order value deviation between 99,99 and 95 percent service level is 33822 euros. Based on the calculation the actual safety stock of material B18 is 198104 meters, which indicates that 99,00 percent service level is reached.

Lead time for material B19 is 16 weeks and standard deviation of demand in 2018 was 5704 meters. Based on the service level calculation 95 % service level is reached by 37418 meters safety stock which value is 24995 euros. Service level of 99 % is reached with 53161 meters safety stock which value is 35512 euros. Service level of 99,9 % is reached with 70501 meters safety stock which is value of 47095 euros. Service level of 99,99 % safety stock is 84876 meters and value of 56697 euros. There is a significant difference in terms of safety stock size between calculated service levels. Comparison between 95 % and 99,99 % service level indicate 44,1 percent difference in safety stock size. Safety stock value and order value deviation between 99,99 and 95 percent service level is 31702 euros. Based on the calculation the actual safety stock of material B19 is 17465 meters, which indicates that 95,00 percent service level is not reached.

Lead time for material B20 is 16 weeks and standard deviation of demand in 2018 was 45276 meters. Based on the service level calculation 95 % service level is reached by 297011 meters safety stock which value is 13187 euros. Service level of 99 % is reached with 421972 meters safety stock which value is 18736 euros. Service level of

99,9 % is reached with 559611 meters safety stock which is value of 24847 euros. Service level of 99,99 % safety stock is 673707 meters and value of 29913 euros. There is a significant difference in terms of safety stock size between calculated service levels. Comparison between 95 % and 99,99 % service level indicate 44,1 percent difference in safety stock size. Safety stock value and order value deviation between 99,99 and 95 percent service level is 16725 euros. Based on the calculation the actual safety stock of material B20 is 321578 meters, which indicates that 95,00 percent service level is reached.

Lead time for material B21 is 8 weeks and standard deviation of demand in 2018 was 53464 meters. Based on the service level calculation 95 % service level is reached by 243361 meters safety stock which value is 29787 euros. Service level of 99 % is reached with 345750 meters safety stock which value is 42320 euros. Service level of 99,9 % is reached with 458527 meters safety stock which is value of 56124 euros. Service level of 99,99 % safety stock is 552013 meters and value of 67566 euros. There is a significant difference in terms of safety stock size between calculated service levels. Comparison between 95 % and 99,99 % service level indicate 44,1 percent difference in safety stock size. Safety stock value and order value deviation between 99,99 and 95 percent service level is 37762 euros. Based on the calculation the actual safety stock of material B21 is 102598 meters, which indicates that 95,00 percent service level is not reached.

Lead time for material B22 is 19 weeks and standard deviation of demand in 2018 was 26883 meters. Based on the service level calculation 95 % service level is reached by 192176 meters safety stock which value is 15624 euros. Service level of 99 % is reached with 273030 meters safety stock which value is 22197 euros. Service level of 99,9 % is reached with 362087 meters safety stock which is value of 29438 euros. Service level of 99,99 % safety stock is 435911 meters and value of 35440 euros. There is a significant difference in terms of safety stock size between calculated service levels. Comparison between 95 % and 99,99 % service level indicate 44,1 percent difference in safety stock size. Safety stock value and order value deviation between 99,99 and 95 percent service level is 19816 euros. Actual safety stock for material B22 was not determined as there were no order arrivals during data collection period.

Lead time for material B23 is 12 weeks and standard deviation of demand in 2018 was 6910 meters. Based on the service level calculation 95 % service level is reached by 39257 meters safety stock which value is 15451 euros. Service level of 99 % is reached with 55773 meters safety stock which value is 21952 euros. Service level of 99,9 % is reached with 73965 meters safety stock which is value of 29113 euros. Service level of 99,99 % safety stock is 89045 meters and value of 35048 euros. There is a significant difference in terms of safety stock size between calculated service levels. Comparison between 95 % and 99,99 % service level indicate 44,1 percent difference in safety stock size. Safety stock value and order value deviation between 99,99 and 95 percent service level is 19597 euros. Based on the calculation the actual safety stock of material B23 is 35095 meters, which indicates that 95,00 percent service level is not reached.

Lead time for material B24 is 19 weeks and standard deviation of demand in 2018 was 46866 meters. Based on the service level calculation 95 % service level is reached by 335026 meters safety stock which value is 22212 euros. Service level of 99 % is reached with 475982 meters safety stock which value is 31558 euros. Service level of 99,9 % is reached with 631238 meters safety stock which is value of 41851 euros. Service level of 99,99 % safety stock is 759937 meters and value of 50384 euros. There is a significant difference in terms of safety stock size between calculated service levels. Comparison between 95 % and 99,99 % service level indicate 44,1 percent difference in safety stock size. Safety stock value and order value deviation between 99,99 and 95 percent service level is 28172 euros. Based on the calculation the actual safety stock of material B24 is 98760 meters, which indicates that 95,00 percent service level is not reached.

Lead time for material B25 is 19 weeks and standard deviation of demand in 2018 was 9105 meters. Based on the service level calculation 95 % service level is reached by 65088 meters safety stock which value is 8852 euros. Service level of 99 % is reached with 92473 meters safety stock which value is 12576 euros. Service level of 99,9 % is reached with 122635 meters safety stock which is value of 16678 euros. Service level of 99,99 % safety stock is 147639 meters and value of 20079 euros. There is a significant difference in terms of safety stock size between calculated service levels. Comparison between 95 % and 99,99 % service level indicate 44,1 percent difference in safety stock size. Safety stock value and order value deviation between 99,99 and 95 percent service level is 11227 euros. Based on the calculation the actual safety stock of material B25 is 99267 meters, which indicates that 99,00 percent service level is reached.

Table 11. below concludes the safety stock value in euros for each B class material for desired service level.

Table 11. B class material safety stock value in euros (€) for desired service level in percent (%)

Material	95 %	99 %	99,90 %	99,99 %
B1	43602	61947	82153	98903
B2	68943	97949	129898	156382
B3	196272	278851	369806	445203
B4	31508	44765	59366	71470
B5	35320	50180	66548	80116
B6	74009	105147	139444	167875
B7	46919	66660	88403	106427
B8	12221	17362	23025	27720
B9	35320	50180	66548	80116
B10	12670	18001	23873	28740
B11	37004	52572	69720	83935
B12	25691	36500	48406	58275
B13	16965	24103	31965	38482
B14	39700	56403	74800	90051
B15	39909	56700	75194	90525
B16	54334	77194	102373	123245
B17	13105	18619	24692	29726
B18	14953	21244	40520	48781
B19	24995	35512	47095	56697
B20	13187	18736	24847	29913
B21	29787	42320	56124	67566
B22	15624	22197	29438	35440
B23	15451	21952	29113	35048
B24	22212	31558	41851	50384
B25	8852	12576	16678	20079
Total (€)	928555	1319227	1761880	2121098

In order to have 95 percent safety stock for selected B class materials it would cost 928555 euros. 99 percent service level value is 1319227 euros, for 99,90 percent the value of safety stock is 1761880 euros and 2121098 euros for 99,99 percent service level. Table shows in theory the lowest inventory value that can be reached by using service level approach in determining safety stock size.

Table 12. below illustrates the safety stock value and value of single order. In theory table illustrates the maximum inventory value for desired service level and for the time replenishment of inventory occurs.

Table 12. B class materials safety stock and order value in euros (€) for desired service level in percent (%)

Material	95 %	99 %	99,90 %	99,99 %
B1	91084	109429	129635	146385
B2	88661	117667	149616	176100
B3	229668	312247	403202	478599
B4	74508	87765	102366	114470
B5	89680	104540	120908	134476
B6	107454	138592	172889	201319
B7	109495	129235	150978	169002
B8	32021	37162	42825	47520
B9	89680	104540	120908	134476
B10	20689	26020	31892	36759
B11	99579	115148	132296	146510
B12	50526	61335	73241	83110
B13	80165	87303	95165	101682
B14	84052	100755	119152	134403
B15	210347	227138	245632	260963
B16	78563	101423	126602	147474
B17	27764	33278	39351	44385
B18	28456	34747	54023	62285
B19	105155	115672	127255	136857
B20	23417	28965	35077	40142
B21	56284	68817	82621	94064
B22	24404	30978	38218	44220
B23	34344	40845	48005	53941
B24	31759	41105	51398	59931
B25	19732	23456	27558	30959
Total (€)	1887489	2278162	2720814	3080033

Safety stock and order arrival would rise the value of inventory to 1887489 euros with 95 percent service level. 99 percent service level would be worth of 2278162 euros, 99,9 percent would cost 2720814 and 99,99 service level 3080033 euros. In practice the value of inventory would not rise that high as materials have different delivery schedules and materials are transferred to work-in-process inventory as they are used in manufacturing.

5.6.2. B class theoretical average inventory calculations

In this section theoretical average inventory calculations for B class materials are analyzed. Theoretical average inventory value is calculated as follows: safety stock per desired safety stock + order quantity / 2 = theoretical average stock.

Figure 14. below illustrates the theoretical average inventory value for material B1. Other B class materials theoretical average inventory figures are included in the appendices section.

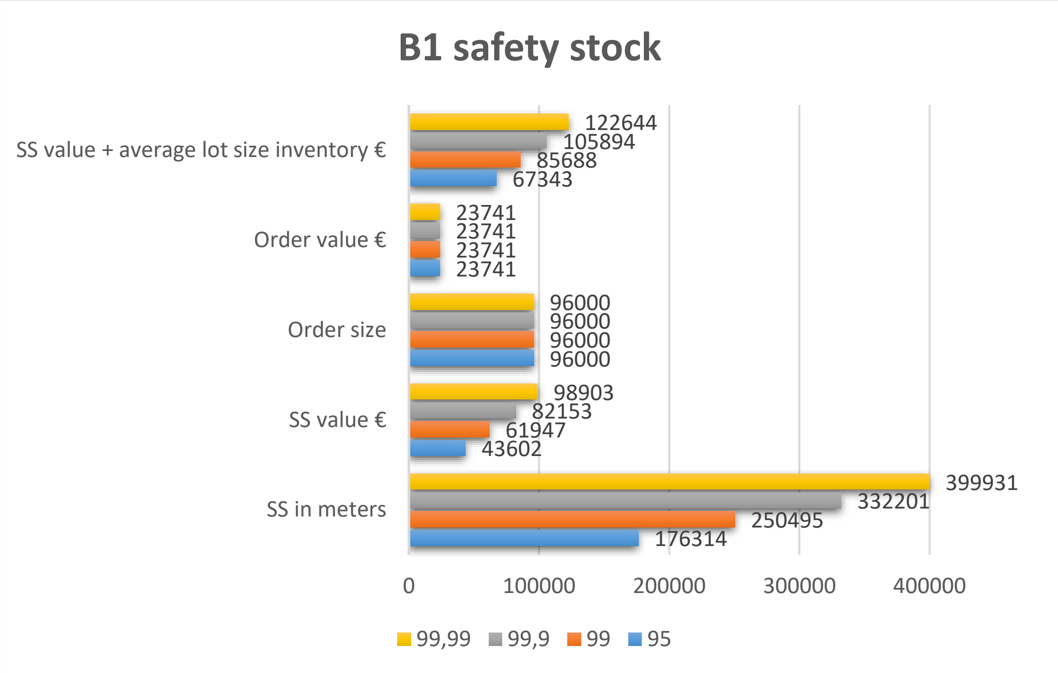

Figure 14. Theoretical average inventory value of material B1 for different service levels

As figure 14. illustrates 95 percent service level with theoretical average stock would be worth of 67343 euros. With 99 percent service level the average value of inventory would be 85688 euros, with 99,9 percent service level 105894 euros and with 99,99 percent service level 122644 euros.

Table 13. below concludes B class materials theoretical average inventory value in euros for desired service level of the inventory.

Table 13. A class materials theoretical average inventory value in euros (€) for desired service level in percent (%)

Material	95 %	99 %	99,90 %	99,99 %
B1	67343	85688	105894	122644
B2	78802	107808	139757	166241
B3	212970	295549	386504	461901
B4	53008	66265	80866	92970
B5	62500	77360	93728	107296
B6	90732	121870	156167	184597
B7	78207	97947	119691	137715
B8	22121	27262	32925	37620
B9	79041	104246	132009	155023
B10	16680	22011	27883	32750
B11	68291	83860	101008	115223
B12	38108	48918	60823	70692
B13	48565	55703	63565	70082
B14	61876	78579	96976	112227
B15	125128	141919	160413	175744
B16	66448	89308	114488	135360
B17	20435	25948	32021	37056
B18	21705	27996	47271	55533
B19	65075	75592	87175	96777
B20	18302	23850	29962	35027
B21	43036	55568	69372	80815
B22	20014	26588	33828	39830
B23	24898	31399	38559	44495
B24	26986	36331	46625	55157
B25	14292	18016	22118	25519
Total (€)	**1424563**	**1825581**	**2279628**	**2648292**

For 95 percent service level the inventory value would be worth of 1424563 euros. 99 percent service level would cost 1825581 euros. 99,90 percent service level would be worth of 2279628 euros and for 99,99 percent inventory value would be 2648292 euros. In comparison to inventory target value of 8,2 million having 95 percent service level for the inventory would tie up approximately 17 % of the working capital. For 99 percent service level inventory would require 22 % of the working capital. For 99,9 percent and 99,99 percent service level the working capital requirement would be 27 % and 32 %.

5.6.3 B class actual average inventory calculations

Chapter concludes the results of actual average inventory calculations of B class materials. Table. 10 below illustrates the actual safety stock quantity of materials in the inventory during previous six months period of 1.4.-30.9.2019. Actual average stock is calculated by summing actual inventory level before replenishment order arrive and dividing that by the amount of order arrivals. Actual safety stock value is calculated by multiplying safety stock quantity with unit price of the material. Actual total average inventory value is calculated by dividing actual order quantity by two and summing up that to actual safety stock value.

Table 14. B Class materials actual safety stock, actual safety stock value and actual total average inventory value

Material	Actual safety stock quantity	Actual safety stock value (€)	Actual total average inventory value (€)
B1	128084m	32020	56020
B2	NA	NA	NA
B3	30506m	33974	50680
B4	11646kg	29434	54706
B5	116408m	26657	54137
B6	123026m	35456	52582
B7	21849m	42758	77984
B8	255557m	43725	54419
B9	151131m	35410	50873
B10	68578m	8455	12524
B11	29763m	58247	93473
B12	78259m	33823	45493
B13	4423kg	18224	59424
B14	NA	NA	NA
B15	NA	NA	NA
B16	4201kg	16201	28077
B17	497298m	25710	33155
B18	198104m	27021	33773
B19	17465m	12295	79879
B20	321578m	14406	19567
B21	102598m	12742	26186
B22	NA	NA	NA
B23	35095m	14108	23756
B24	98760m	6932	11987
B25	99267m	13698	19218
total €		**541296**	**937913**

As the table 14. illustrates the actual safety stock value for A class materials is 541296 euros. Actual total average inventory value is worth of 937913 euros. Comparison between actual total average inventory value and raw material inventory total target value (8,2 million) indicates that with current inventory management practices, approximately 11 percent of the working capital is tied into B class materials inventory.

5.7 Concluding findings of safety stock calculations and development suggestions

Safety stock calculations were compared to actual average stock value of the materials. Based on the comparison over 95 percent service level is not reached with the average stock in majority materials. Long lead times increase the size of safety stock needed to fulfill desired service level due to longer replenishment cycle. Long lead times also decrease flexibility in case of unexpected demand fluctuations. Demand increase in case of long lead times might lead to situation where company is unable to respond to market needs associated with pull manufacturing, which might cause back orders or lost sales. Vice versa, demand decrease might lead to excess accumulation of stock, which has negative impact on working capital ratios. Excess inventory is also associated with risk of deterioration in case of changes in product portfolio or limited shelf life. Inventory management is influenced by supplier capability and flexibility. In order to improve inventory management it could be assessed if there is any potential for lead time reduction for those suppliers who have long lead times to increase agility to respond demand fluctuation.

Theory suggests that A class materials safety stock levels should be lower than B class materials safety stock as A class materials are more expensive (Jonsson 2008). However, in respect to reality and commissioning company the theory can not be applied that straight forward as raw materials are components of actual products and all components are critical for delivery performance of the company. Safety stock levels are also influenced by material demand and lead time. In stead of comparing the size of safety stock between A and B class materials, it can be suggested that more focus should be placed on A class raw materials. Focusing in the A class materials and their safety stock sizes the overall financial performance could be improved to some extent. Related to A class materials there is potential to determine appropriate safety stock sizes for each material, which requires managerial contribution. Materials could be also be evaluated based on their risk awarness meaning that with most critical materials which have greatest impact on production could have some safety stock.

Research results regarding service level calculations must be critically evaluated as they provide solutions which require significant amount of working capital. As stated earlier the raw material inventory target value is less than 8,2 million euros held in inventory. Calculations indicate that by having 99,99 percent service level for A and B class materials would cost approximately 6,7 million euros, only for safety stock held in inventory. In theory 99,99 percent service level in time of replenishment order arriving the raw material stock could rise as high as 9,1 million euros, which is above target of 8 million euros. It must be noted that research covers only 39 raw materials of the total amount of 1160, which would increase raw material stock value further. In respect to reality, it is not wise or possible to have that vast amounts of materials held in the inventory as it is expensive, risk of deterioration and also there is not enough physical space. Large variety of assortments require more physical space and more working capital. Therefore it could be assessed if variability could be decreased in some materials as multiple materials increase stock value and also whether some raw material assortment could be compined in finished products. A more practical approach to managing inventory levels is to check if company's SAP system is utilized as efficiently as possible.

If safety stocks are seen something that should be avoided, Lean practices, considering purchasing and materials planning could be suggested as an alternative. In respect to Lean practices materials handling could be done more in Just-In-Time principles, which requires reliable suppliers and precisely determined order sizes. Also standardization, one of Lean tools, could be considered as multiple variable materials increases the total amount of stock. Another possibility of having safety stocks is expanding utilization of vendor managed inventories (VMIs) where suppliers would hold stock for the company. Advantage of this method is that usually financial responsibility is due after the materials have been consumed. Lastly, considering appropriate safety stock levels, the trade off between holding safety stocks versus the work is done if there is not enough materials for production should be remembered.

6 DISCUSSION AND CONCLUSIONS

This chapter discusses and concludes the key research findings. First, it discusses the overall research findings. Lastly, chapter reminds of the set research aim and answers the research questions by concluding key results of the research.

6.1 Discussion

Based on the economic order quantity calculations and comparison to actual order quantities that are used in the company, it seems that differences between them are marginal. Differences in total costs are also marginal between calculated EOQs and actual order quantities. In analysis of EOQ calculations, the fixed ordering cost of 120 € and holding cost of 15 % should be considered as in reality there is variation what is the actual ordering and holding cost for each material. However, EOQ calculations give certain foundation in which to analyze ordering quantities. In practice order quantities are limited by the supplier capability and capacity to deliver purchased materials, and usually by buying larger quantities cost benefits are achieved. If suppliers are offering fixed order quantities and there are little possibility to influence it is suggested to keep material flow and order quantities as stable as possible as variation disturbs flow of materials. Stable flow of materials regarding economic order quantities and timing stables working capital cycle.

Considering delivery performance and demand fluctuation, decent size safety stock could be evaluated in the company. Safety stocks tie working capital, but they also increase agility of the company if something unexpected happens. In order to avoid excess safety stocks key thing is to determine optimum safety stock level and consider the tradeoff between sufficient safety stock and tied working capital. Considering working capital focus should be kept on A class materials as they are more expensive. Also the trade-off between raw material availability and work that is done when there is no material available due to unexpected events should be remembered. Even though excess inventory is to be avoided it still seems that someone has to take the burden of safety stocks. In this case it can be speculated if it is in this case, commissioning company’s task to evaluate safety stock sizes as the result is dependent of output. As delivery performance is critical for the company and demand fluctuates, safety stocks could provide security, despite the fact that they are costly and tie working capital. However, it must be noted that company's delivery performance is at the moment at excellent level with minimum safety stock of raw materials. Based on this result it can be also speculated if safety stocks are really needed, if operations are properly planned.

In conclusion it seems that order quantities are well determined and total costs are minimized in most cases. Company is using multiple tools in determining safety stock sizes, but still some development could be done to better protect against unexpected events and demand fluctuation in order to reduce risks and ensure delivery performance. Optimized order quantities placed and delivered at right time improve working capital cycle and there supplier performance plays critical role. It should not be forgotten that manufacturing company's existence is dependent of output and therefore financial and operational targets should be optimized by cooperating with both, external and internal stakeholders.

6.2 Conclusions

This research aimed at finding development suggestions for the commissioning company's raw material inventory handling with focus on efficient working capital usage. Main research question (RQ1) was: "*How to determine optimal safety stock level and inventory turnover in order to avoid excessive tied capital but at the same time ensure delivery performance?"* Based on the literature it can be argued that best way to ensure delivery performance is to have some kind of safety stock as it balances supply and demand. However, the chosen safety stock calculation method using service level is not the best solution for the company operating in manufacturing industry. Safety stock calculations based on the set service level require too much working capital and therefore, some other techniques could be more applicable such as utilizing SAP system more efficiently, in addition to manual estimation of sufficient safety stock. Considering inventory turnover company management has set target that the inventory turnover of raw materials should be less than 44 days in inventory. Based on the research majority of raw materials achieve this goal. Decreasing inventory turnover days from 44 days could improve working capital ratios. However, it should be remembered that too strict inventory management policy may lead to supply challenges. Supply challenges cause problems in delivery performance, and taking into consideration company’s Pull manufacturing strategy and supplier lead times it is better to have some inventory for raw materials.

First subquestion (RQ2) for the research was: *“What are the optimized order sizes for A and B items?”* Optimized order quantities were calculated with economic order quantity (EOQ) formula. Based on the research, it can be concluded that optimized order sizes are widely used in the company and there is not that much potential in changing order quantities. Regulated business environment limits possibility for changes as many of the materials are custom made and some materials have certain shelf lives that should be considered. Supplier production capacity limits optimization of order quantities meaning that smaller order quantities could cause increased prices due to setting costs of the suppliers. Cost benefits are achieved by buying large quantities for volume items and by combining transportation. Based on the observation of research data including annual raw material budget and consumption during 2018, it seems that order sizes are convenient in respect to budget, but demand fluctuations cause challenges. Considering possibility for improvement of order sizes potential is to seek alternative supplier with more flexibility. However, it should be noted that the company has limited chance to influence sourcing. With current suppliers further development of cooperation is suggested to ensure raw material availability and beneficial purchasing conditions.

Second subquestion (RQ3) was**:** *“What could be the optimal safety stock size for A and B items?”* In the research safety stock were calculated based on desired service level. Service level calculations provided high safety stock levels, which require a lot of working capital and are unpractical. In respect to practice some other techniques could be applied such as coverage profiles in weeks or per manufacturing orders. Related to safety stocks it is more important to determine safety stock levels and communicate those clearly than the chosen safety stock method. Focus should be kept in A class materials as they are more expensive and increase working capital tied into inventories. Even though focus should be in A class materials, other materials should be taken into consideration as they are components of actual product and if one item is missing it can cause back orders. Despite fact that determining appropriate safety stock level is challenging, safety stocks requirement could be assessed in the company. Safety stocks provide security for unexpected demand fluctuations and increase agility, which is important in competitive markets.

As suggestion for further research order quantity discounts of raw materials could be taken into consideration as they were excluded from this research. Order quantities could be calculated with expanded EOQ formula to get even more specific results regarding economic order quantities. Service loss calculations could be also included in further research as they were excluded from this research due to their complexity. Research could be also expanded to cover for example the whole B class materials to investigate in more details where working capital is tied.

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APPENDICES

Appendix 1. Example of EOQ calculation sheet

EOQ formula = √((2×D×O)/(i×c))			Units	Total costs	Ordering costs	Holding costs
D=	12000	demand per time unit	100	1400	1200	200
O=	10	incremental ordering or set-up cost per order event	110	1311	1091	220
c=	4	unit cost/goods value per item	120	1240	1000	240
i=	15	incremental inventory carrying cost in % per time and time unit	130	1183	923	260
			140	1137	857	280
EOQ	245	economic order quantity	150	1100	800	300
TC	980	total costs	160	1070	750	320
			170	1046	706	340
Ordering costs formula=	$D/Q \times O$		180	1027	667	360
Holding costs formula=	$Q/2 \times i \times c$		190	1012	632	380
Total costs formula=	$\frac{Q}{2} \times i \times c + \frac{D}{Q} \times O$		200	1000	600	400
			210	991	571	420
				…85	545	440
				…82	522	460
				…80	500	480
				…80	480	500
				…82	462	520
				…84	444	540
				…89	429	560
				…94	414	580
				…00	400	600
				…07	387	620
				…15	375	640
				…24	364	660
				…33	353	680
				…43	343	700
				…53	333	720
				…64	324	740
				…76	316	760
				…88	308	780
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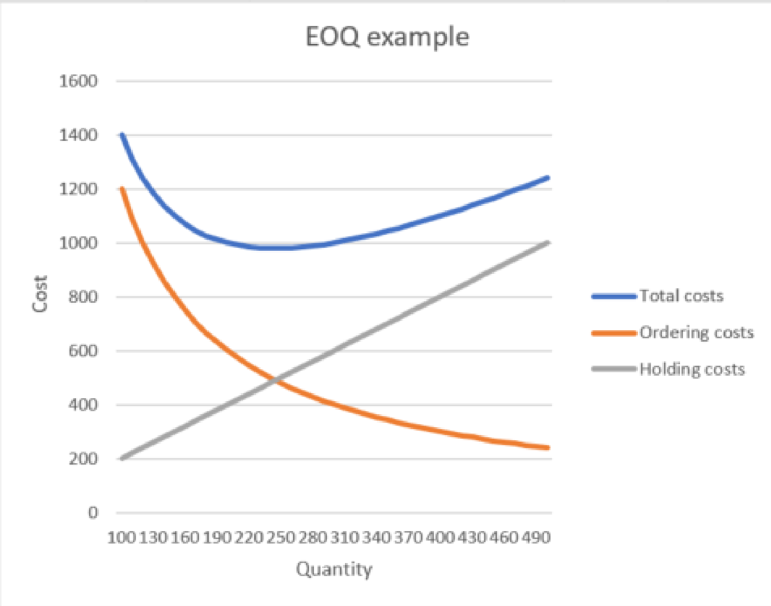
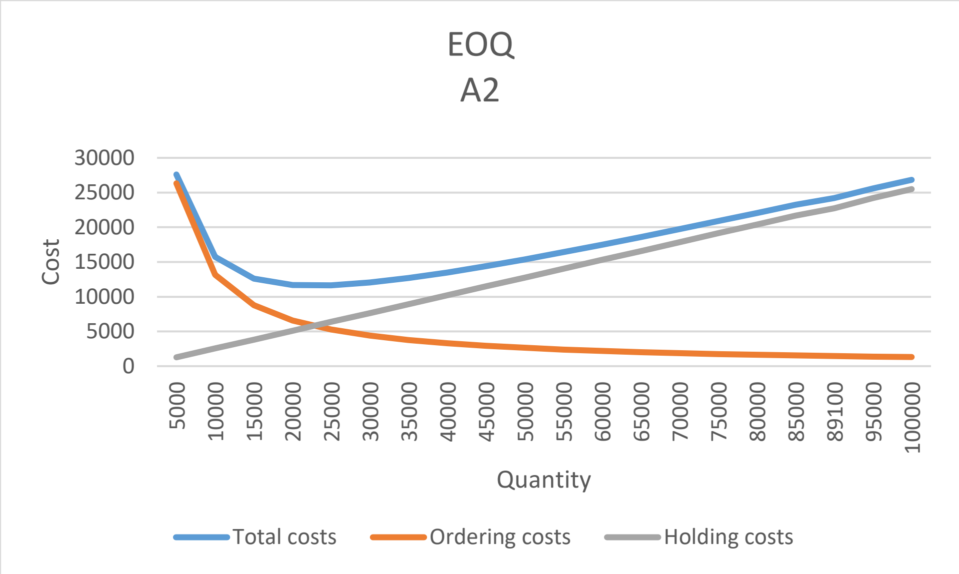
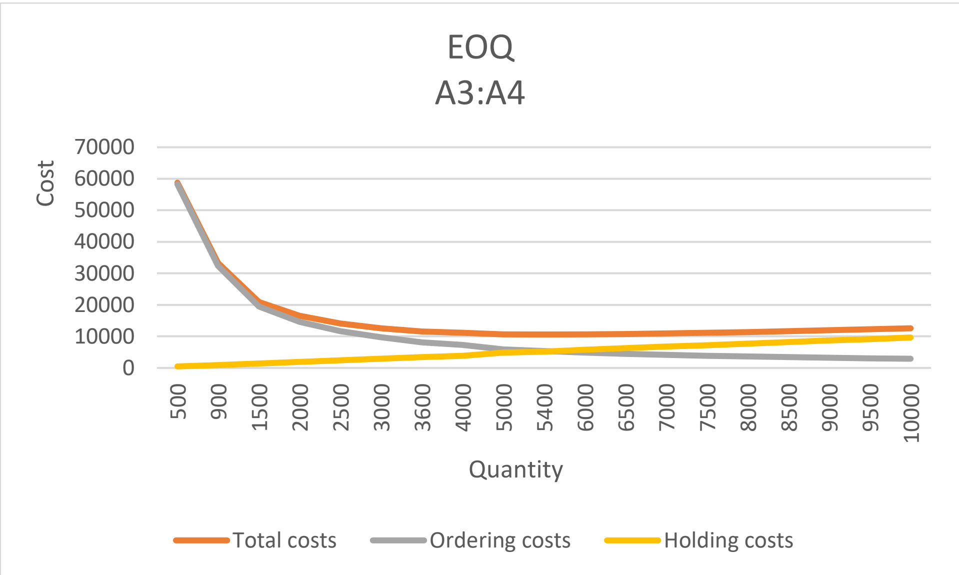
				…113	293	820
				…126	286	840
				…139	279	860
				…153	273	880

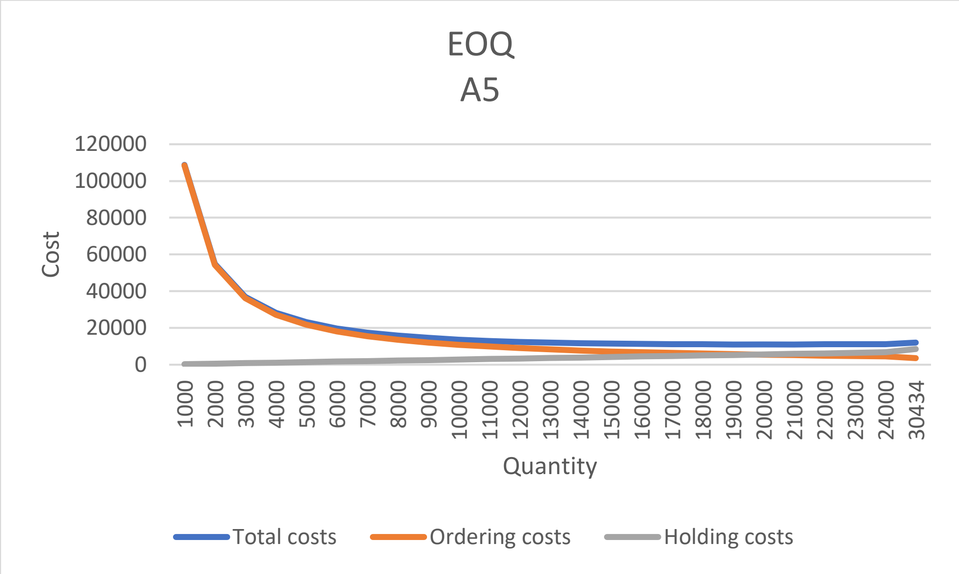


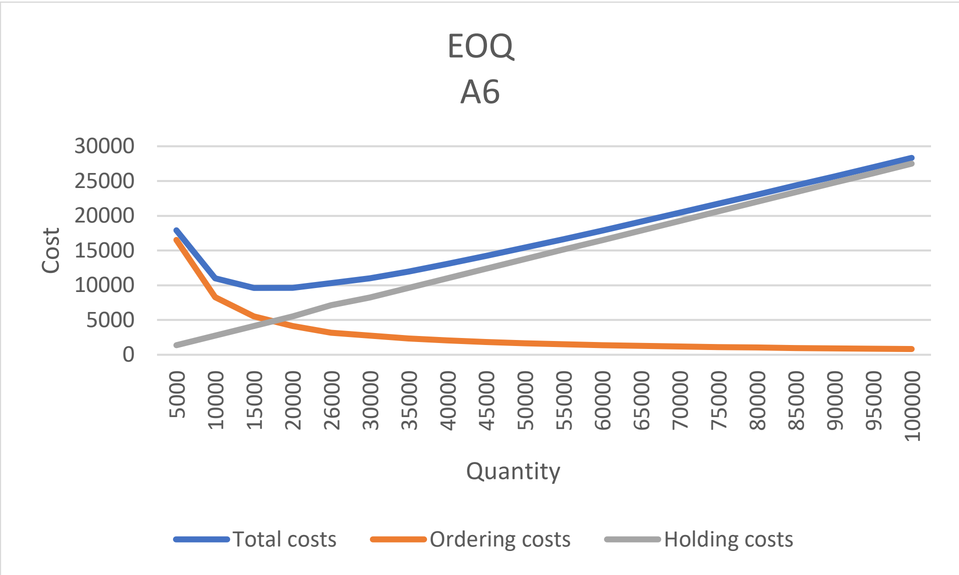
Appendix 2. Materials A2 and A3 EOQ



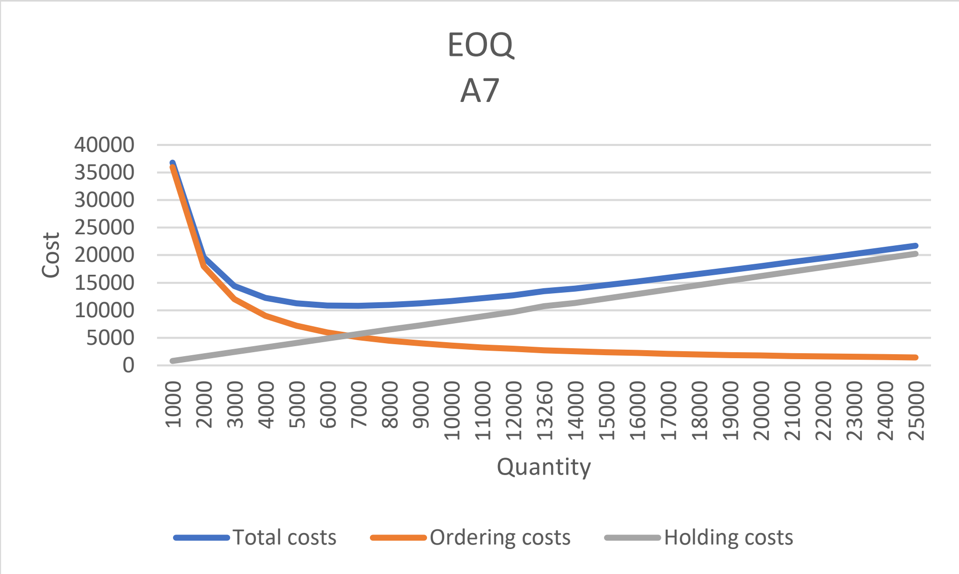


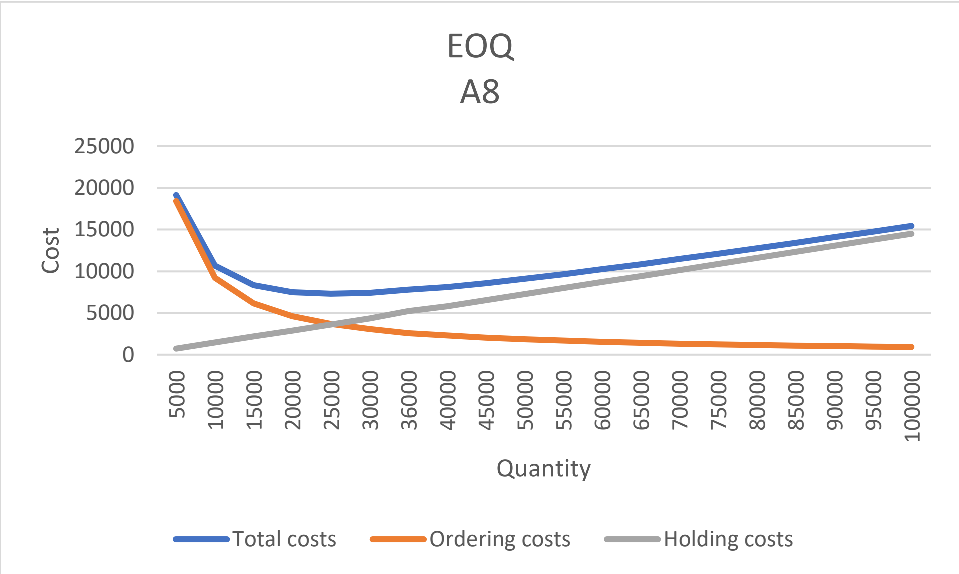
Appendix 3. Materials A5 and A6 EOQ



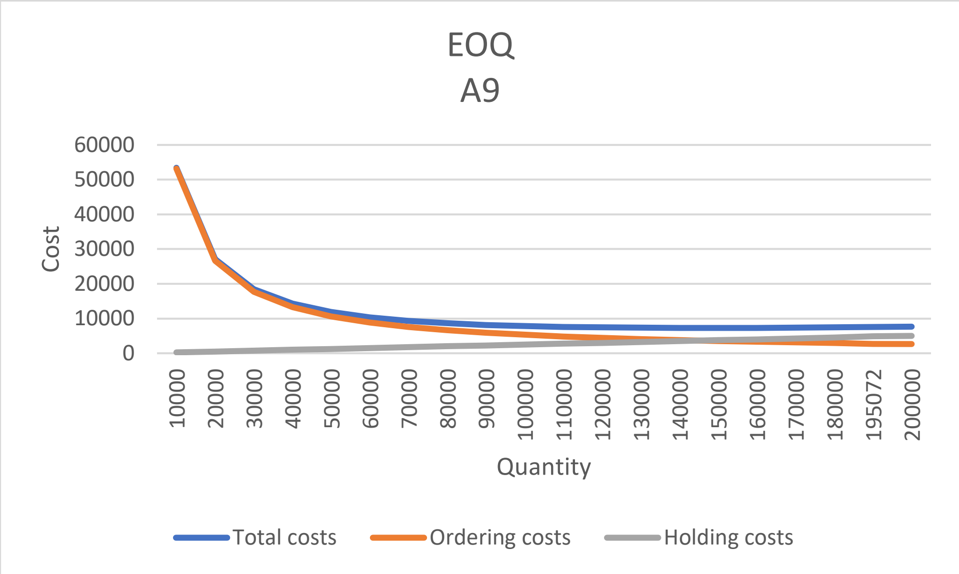


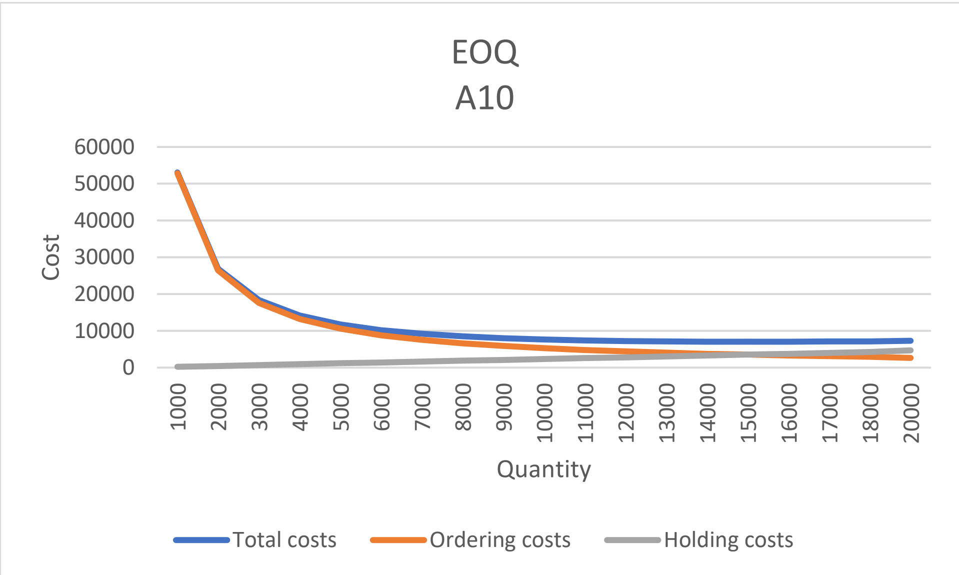
Appendix 4. Materials A7 and A8 EOQ



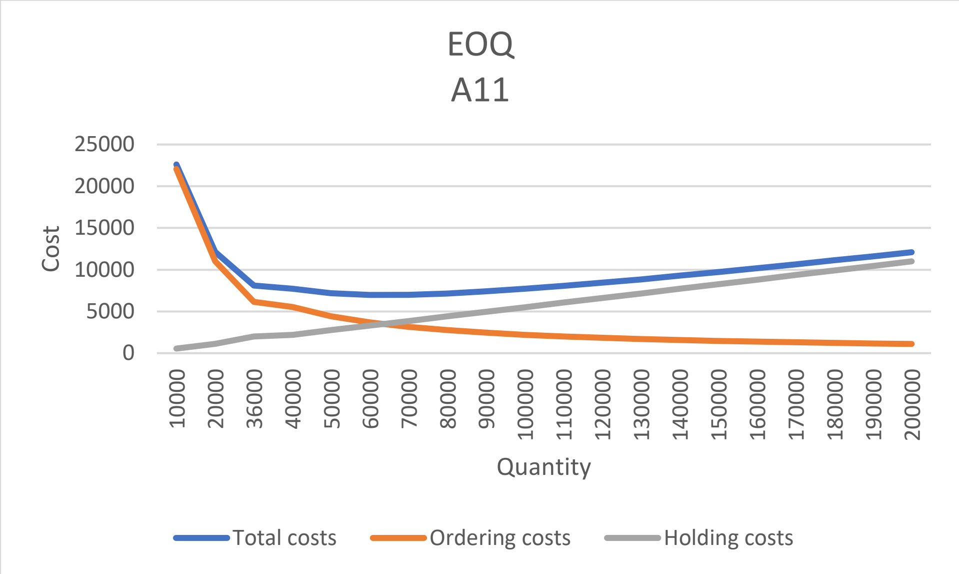


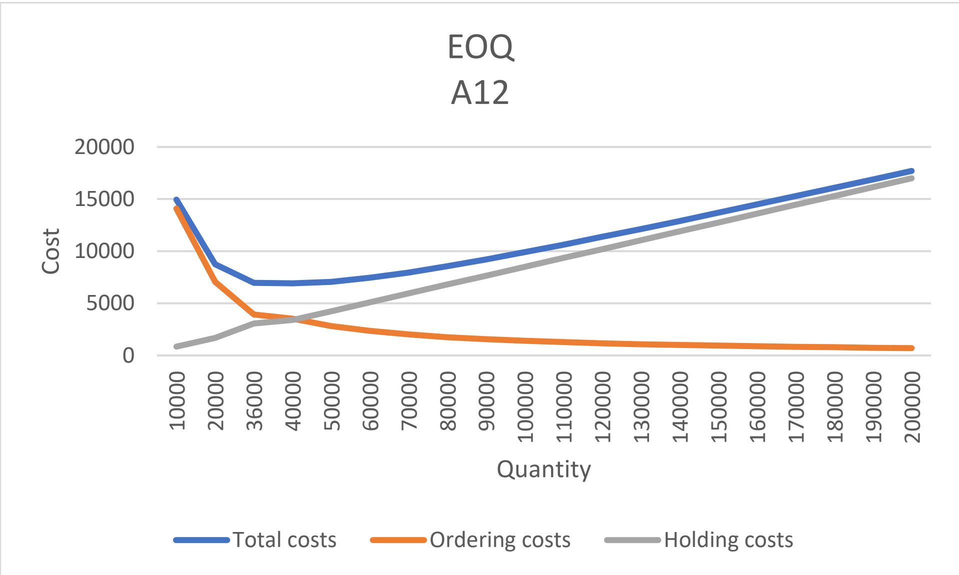
Appendix 5. Materials A9 and A10 EOQ



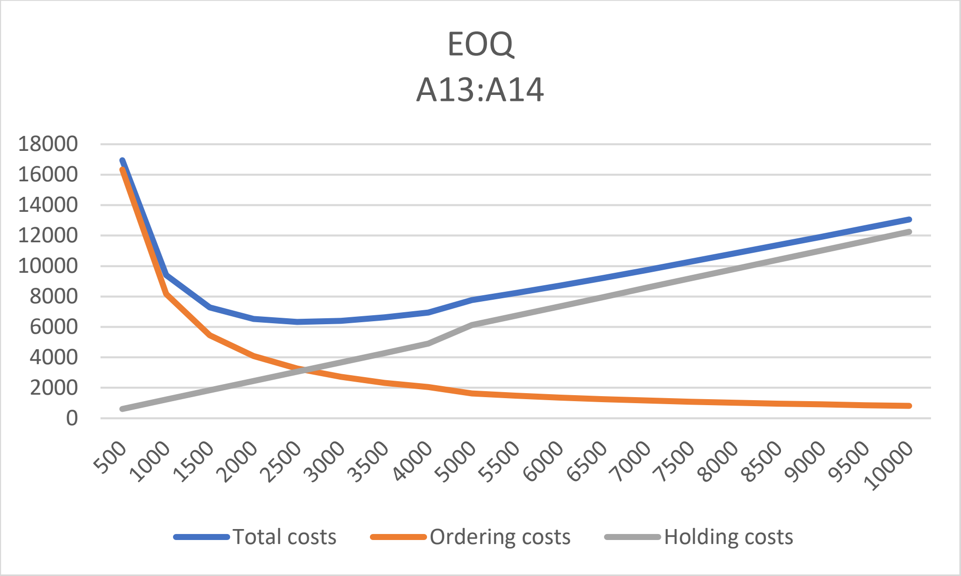


Appendix 6. Materials A11 and A12 EOQ

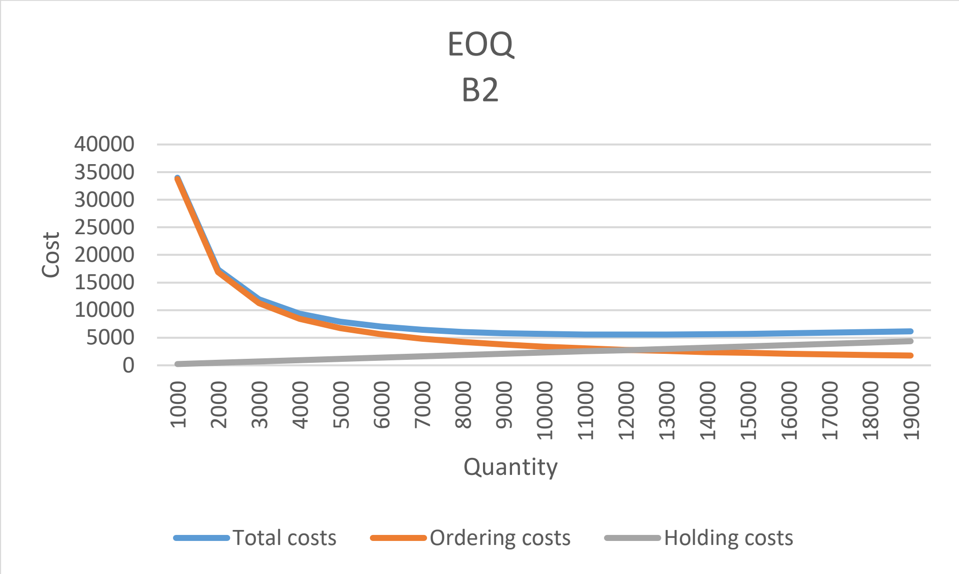


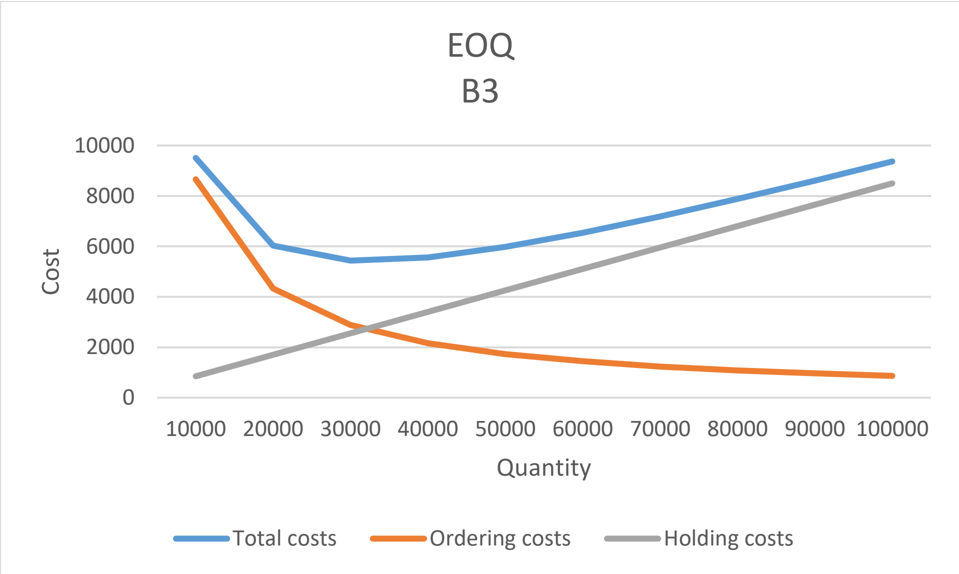


Appendix 7. Materials A13 and A14 EOQ

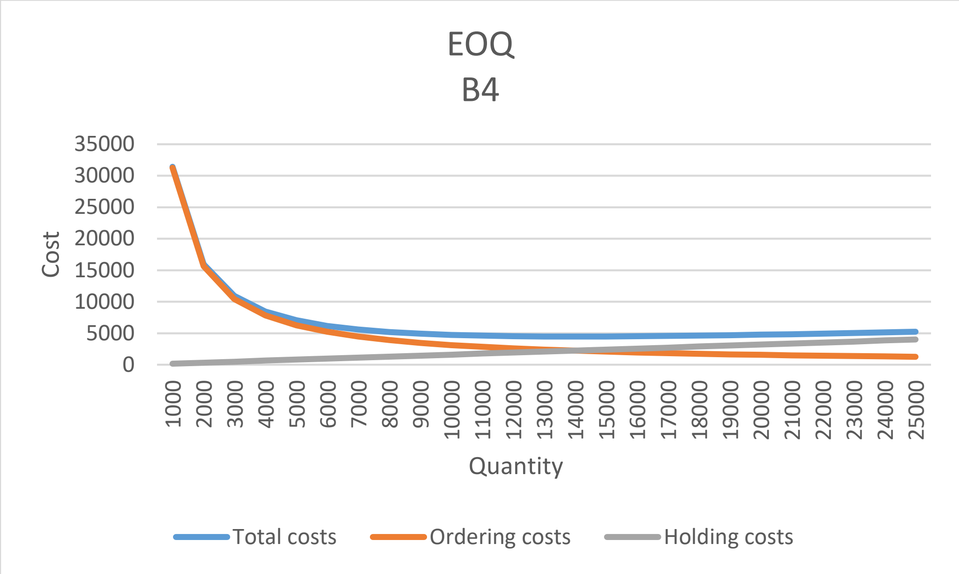


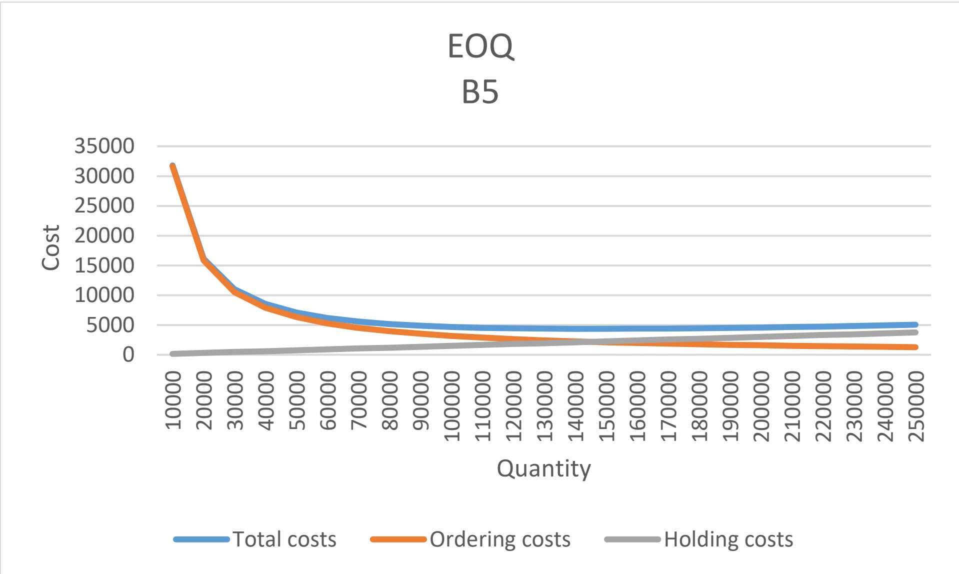
Appendix 8. Materials B2 and B3 EOQ

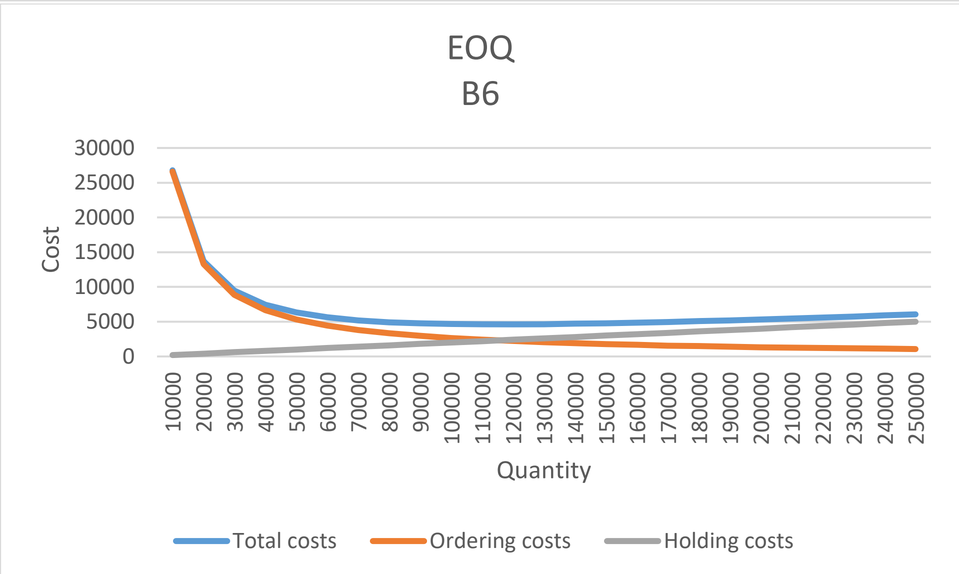




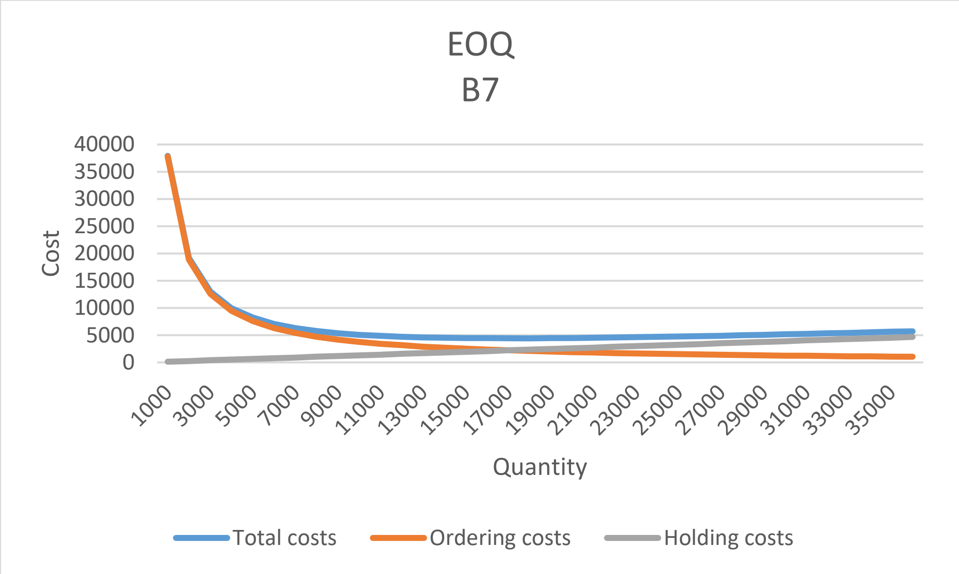
Appendix 9. Materials B4, B5 and B6 EOQ

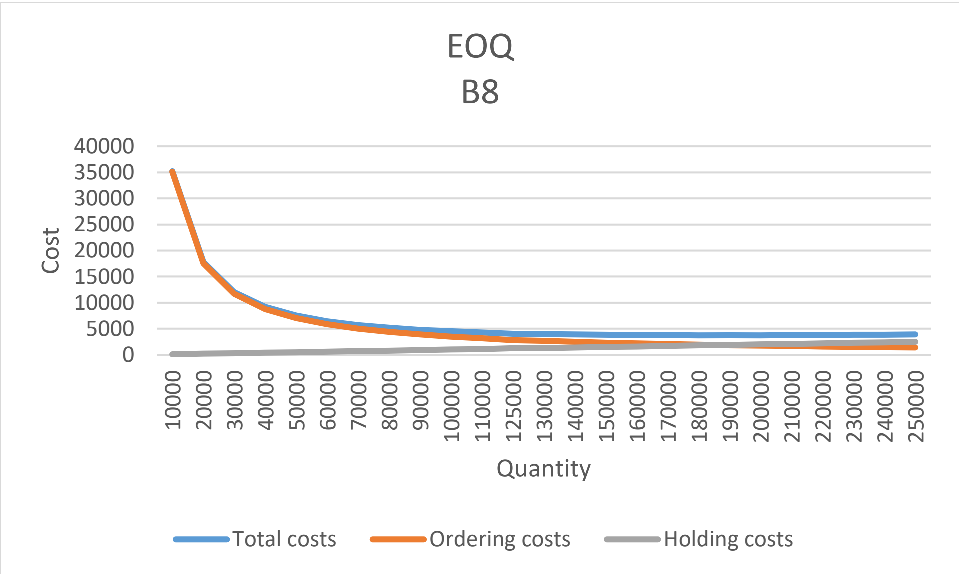


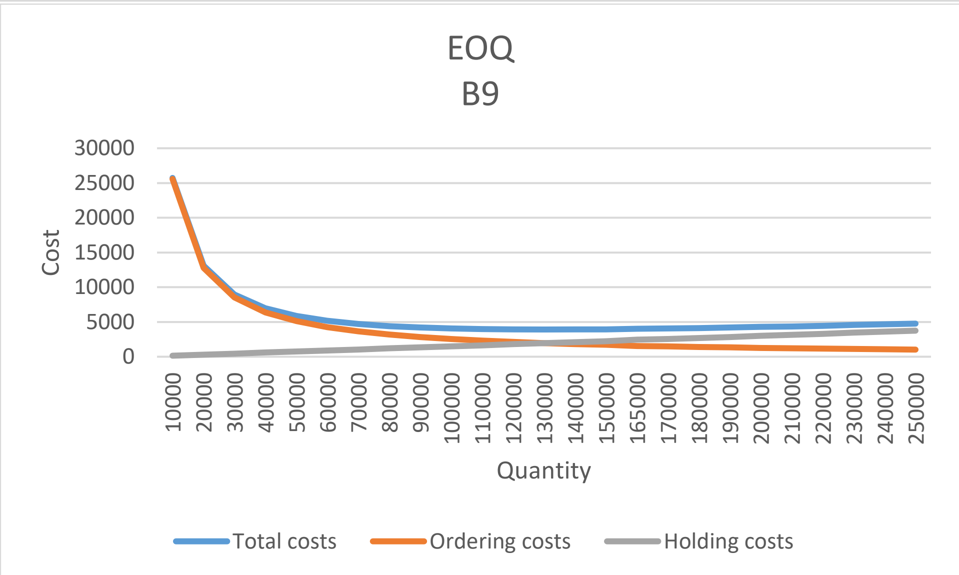




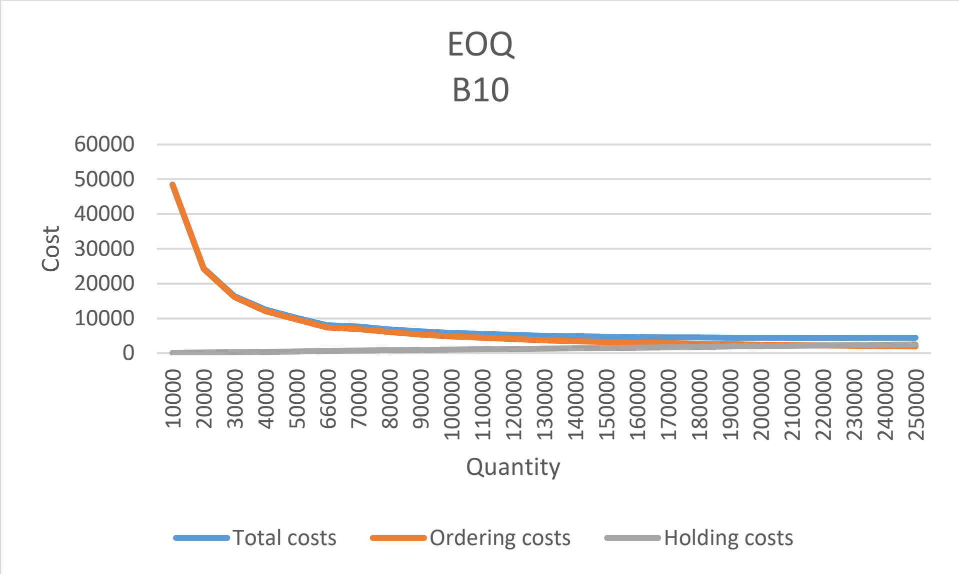
Appendix 10. Materials B7, B8 and B9 EOQ

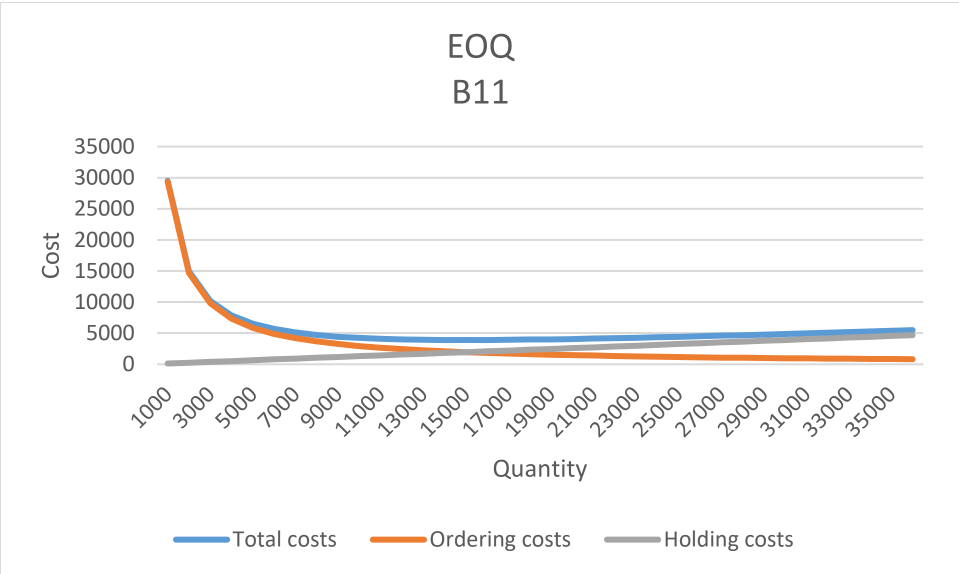


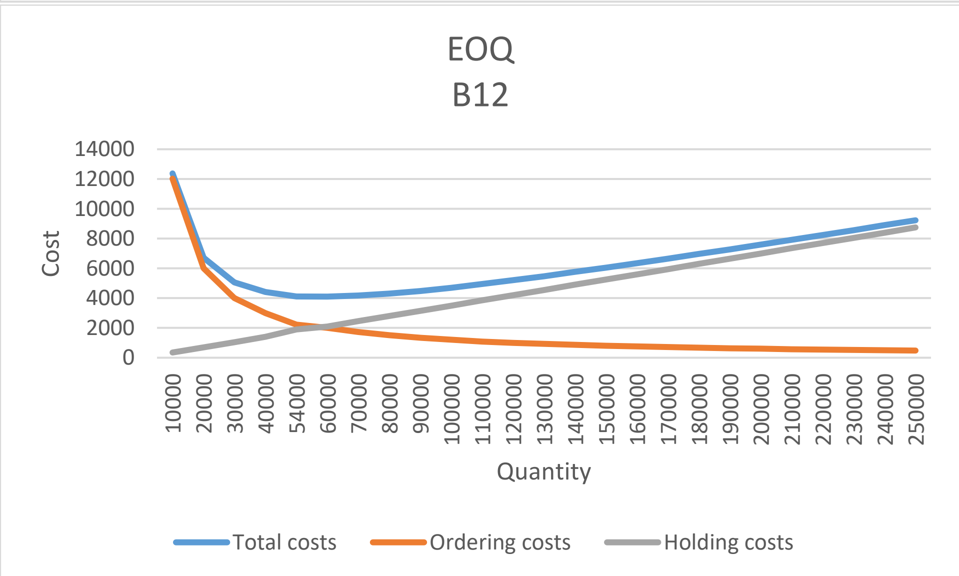




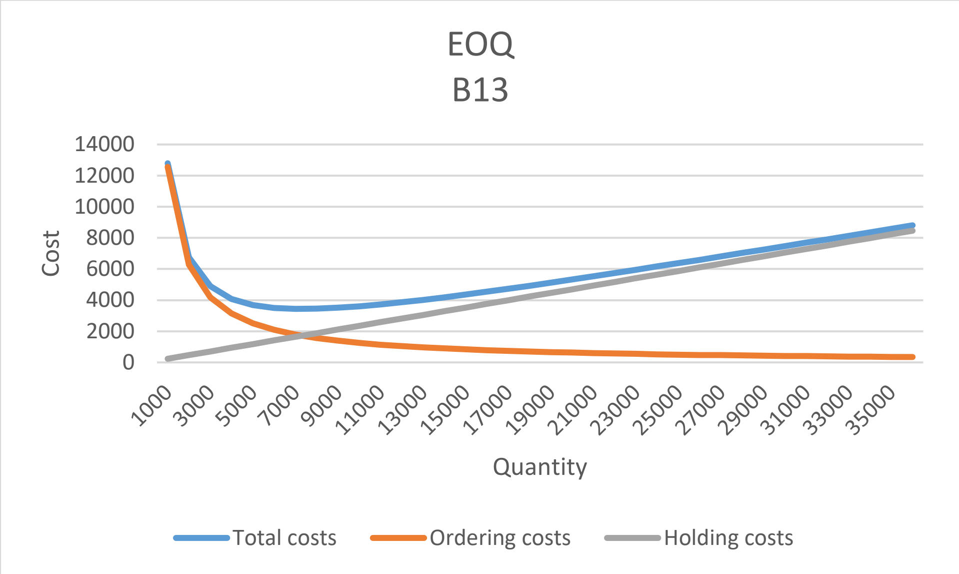
Appendix 11. Materials B10, B11 and B12 EOQ

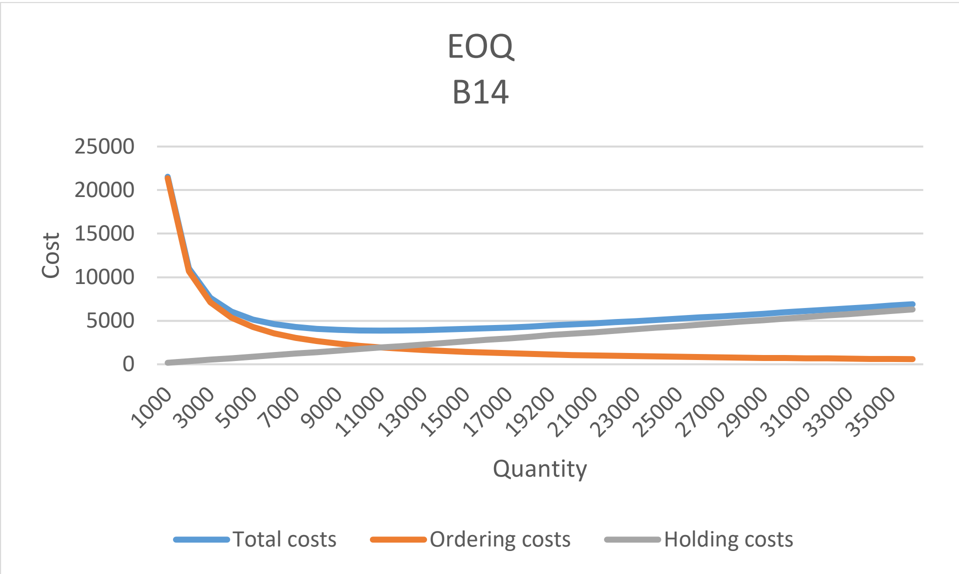


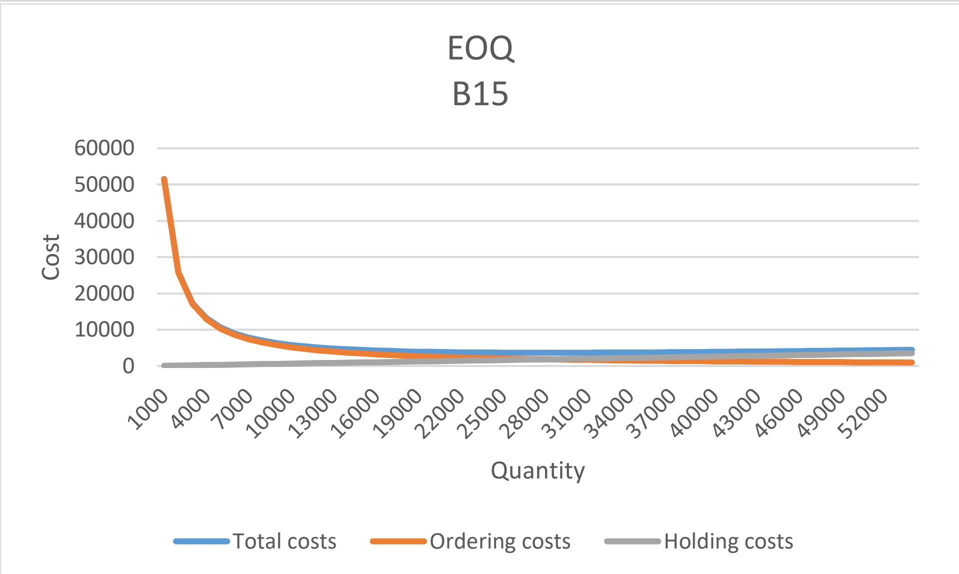




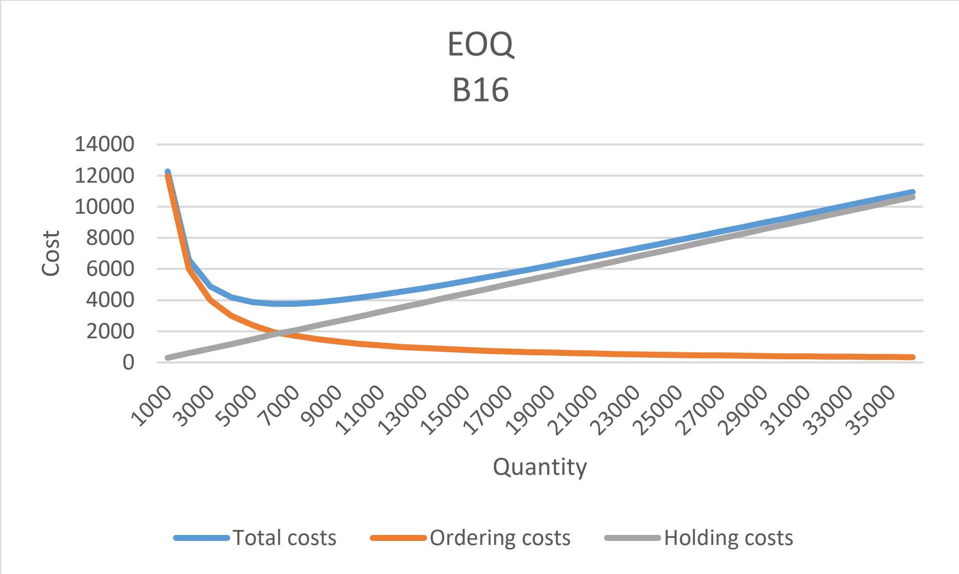
Appendix 12. Materials B13, B14 and B15 EOQ

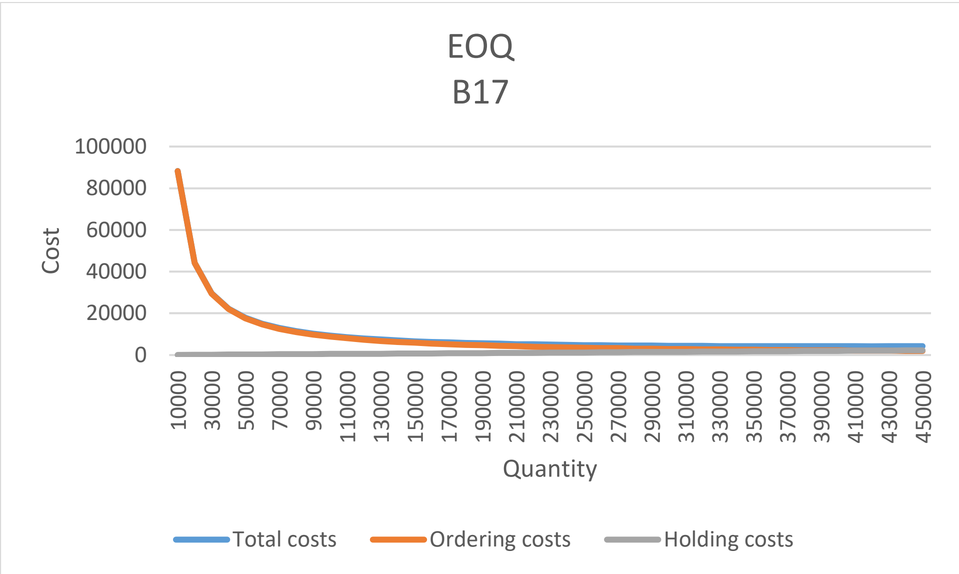


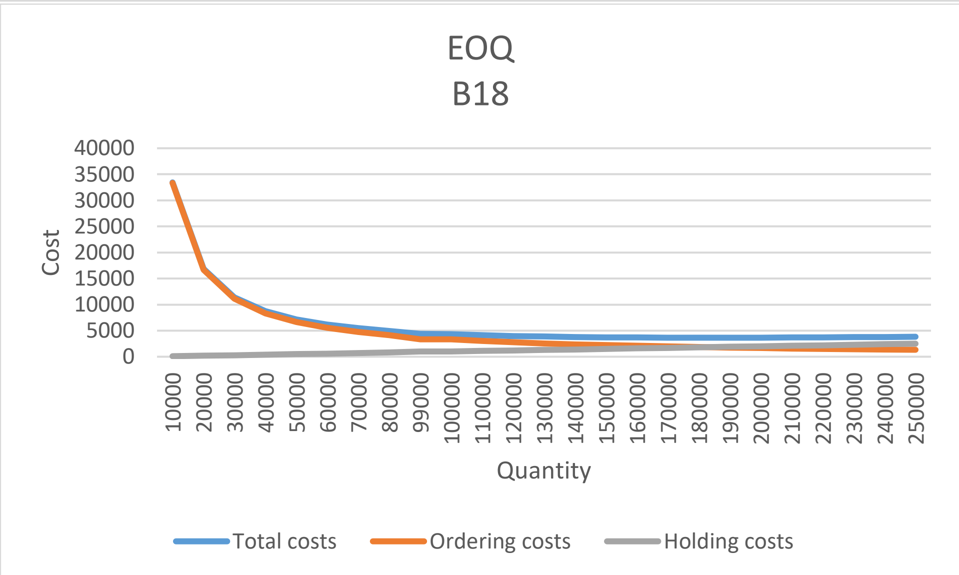




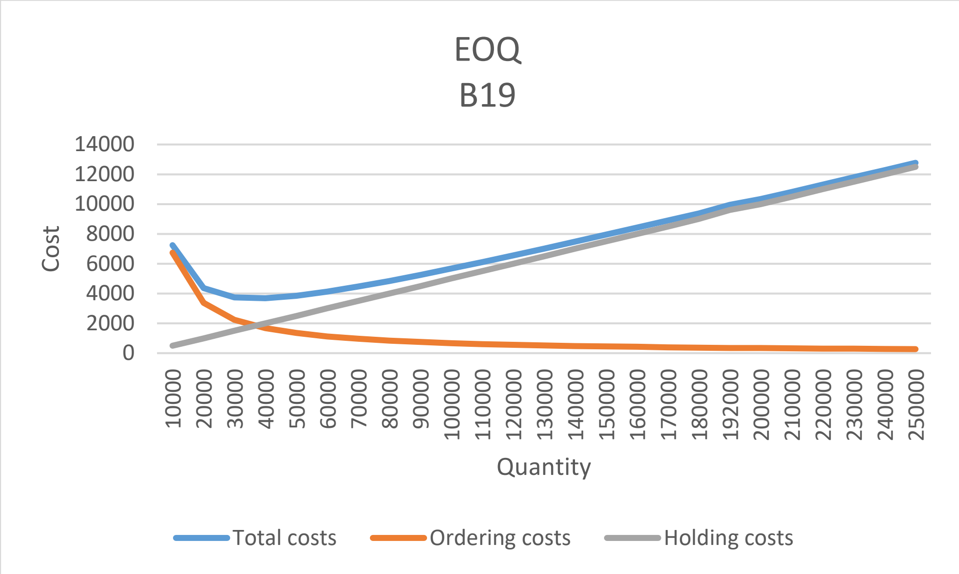
Appendix 13. Materials B16, B17 and B18 EOQ

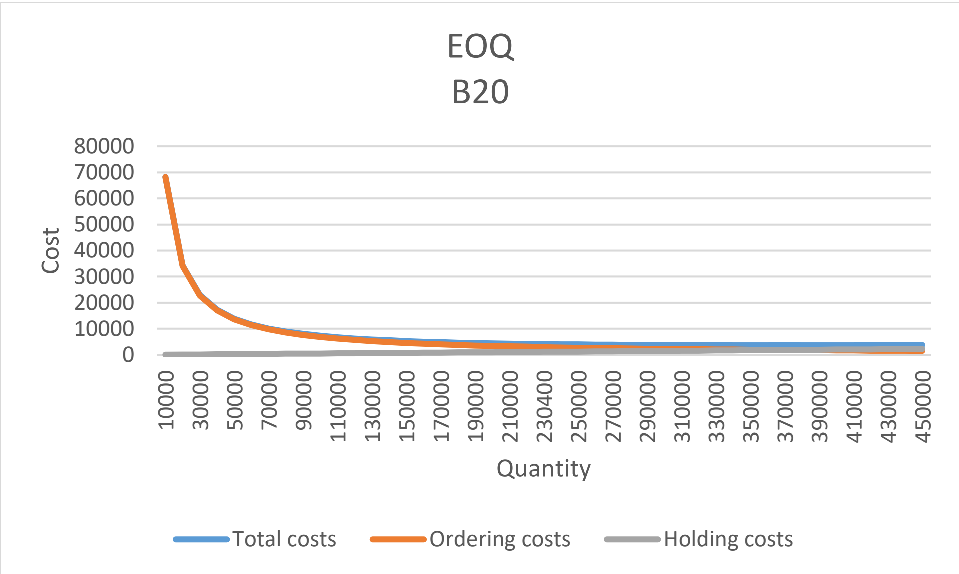


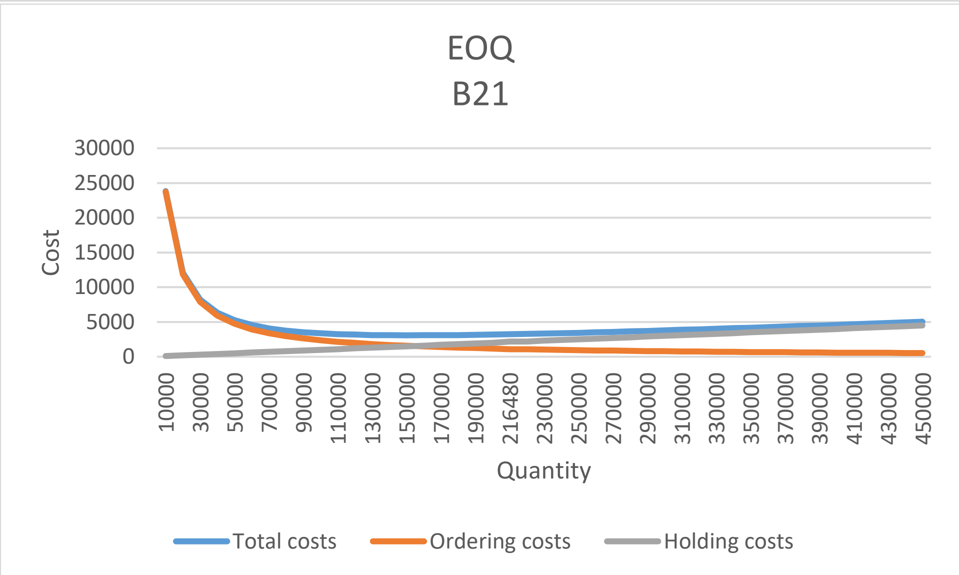




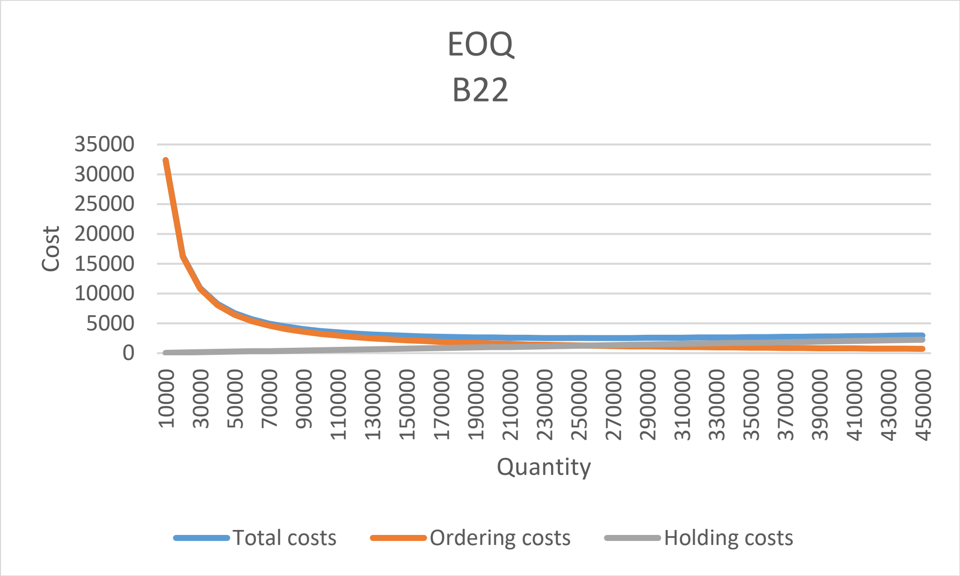
Appendix 14. Materials B19, B20 and B21 EOQ

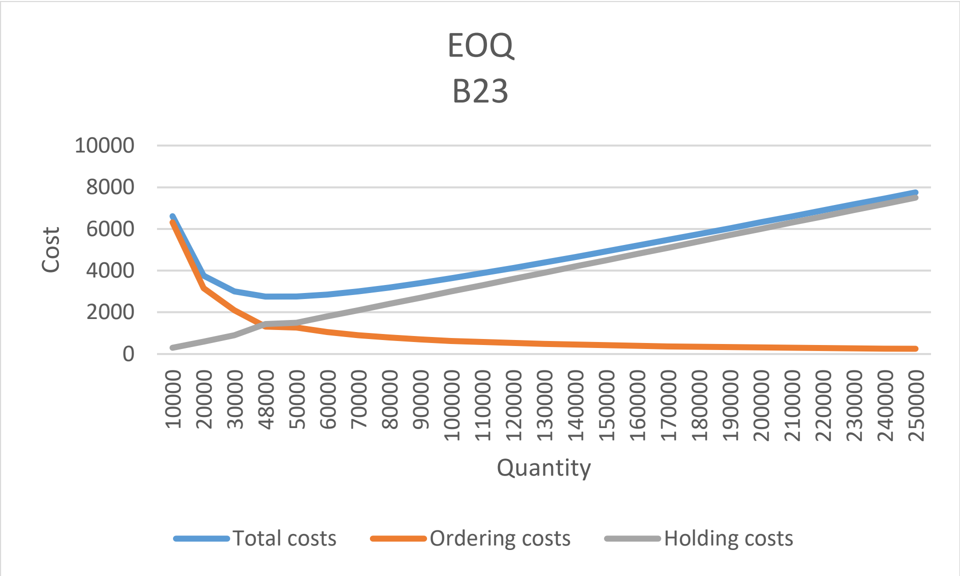


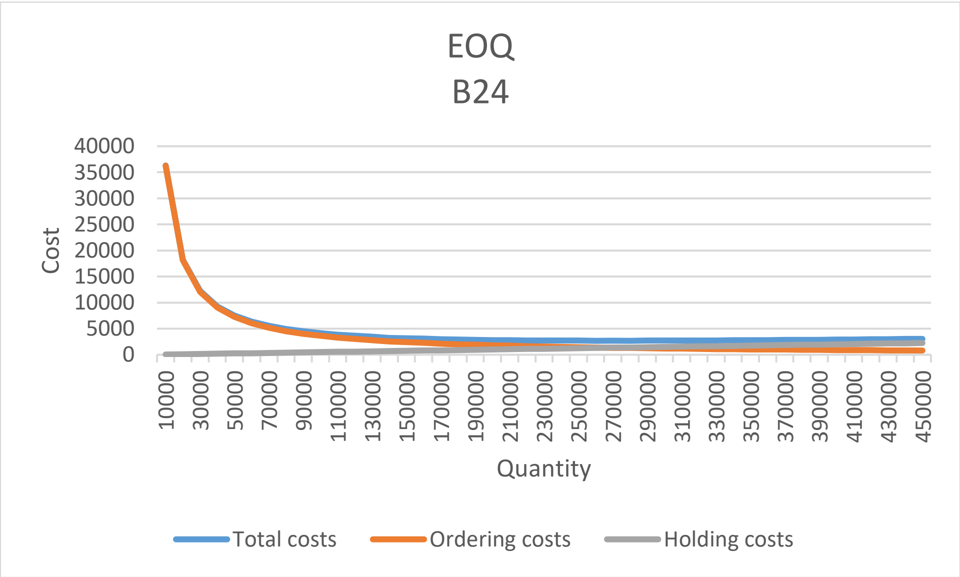




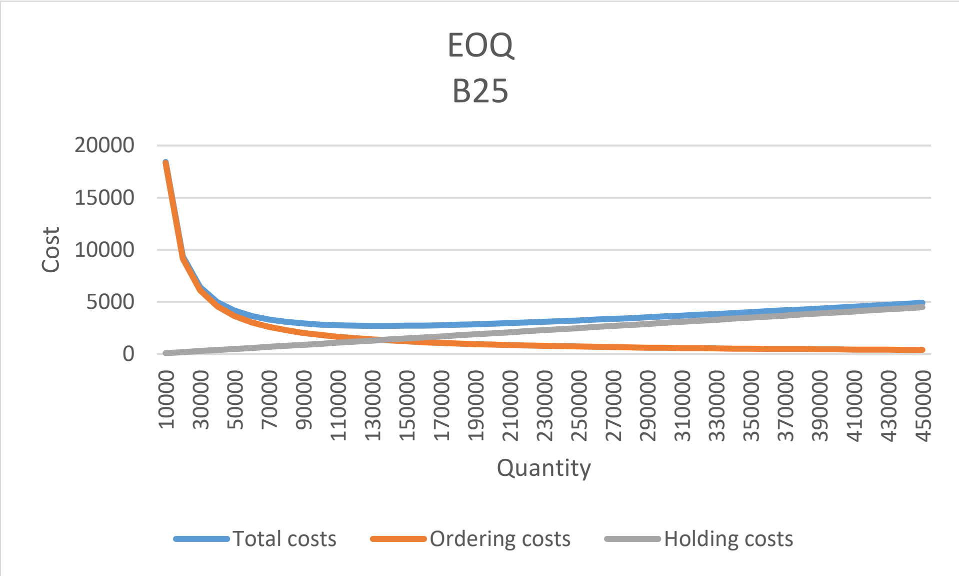
Appendix 14. Materials B22, B23 and B24 EOQ



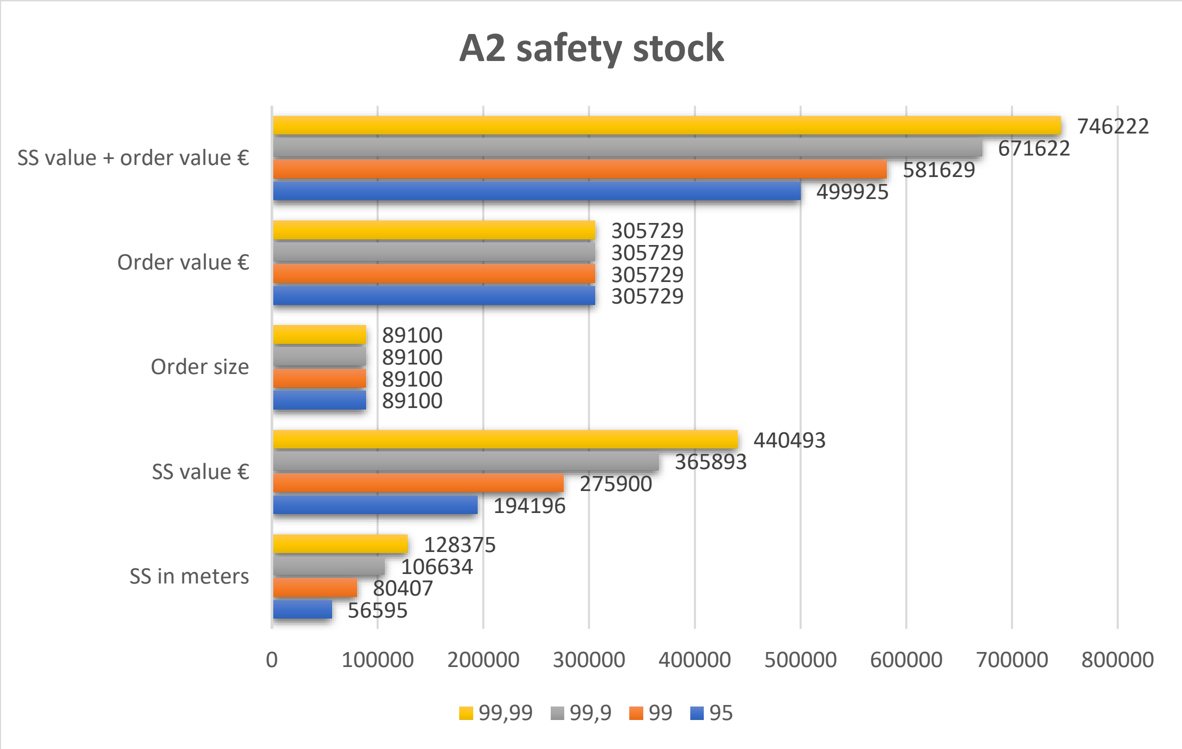


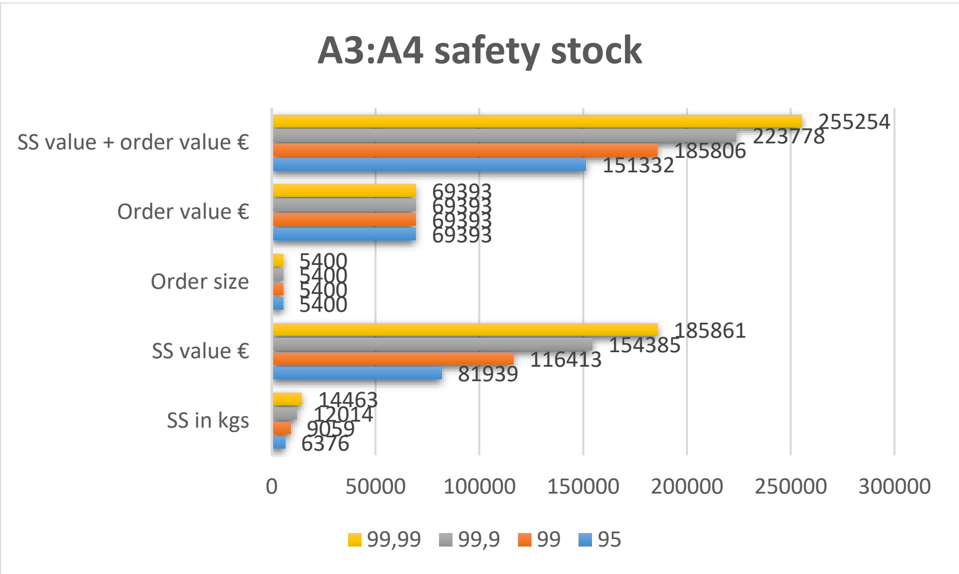


Appendix 15. Materials B25 EOQ

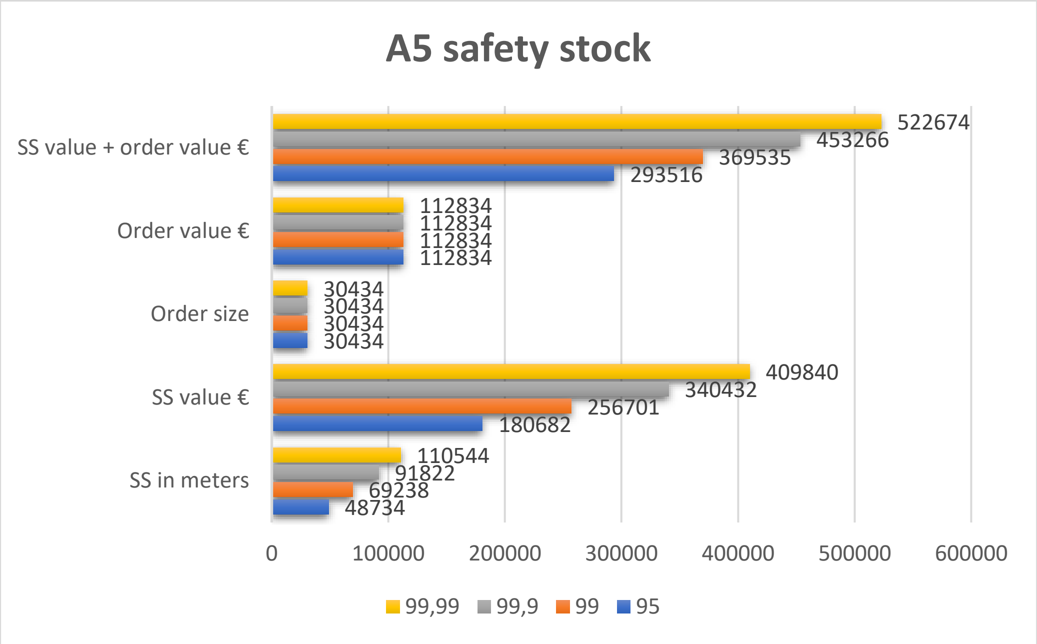


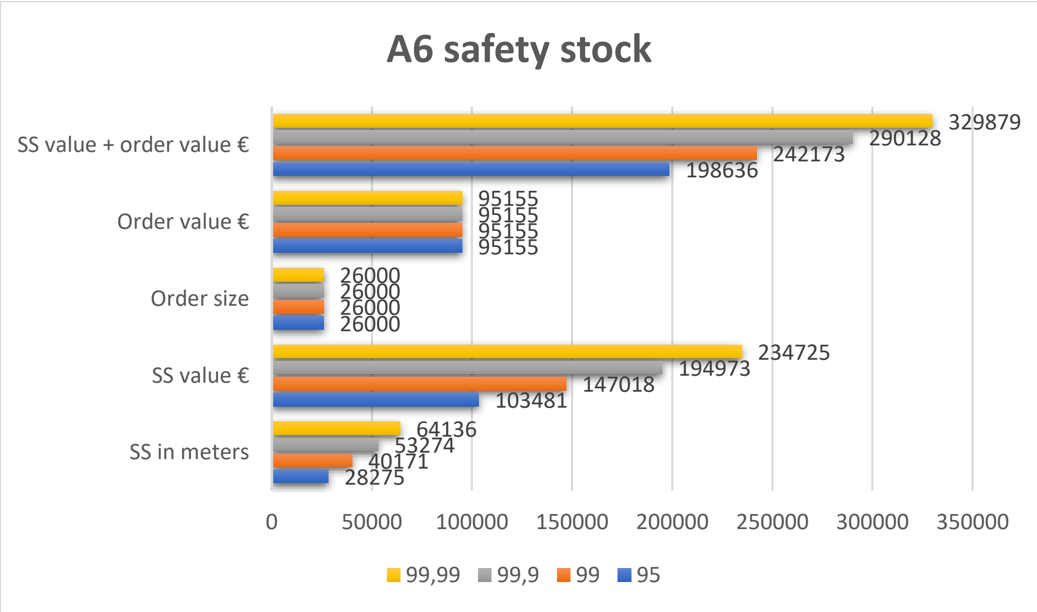
Appendix 16. maximum inventory value of material A2 and A3 for desired service level



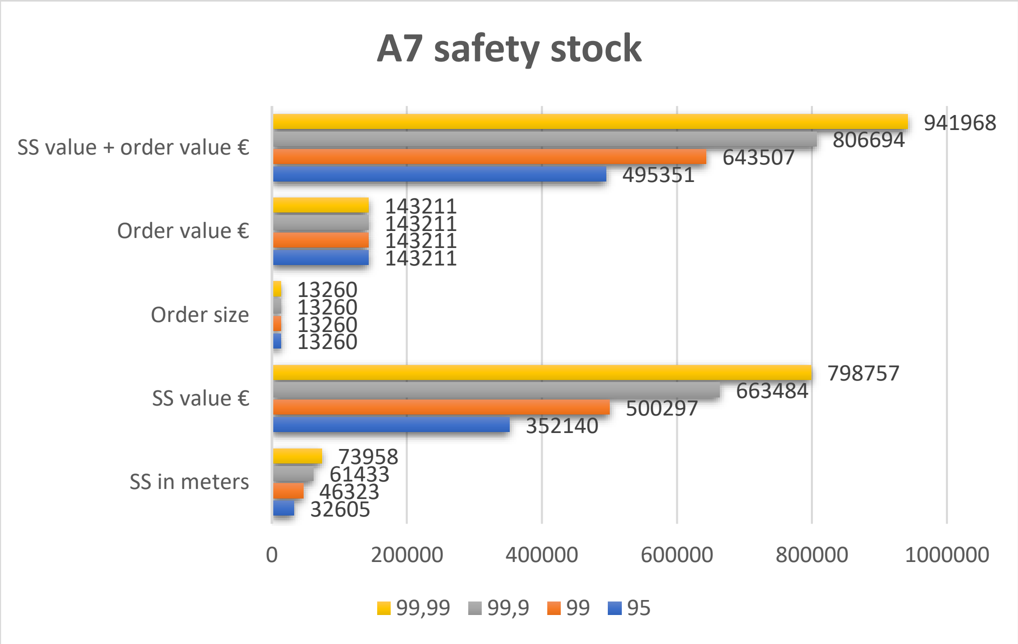


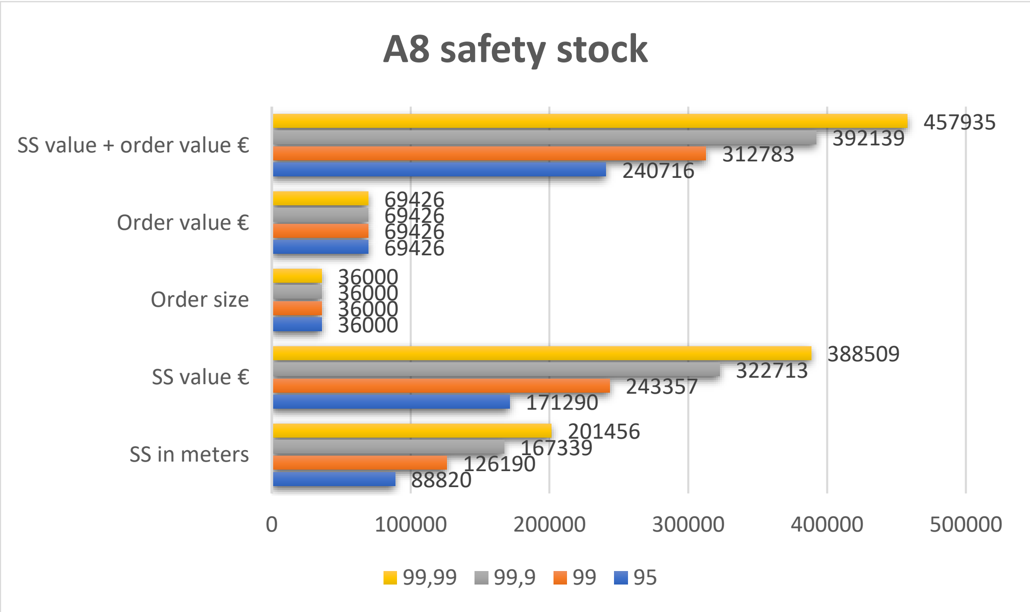
Appendix 17. maximum inventory value of material A5 and A6 for desired service level



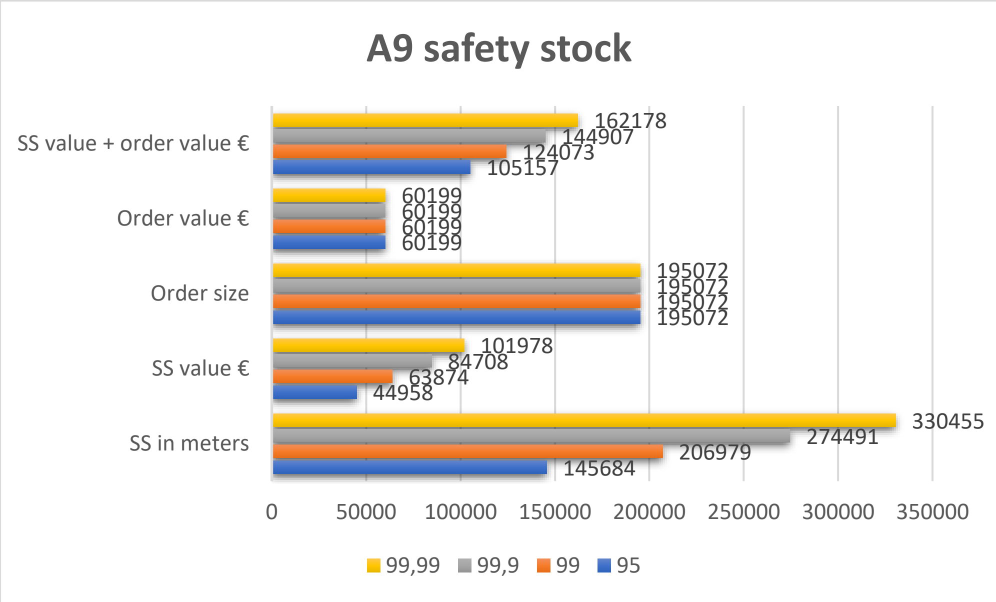


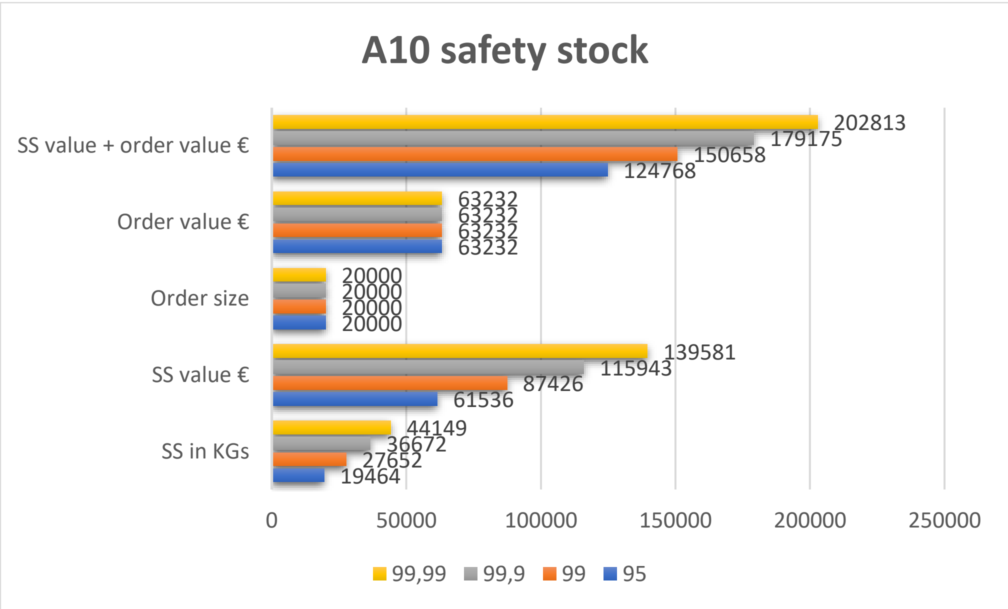
Appendix 18. maximum inventory value of material A7 and A8 for desired service level



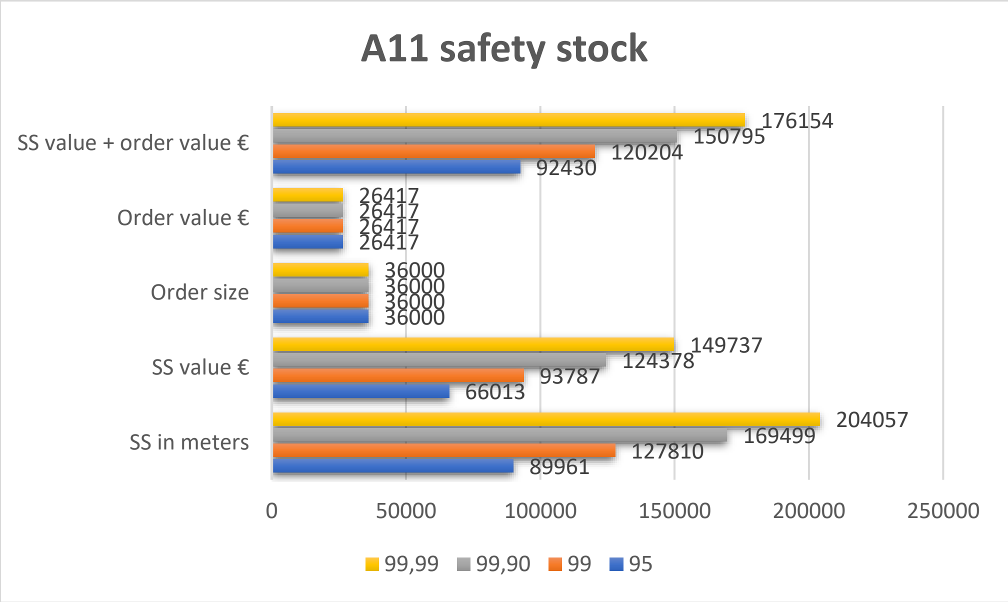


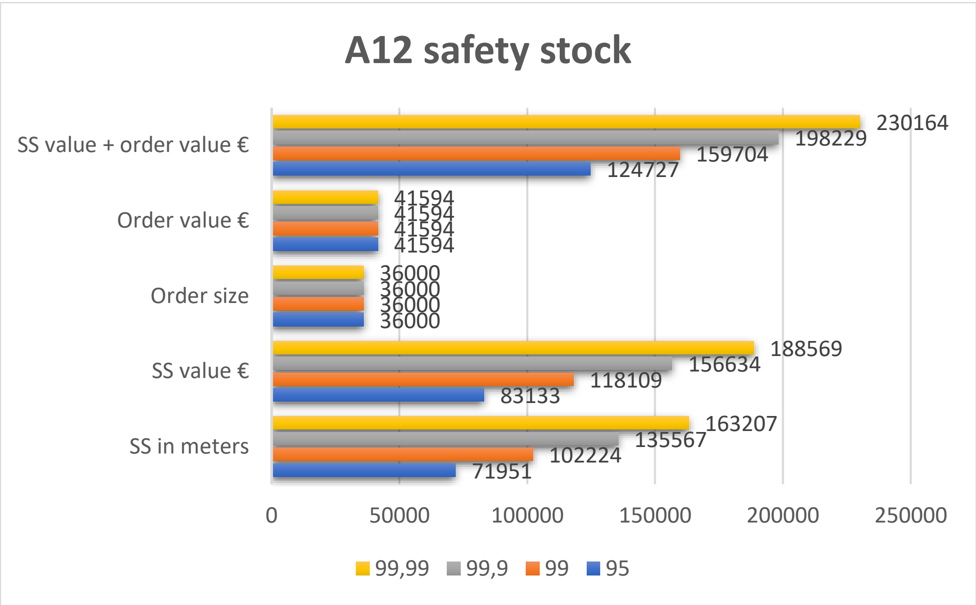
Appendix 18. maximum inventory value of material A9 and A10 for desired service level



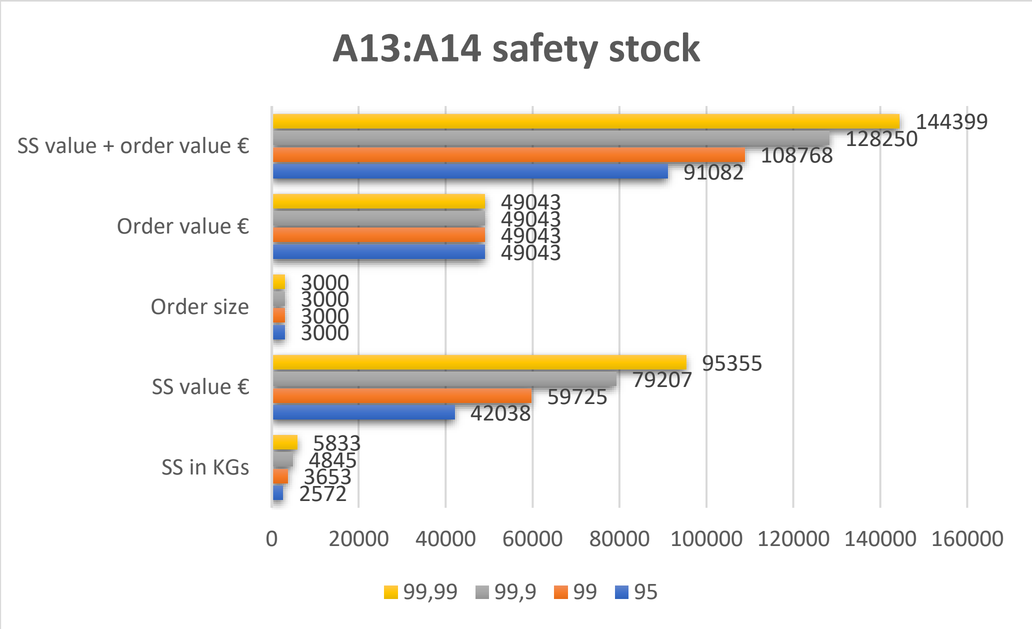


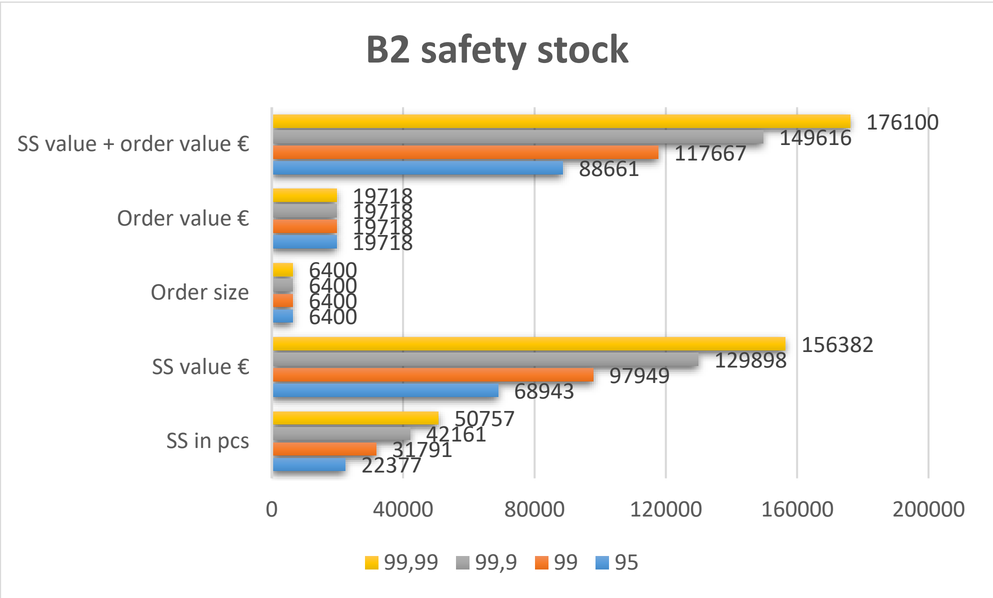
Appendix 19. maximum inventory value of material A11 and A12 for desired service level



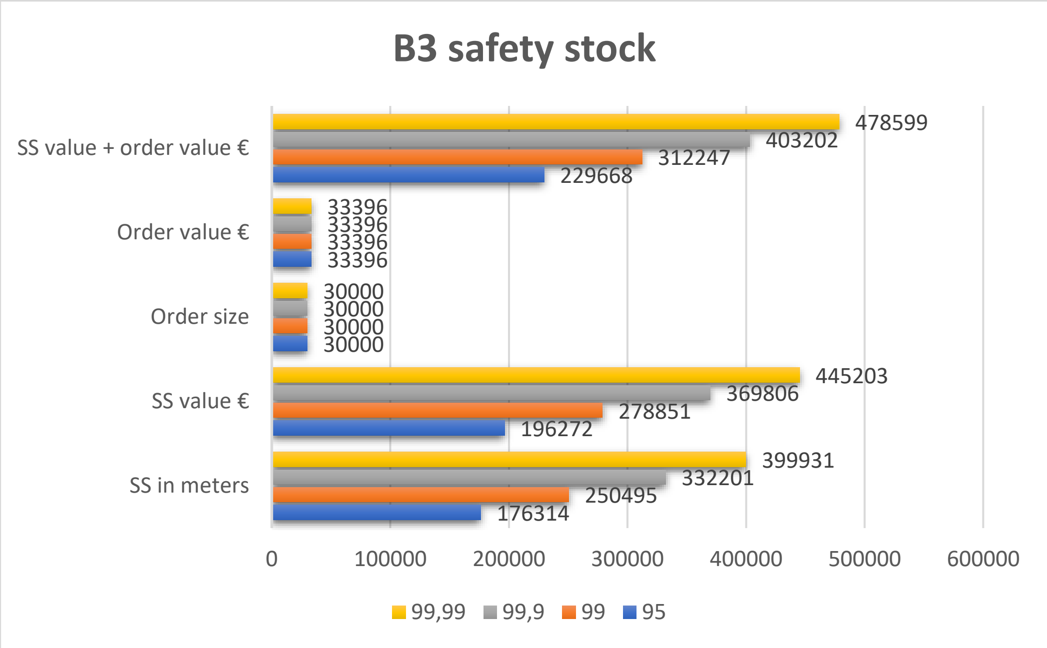


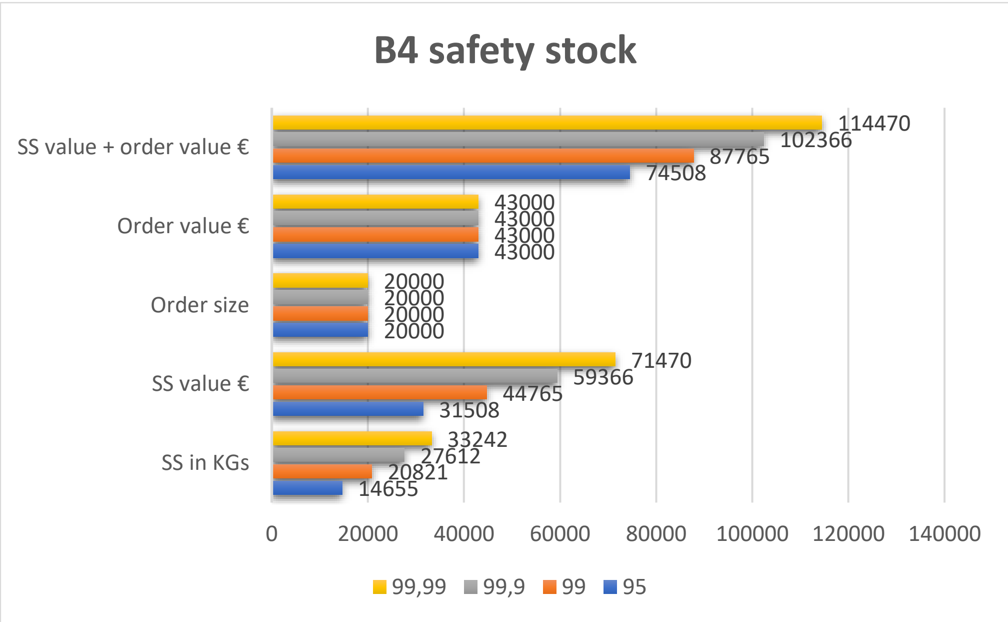
Appendix 20. maximum inventory value of material A14, A14 and B2 for desired service level



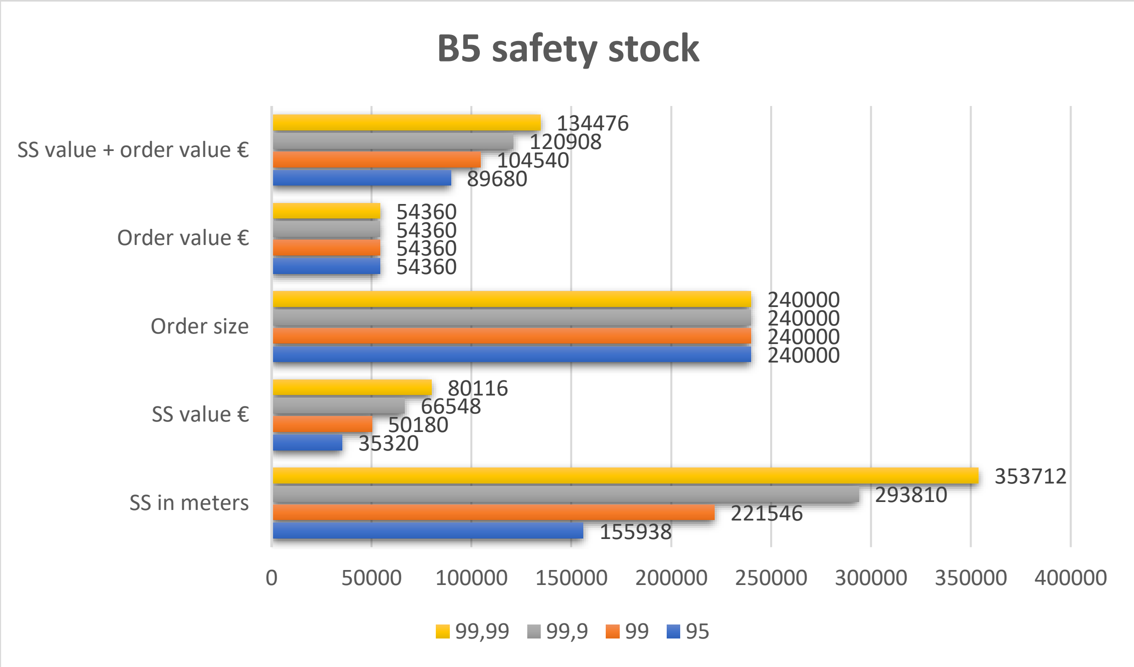


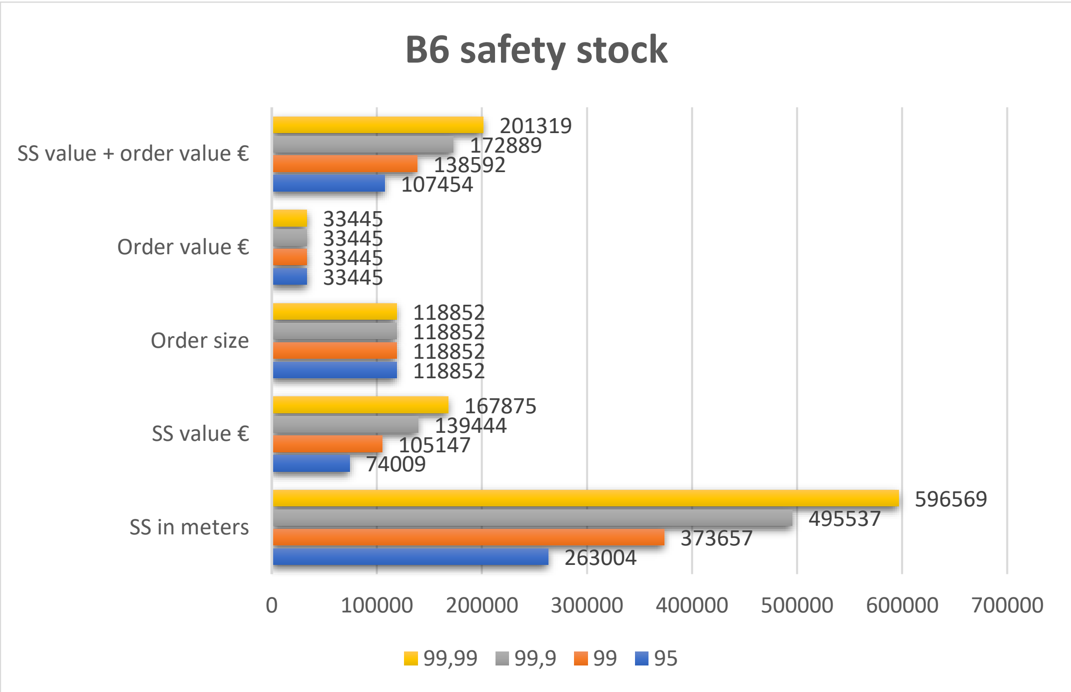
Appendix 21. maximum inventory value of material B3 and B4 for desired service level



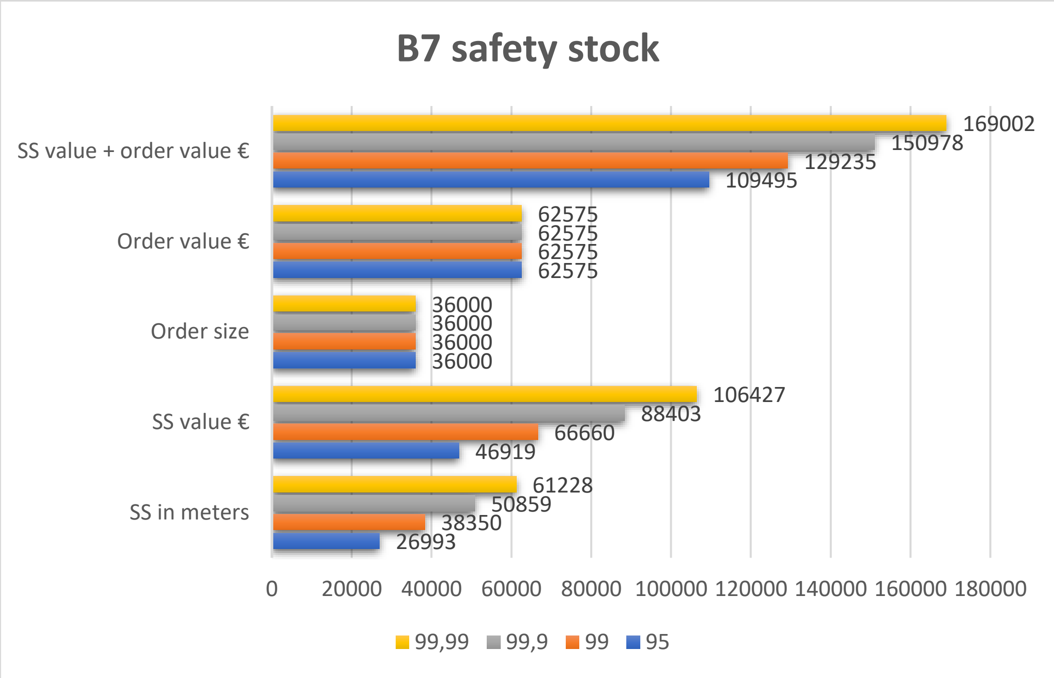


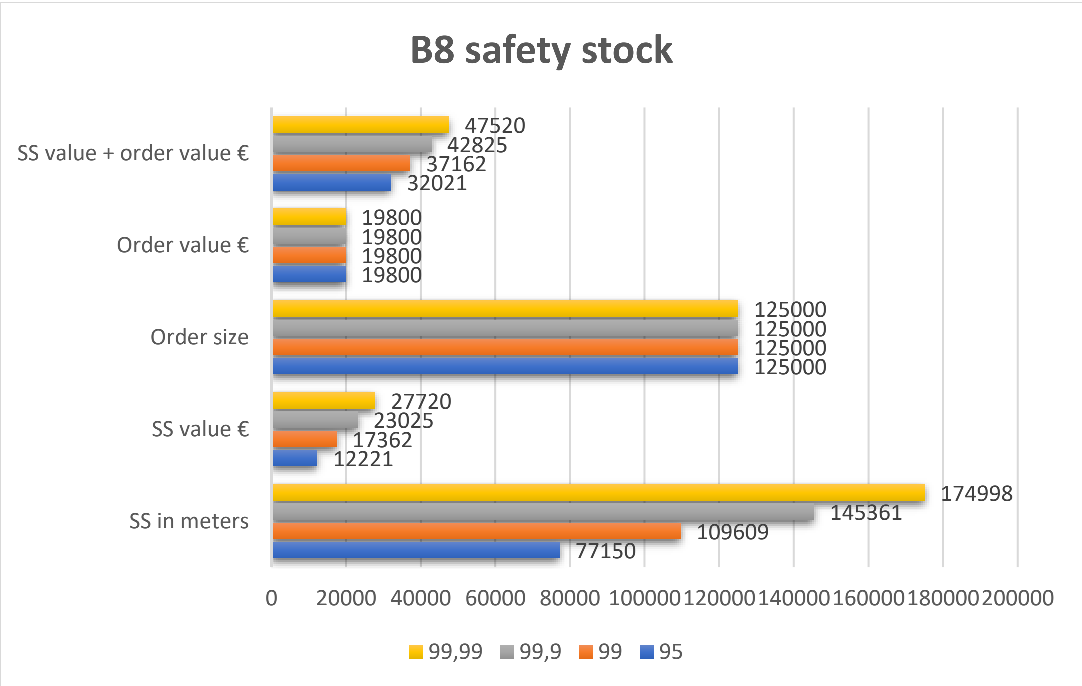
Appendix 22. maximum inventory value of material B5 and B6 for desired service level



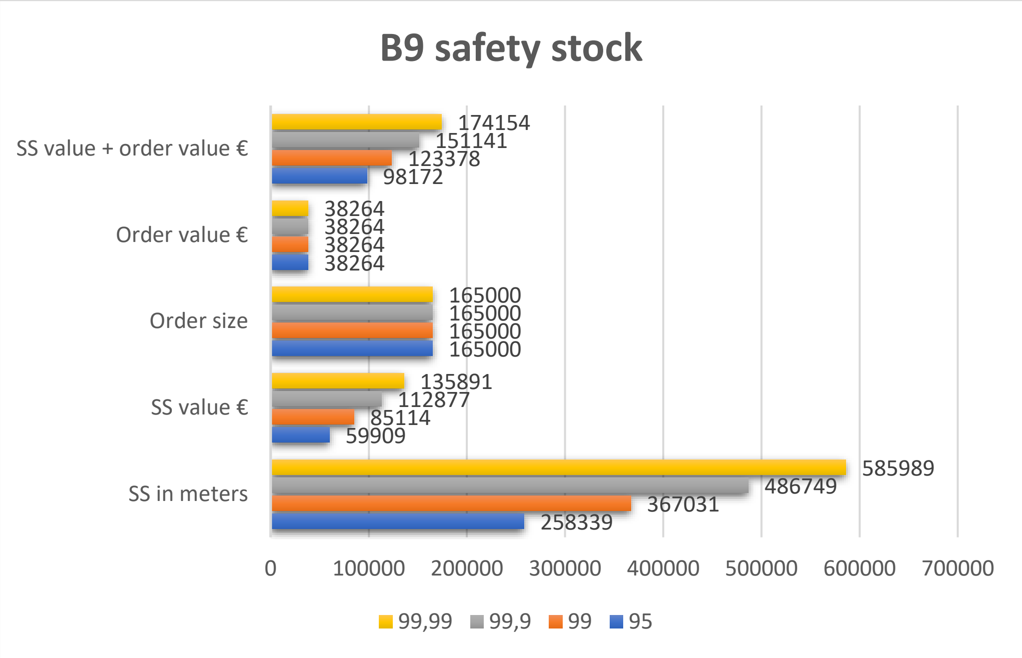


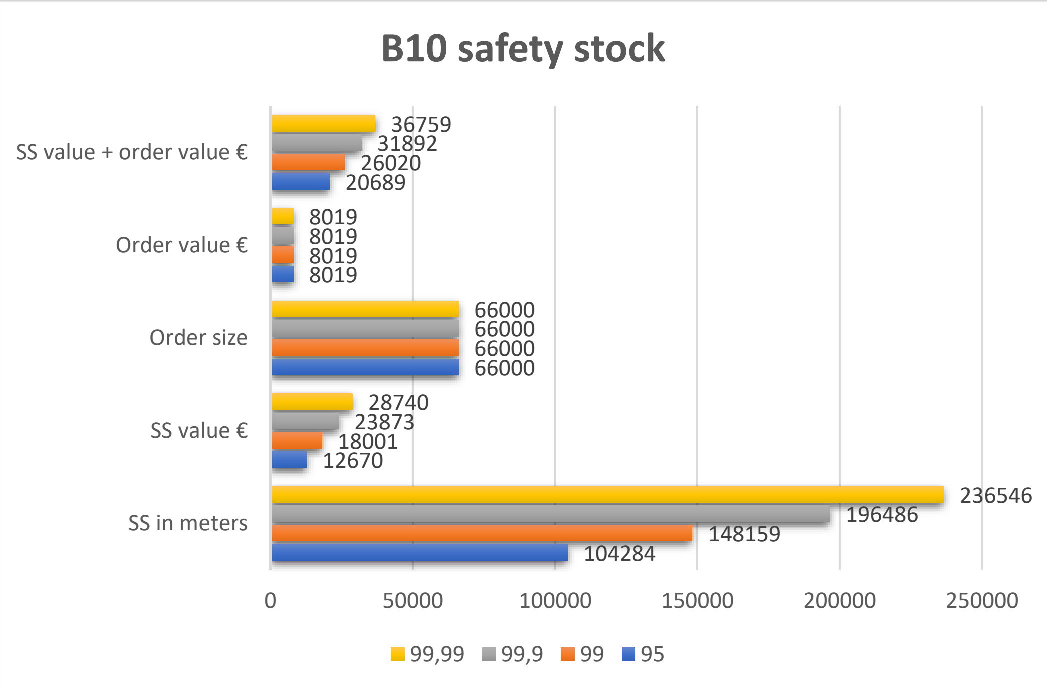
Appendix 23. maximum inventory value of material B7 and B8 for desired service level



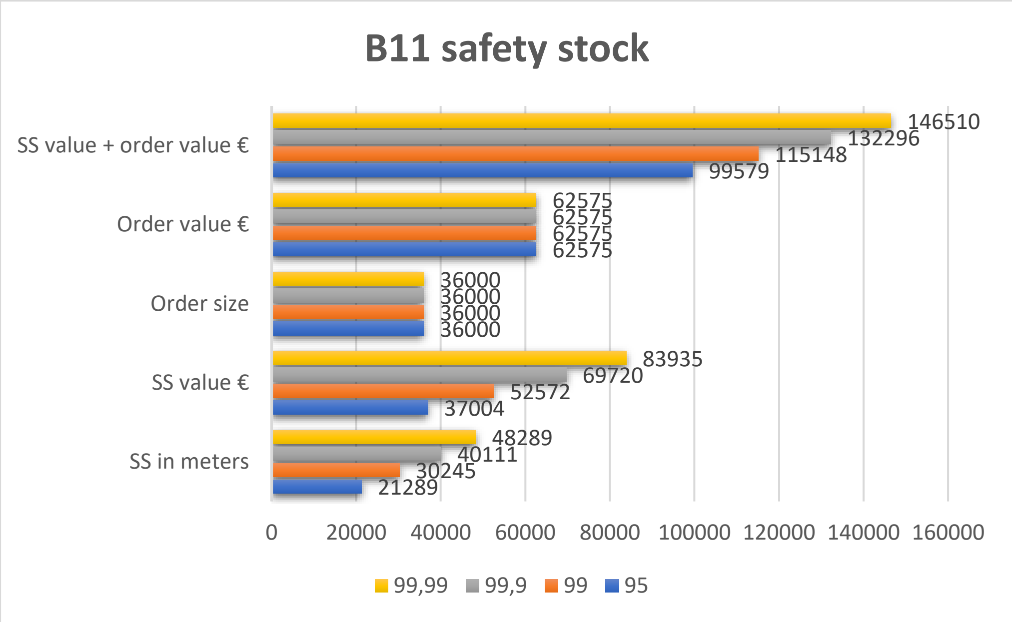


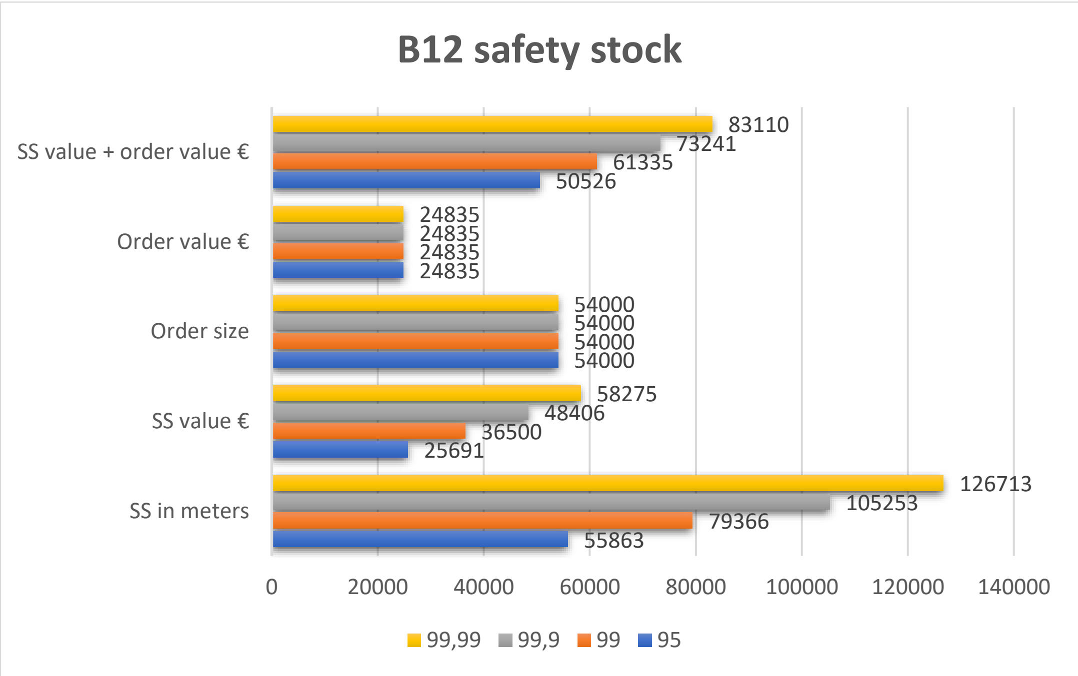
Appendix 24. maximum inventory value of material B9 and B10 for desired service level



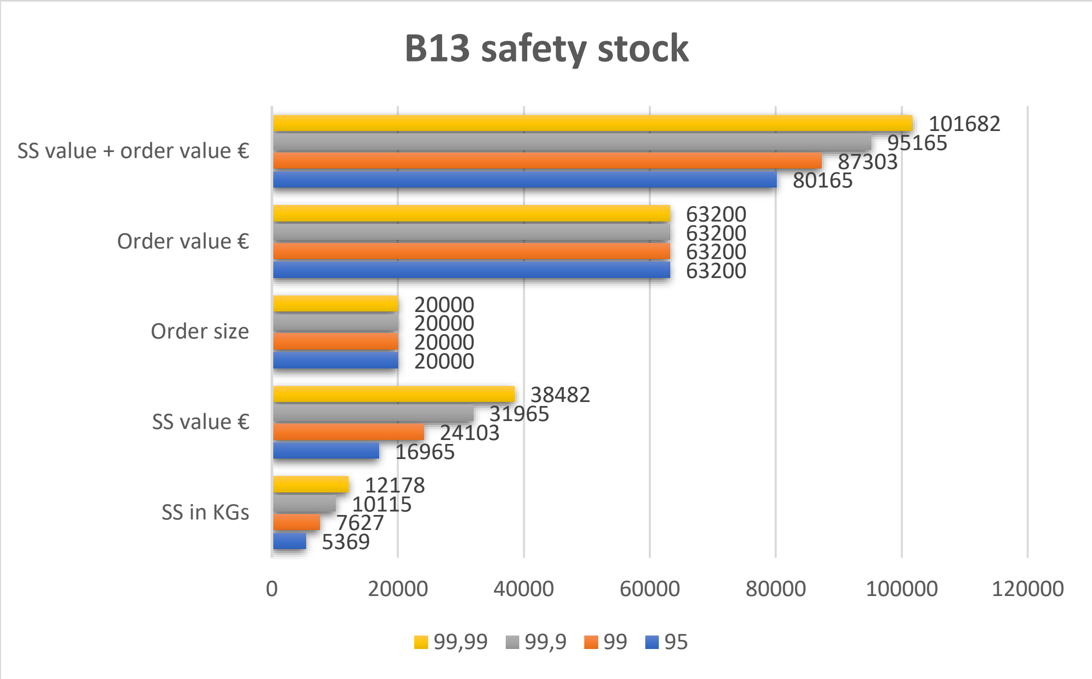


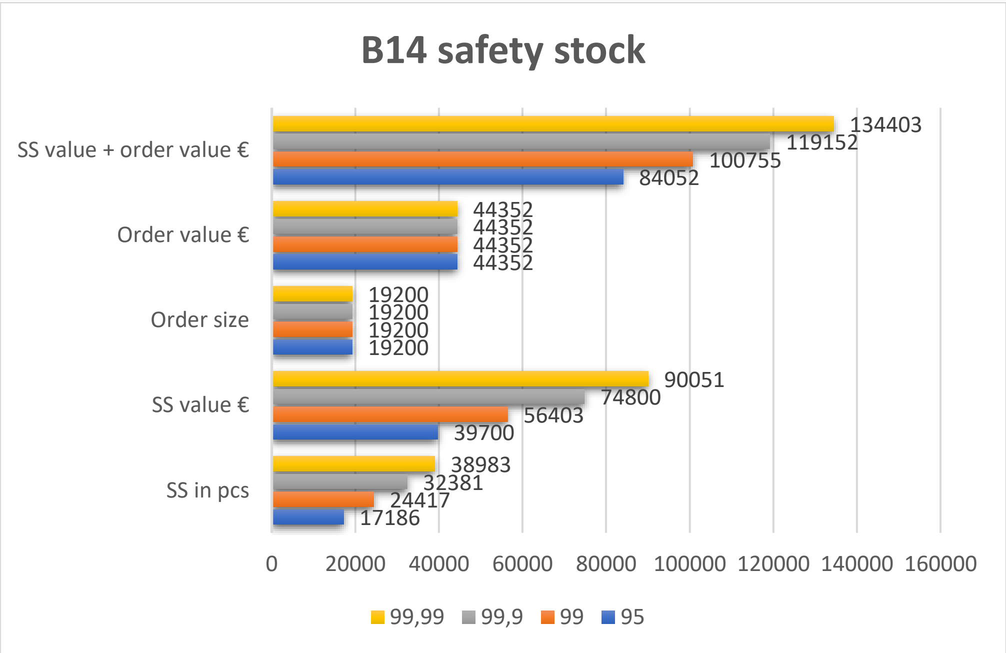
Appendix 25. maximum inventory value of material B11 and B12 for desired service level



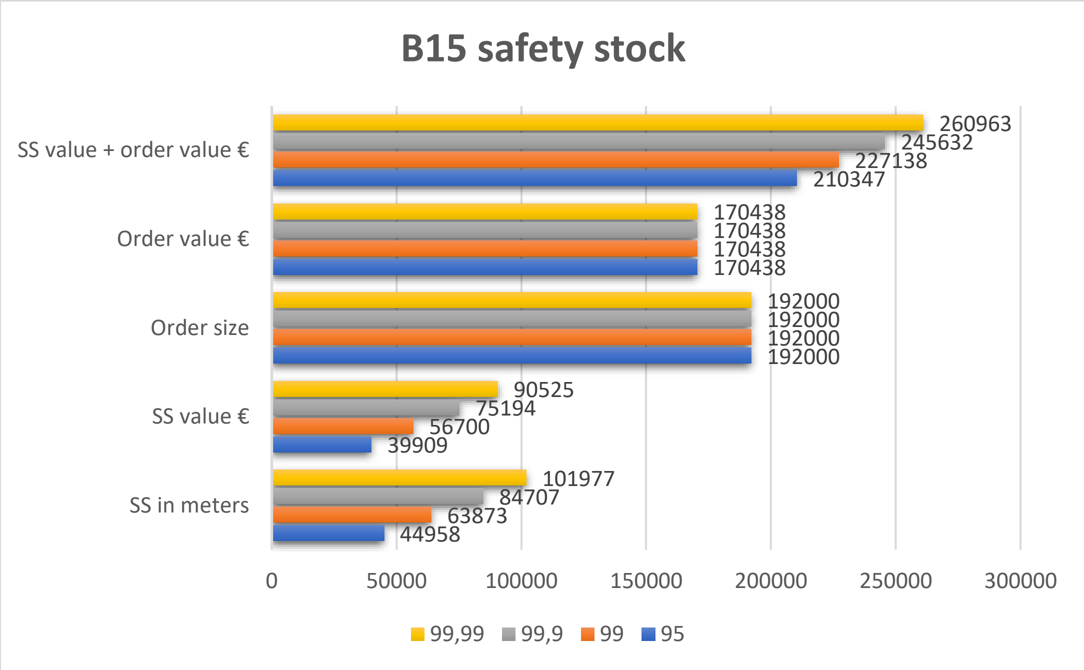


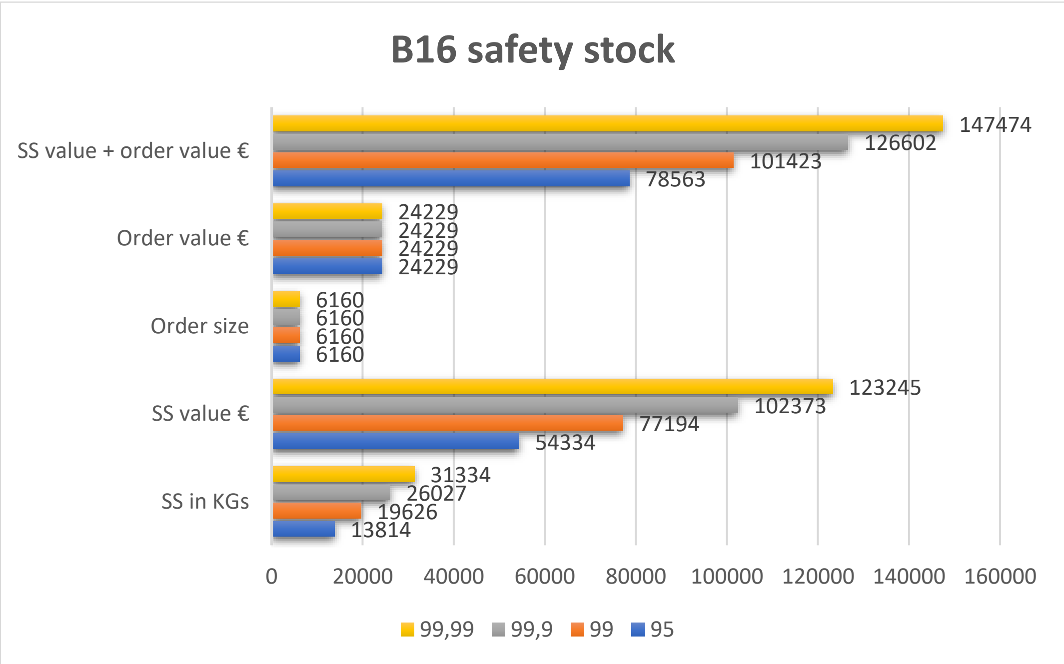
Appendix 26. maximum inventory value of material B13 and B14 for desired service level



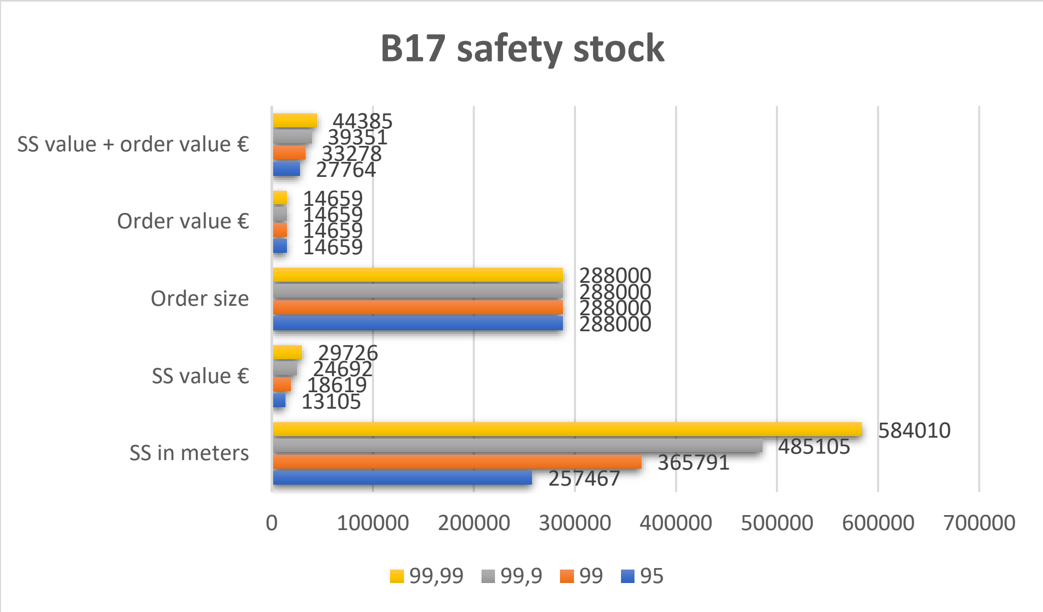


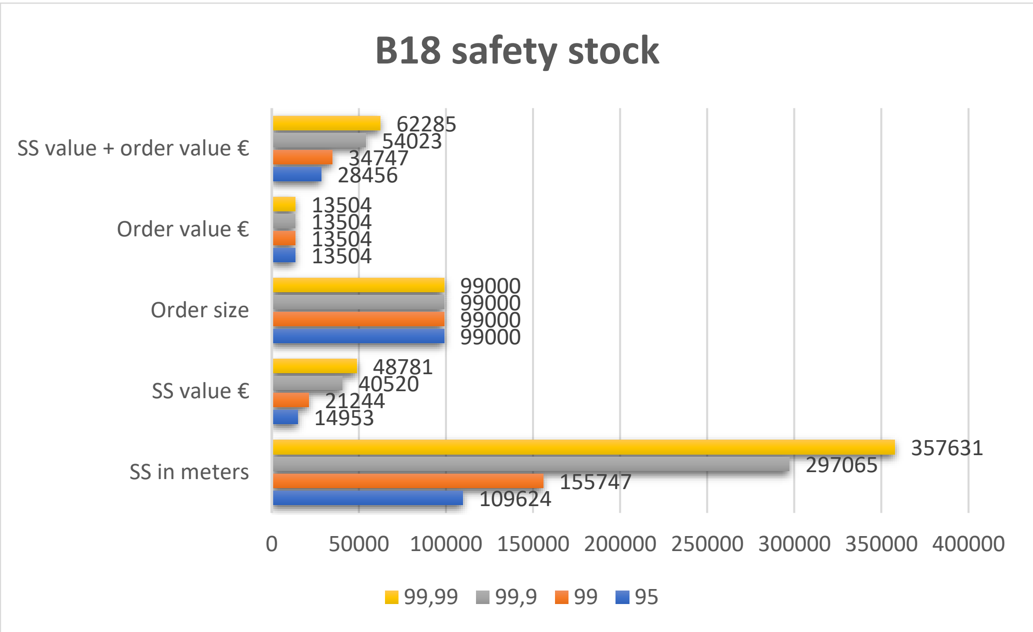
Appendix 26. maximum inventory value of material B15 and B16 for desired service level



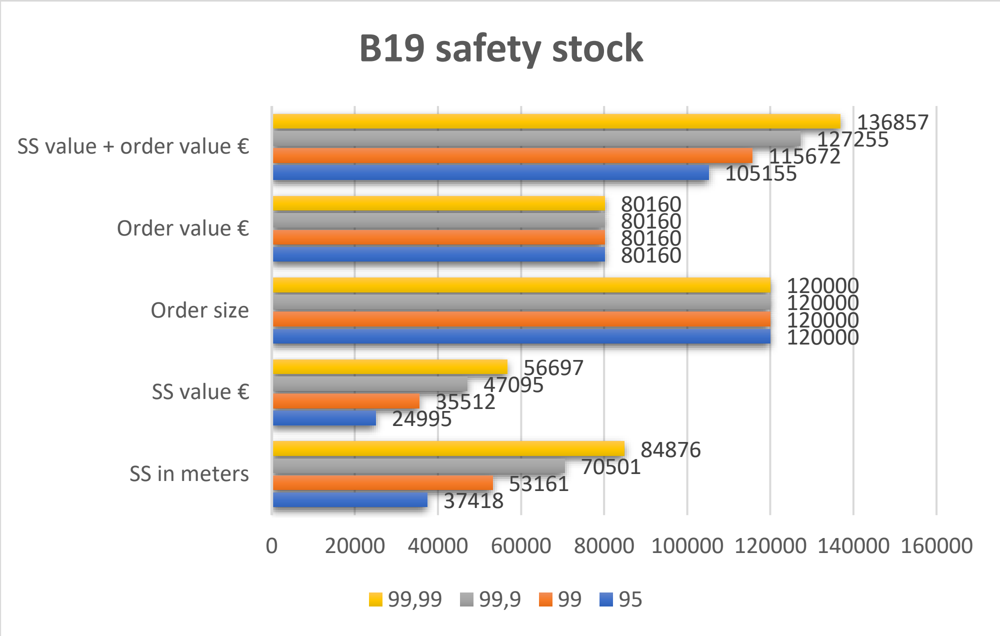


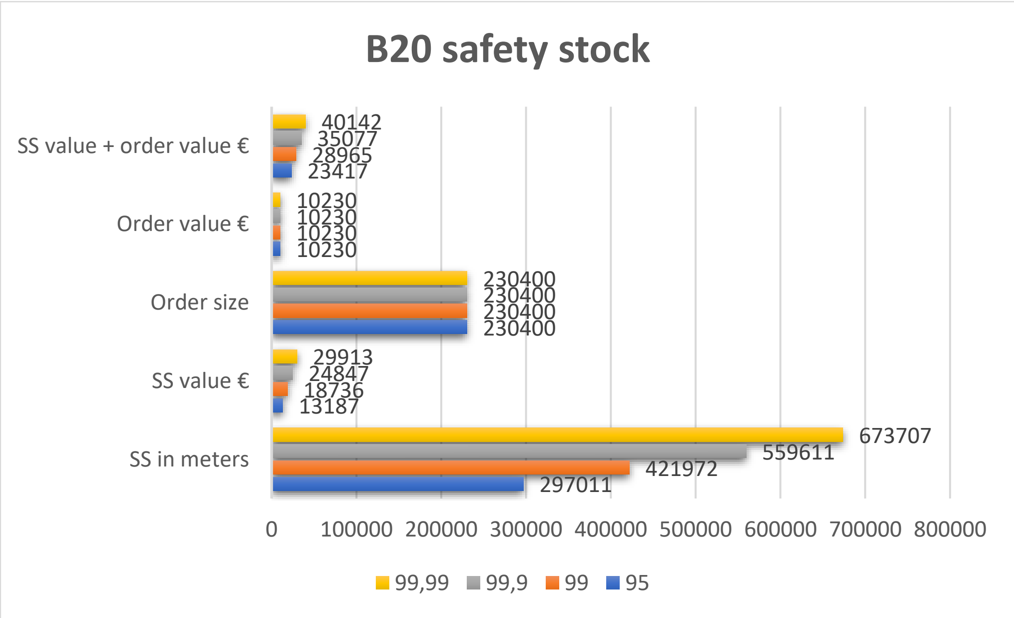
Appendix 27. maximum inventory value of material B17 and B18 for desired service level



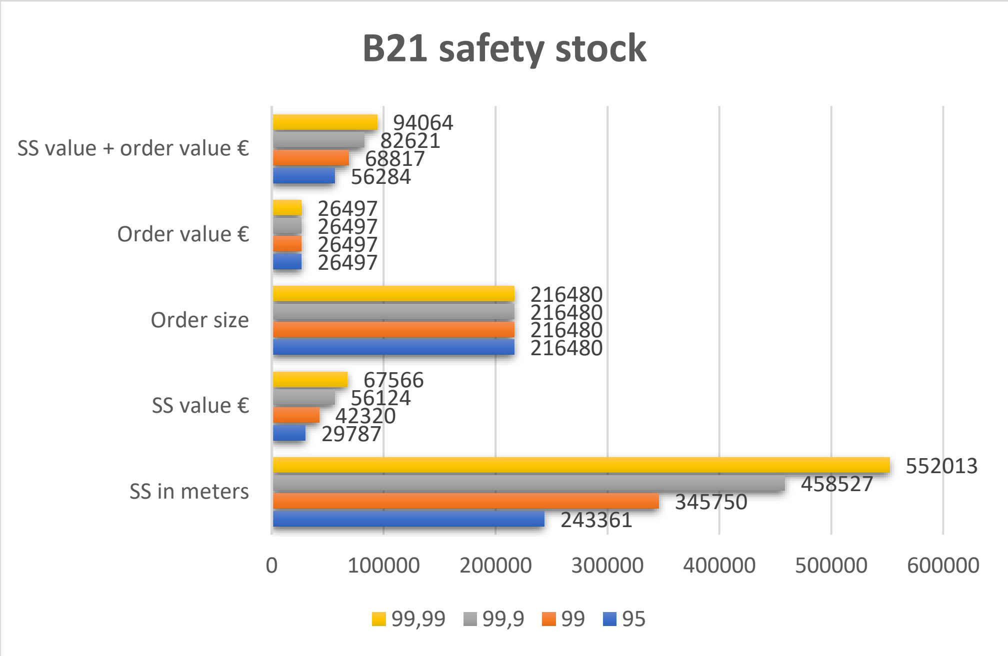


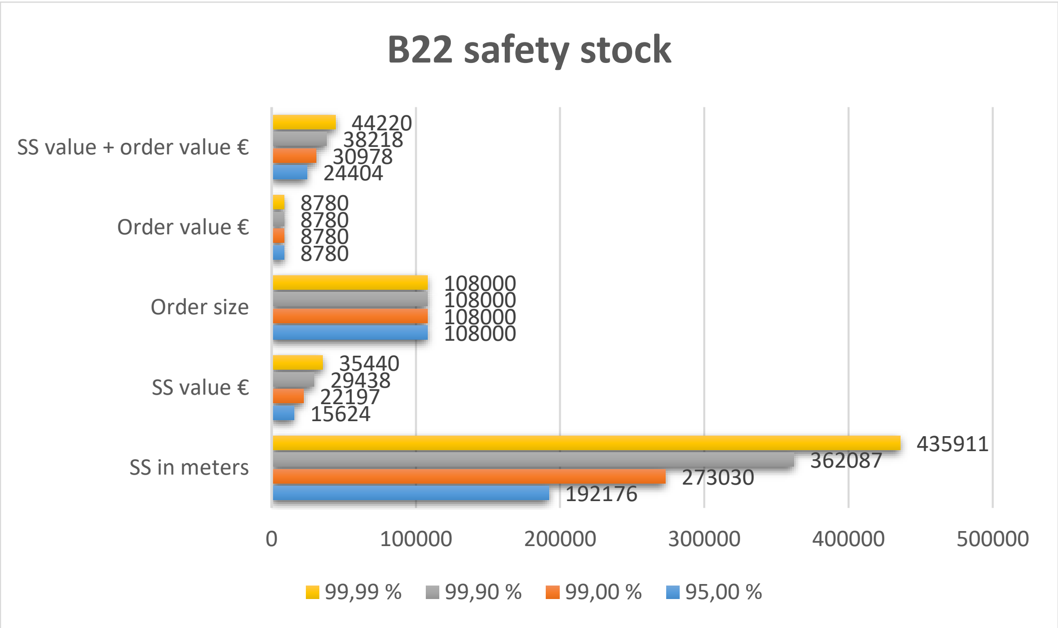
Appendix 28. maximum inventory value of material B19 and B20 for desired service level



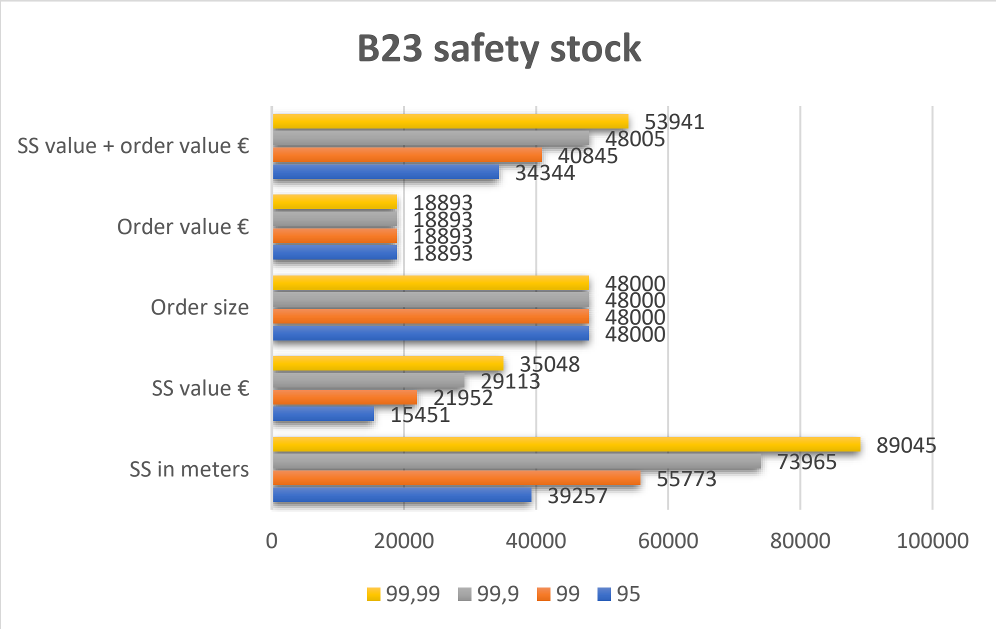


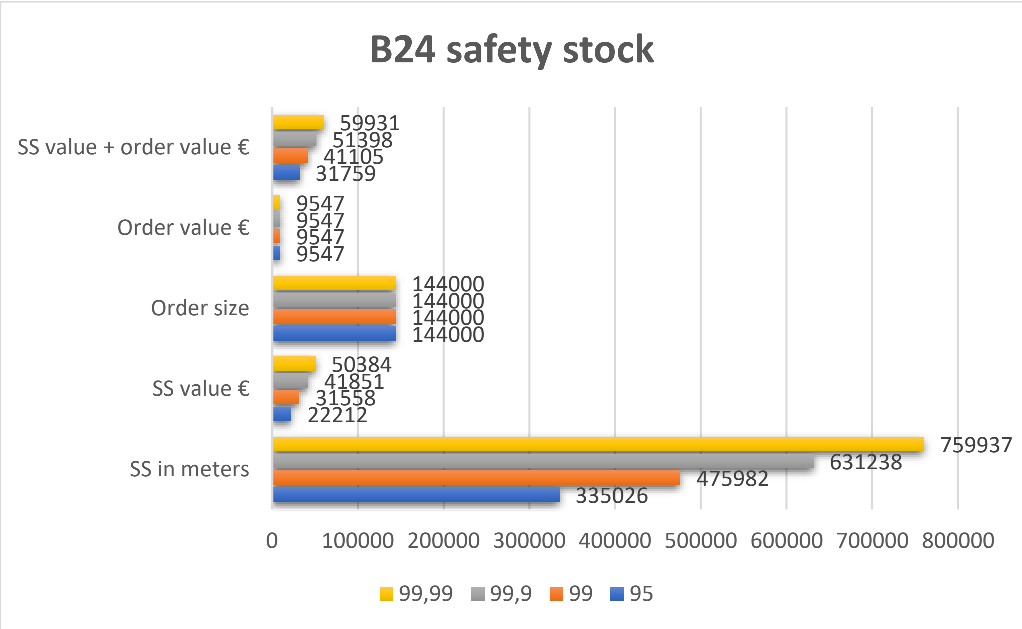
Appendix 29. maximum inventory value of material B21 and B22 for desired service level



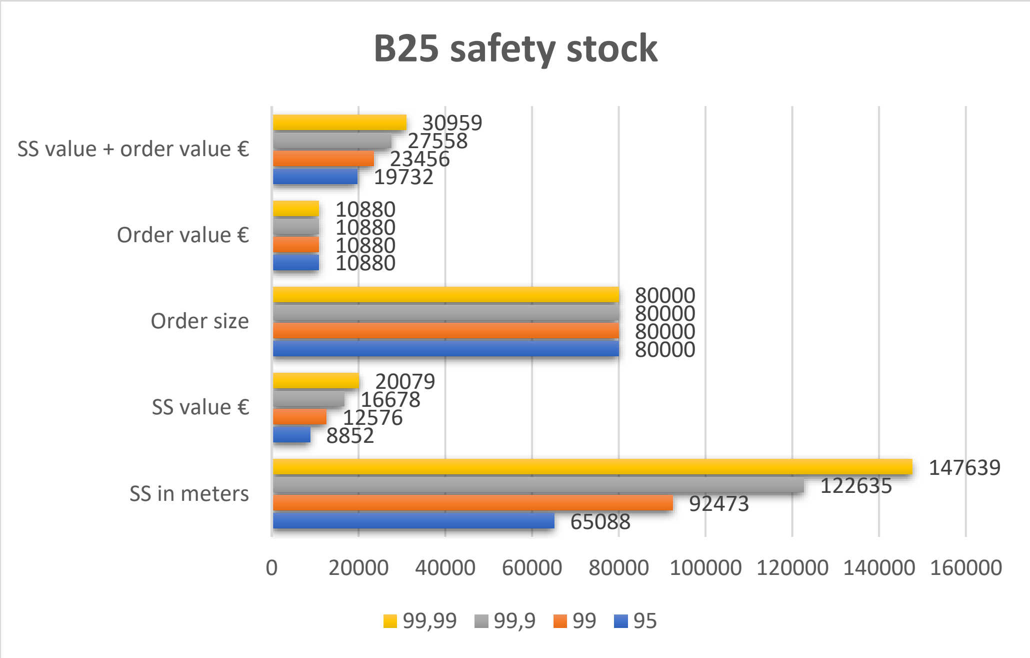


Appendix 30. maximum inventory value of material B23 and B24 for desired service level

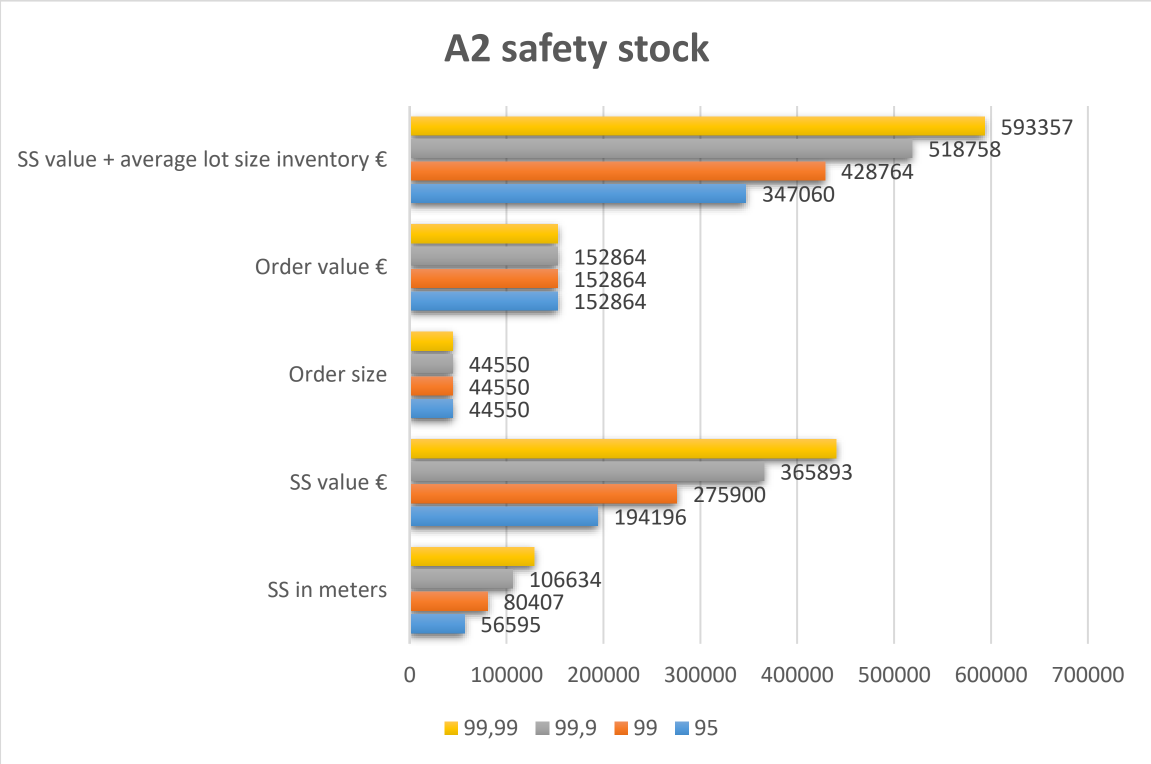


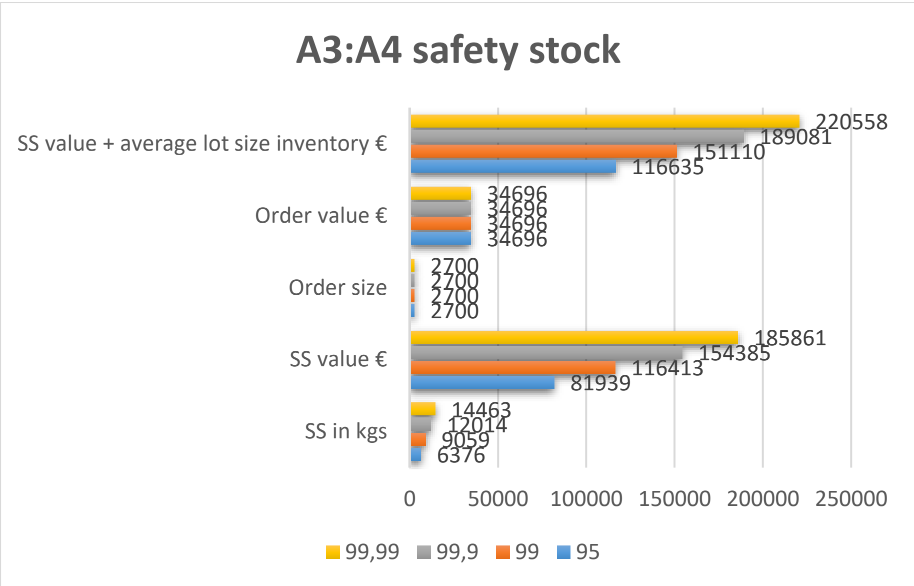


Appendix 31. maximum inventory value of material B25 for desired service level

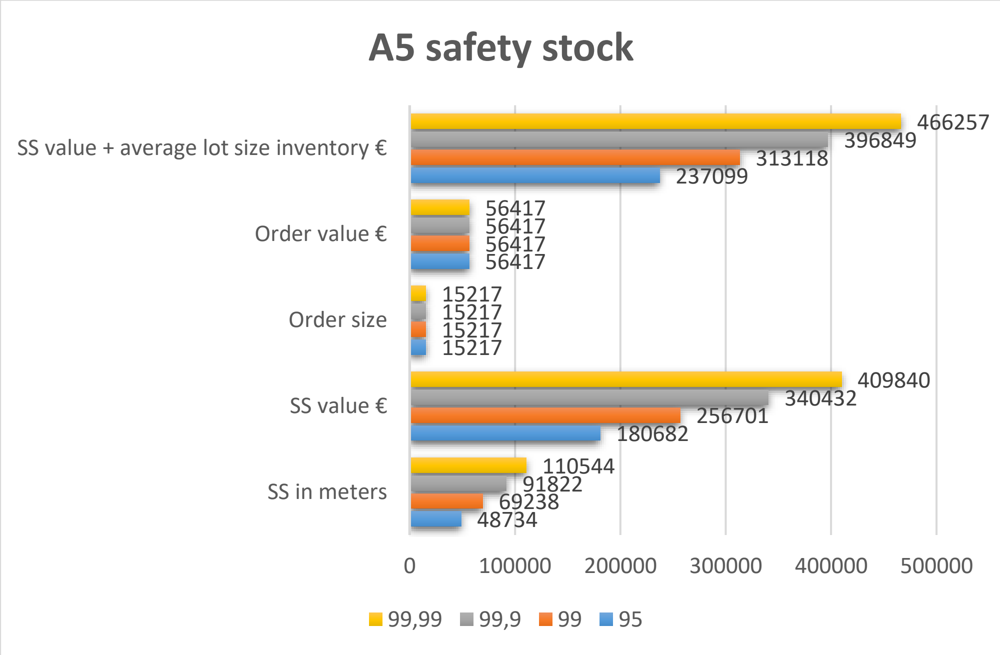


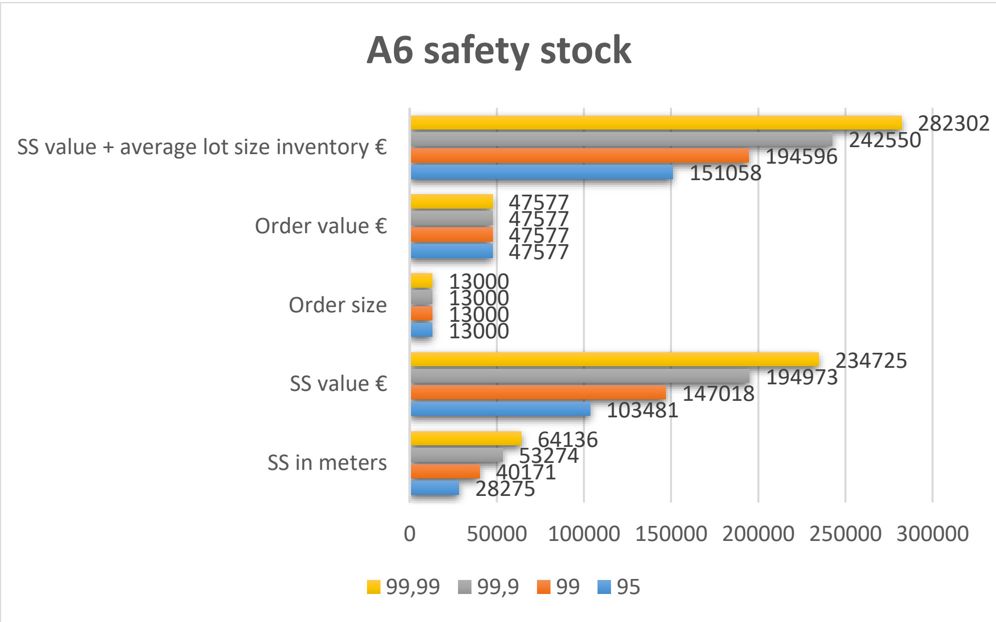
Appendix 32. average inventory value of material A2 and A3&A4 for desired service level



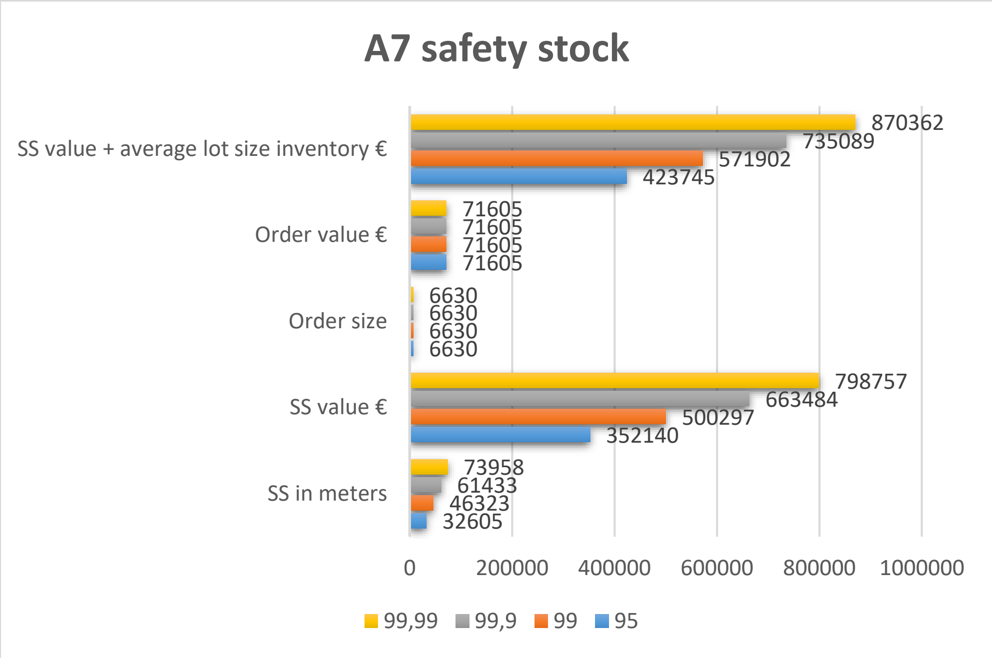


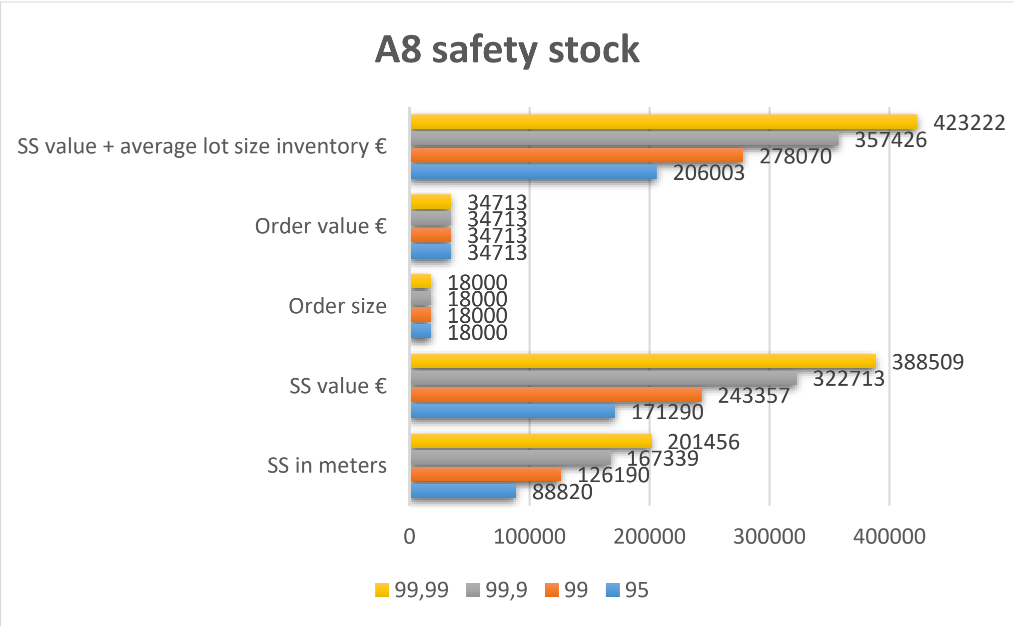
Appendix 33. average inventory value of material A5 and A6 for desired service level



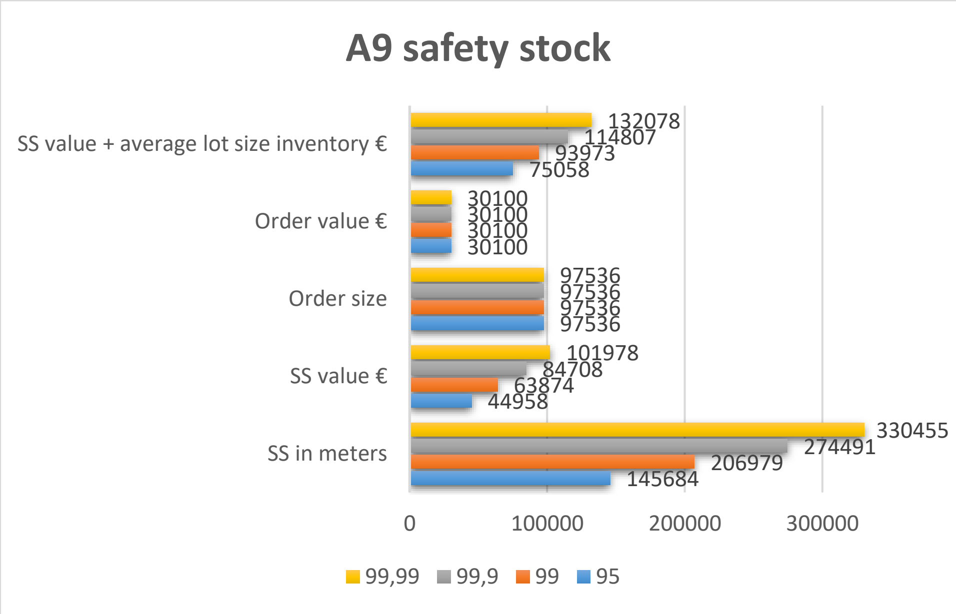


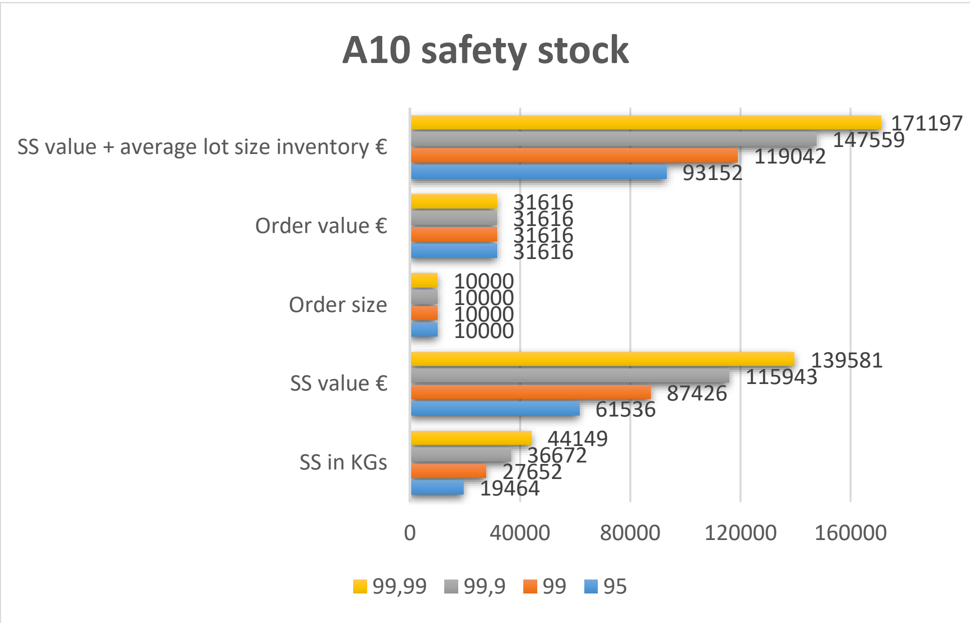
Appendix 34. average inventory value of material A7 and A8 for desired service level



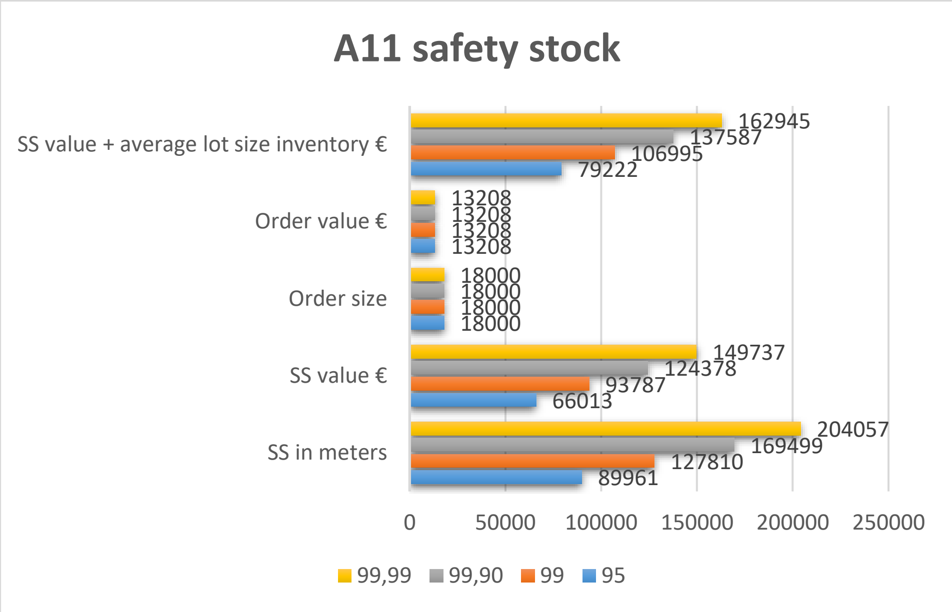


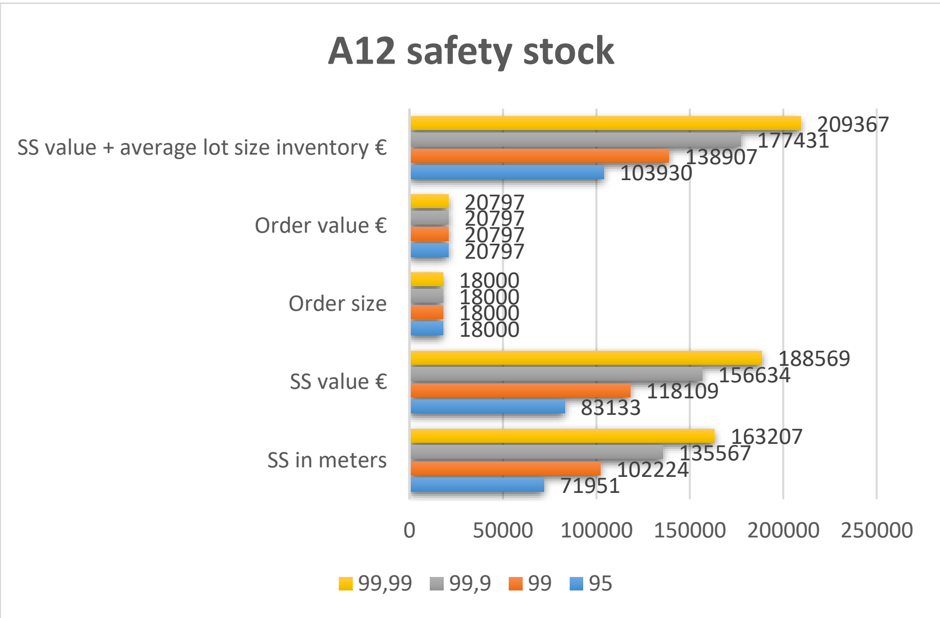
Appendix 35. average inventory value of material A9 and A10 for desired service level



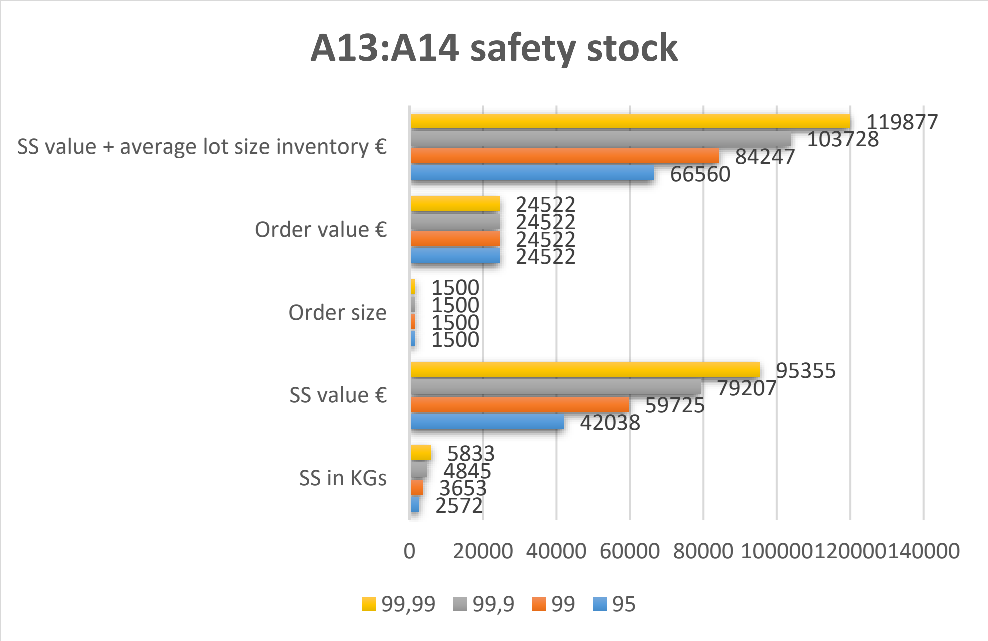


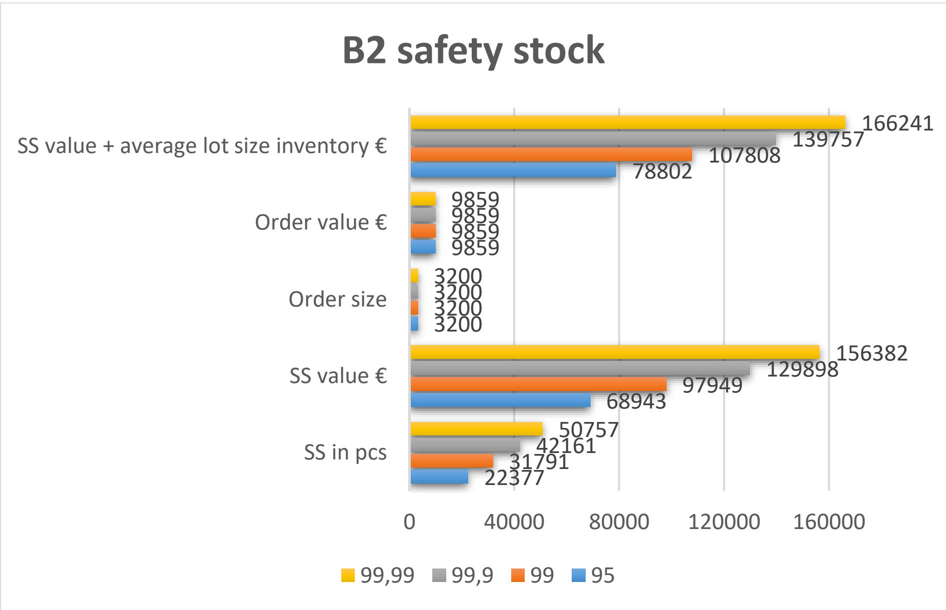
Appendix 36. average inventory value of material A11 and A12 for desired service level



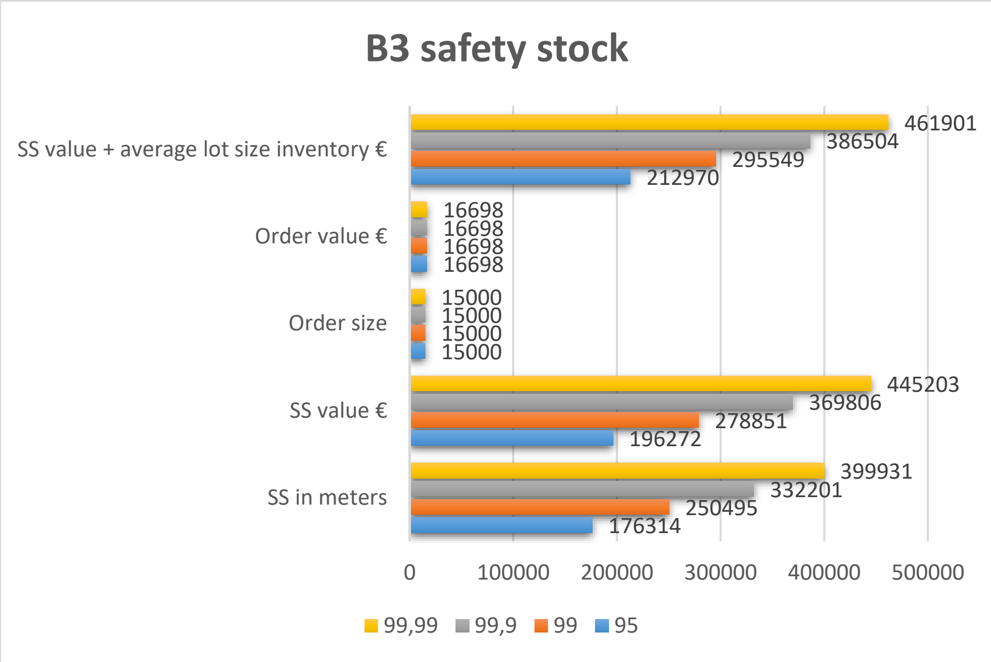


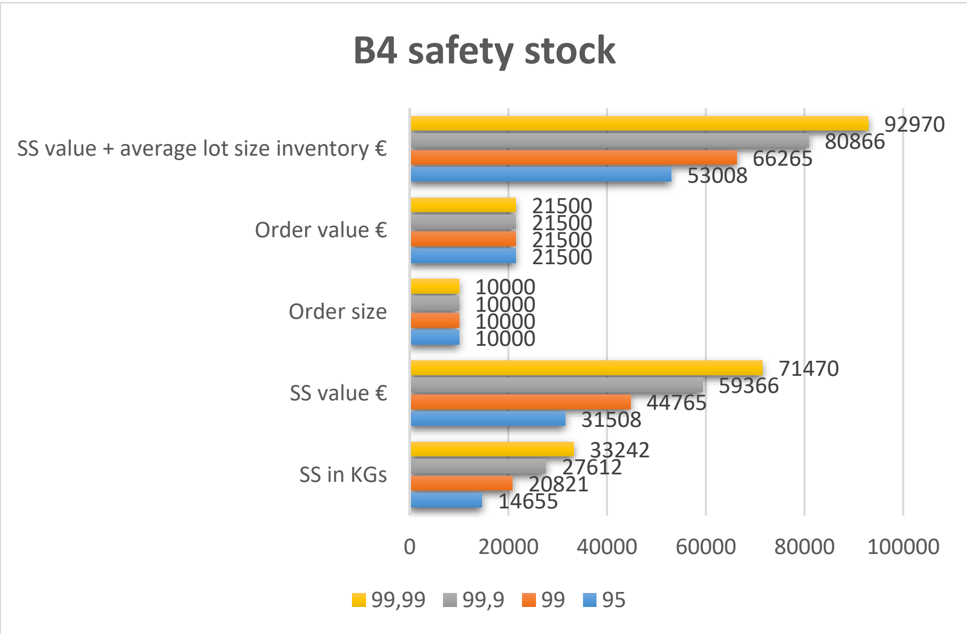
Appendix 37. average inventory value of material A13&A14 and B2 for desired service level



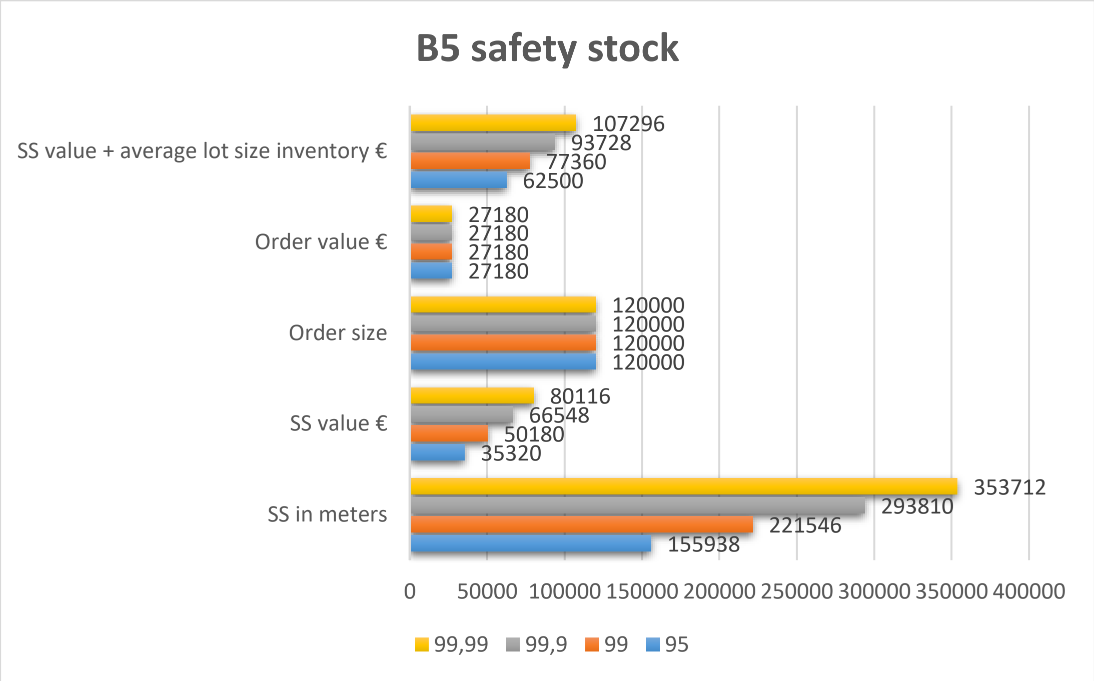


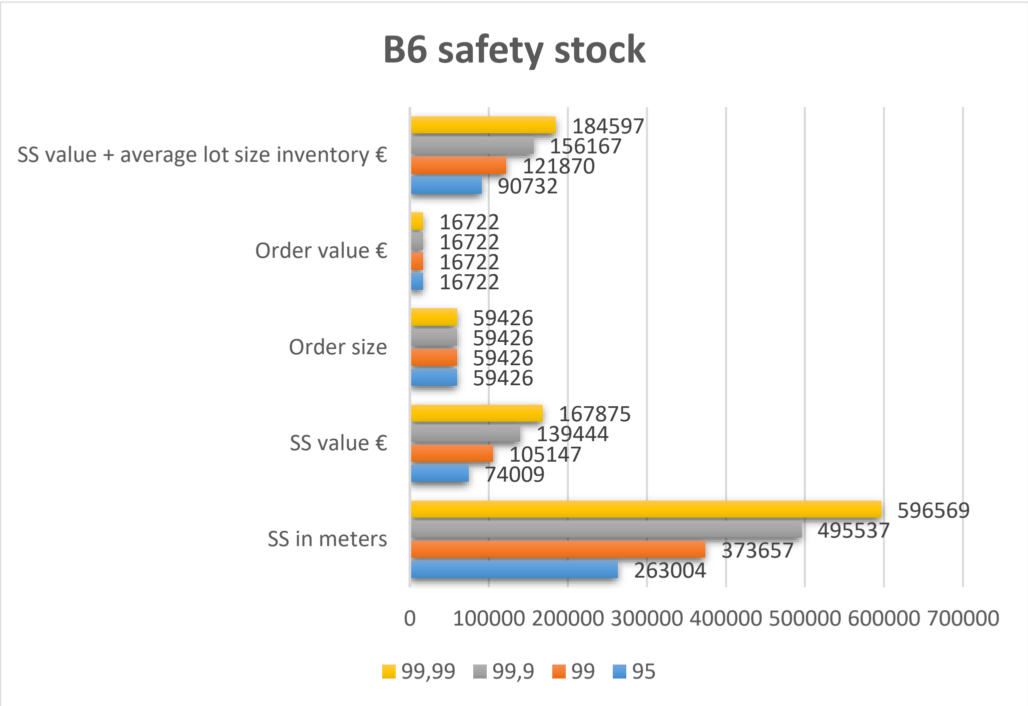
Appendix 38. average inventory value of material B3 and B4 for desired service level



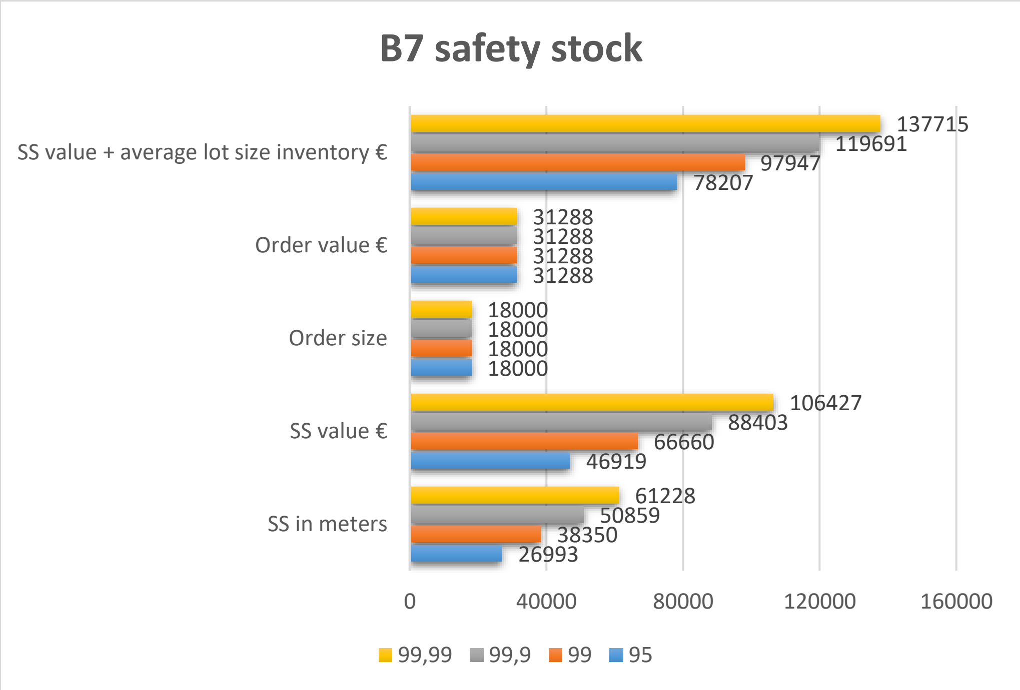


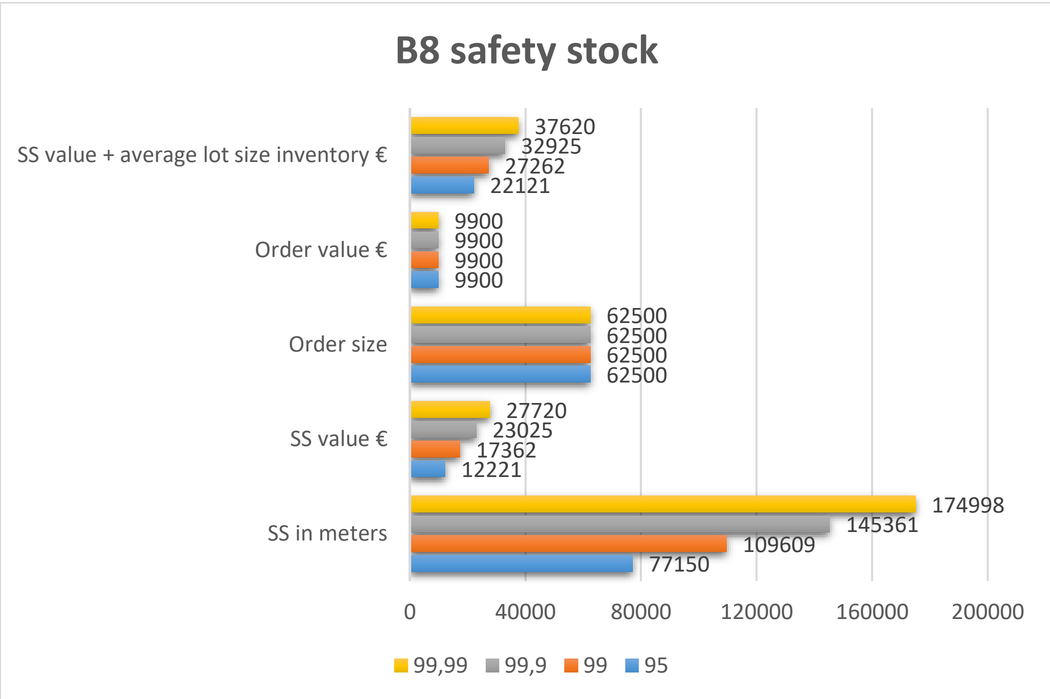
Appendix 39. average inventory value of material B5 and B6 for desired service level



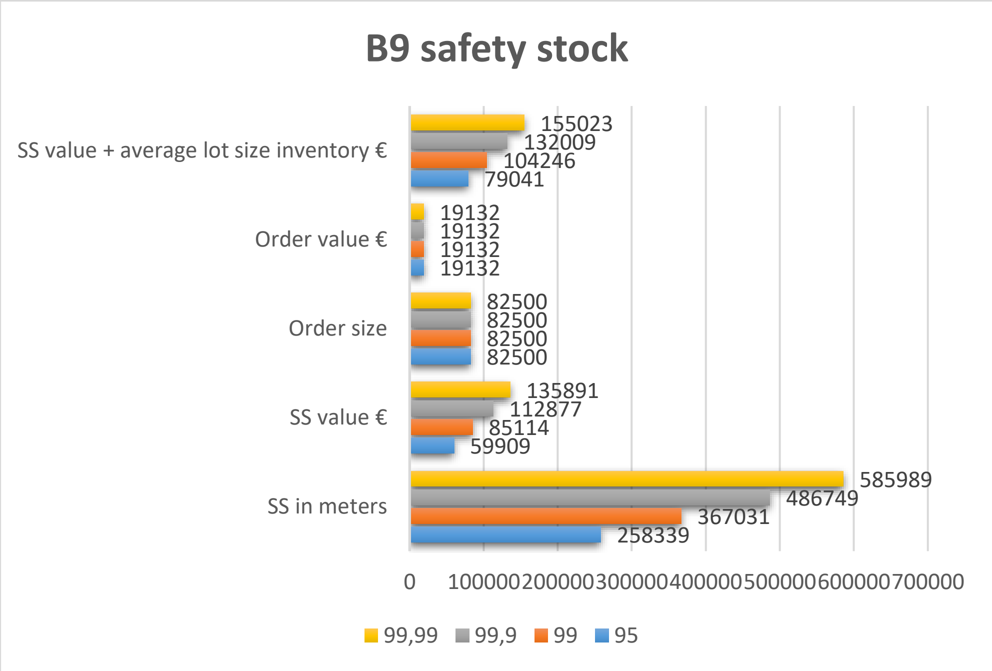


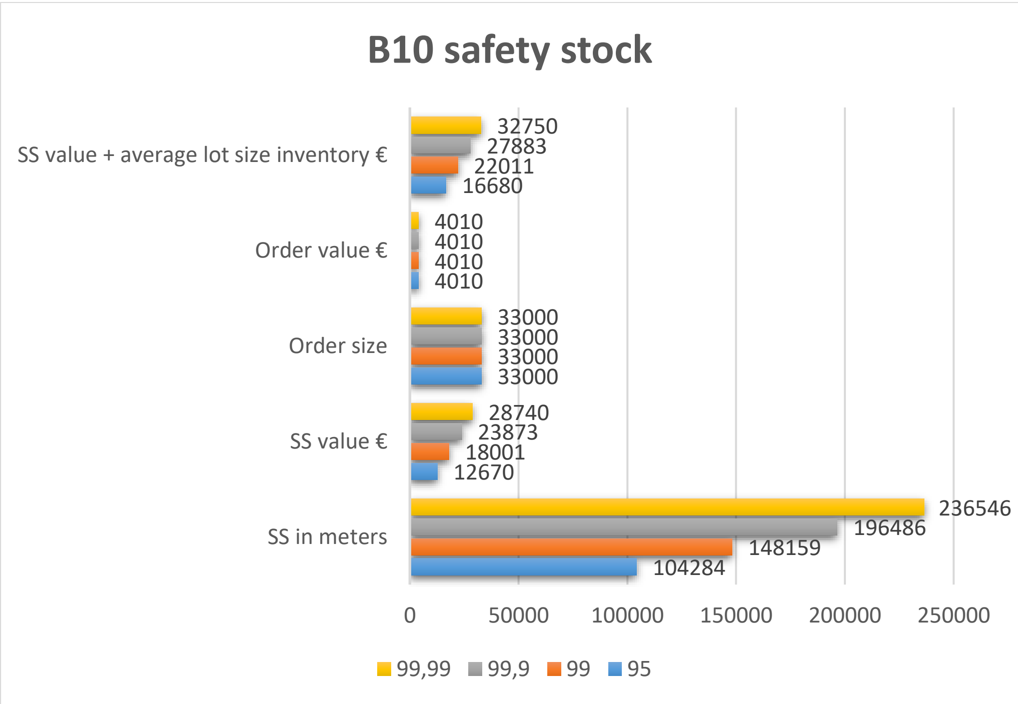
Appendix 40. average inventory value of material B7 and B8 for desired service level



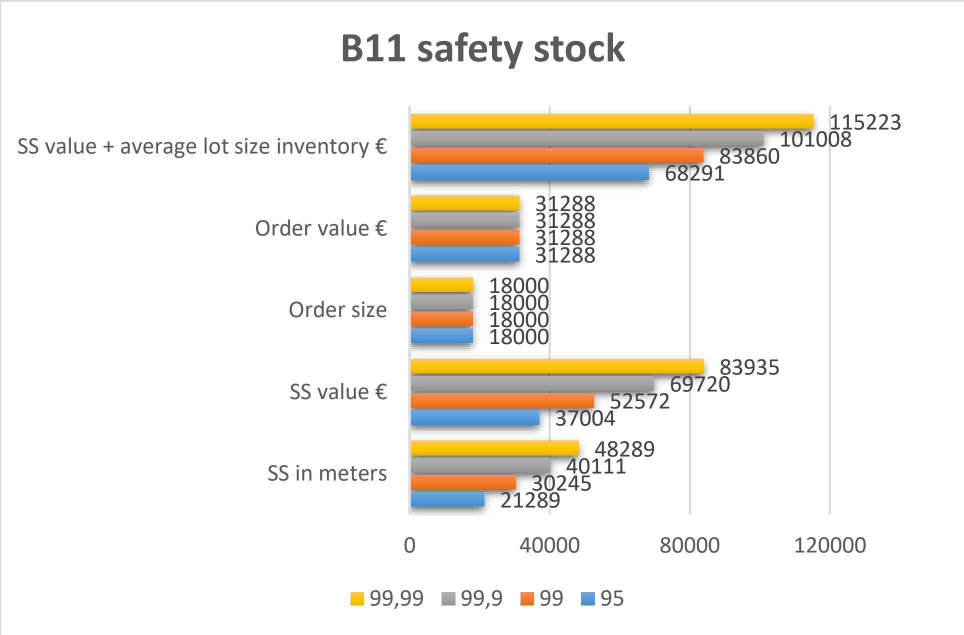


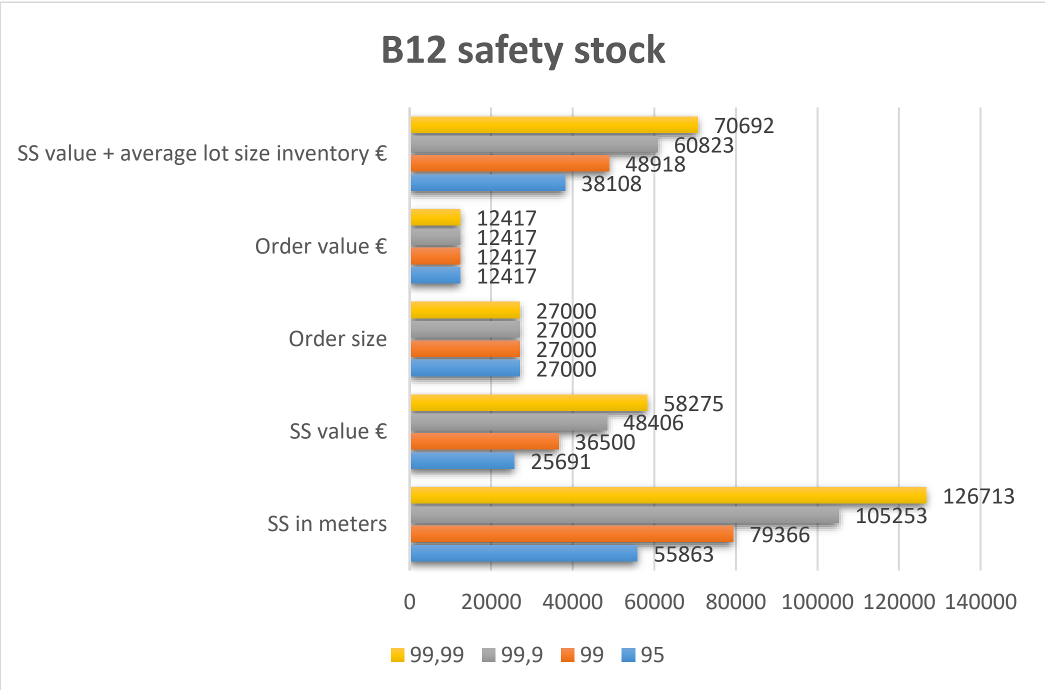
Appendix 41. average inventory value of material B9 and B10 for desired service level



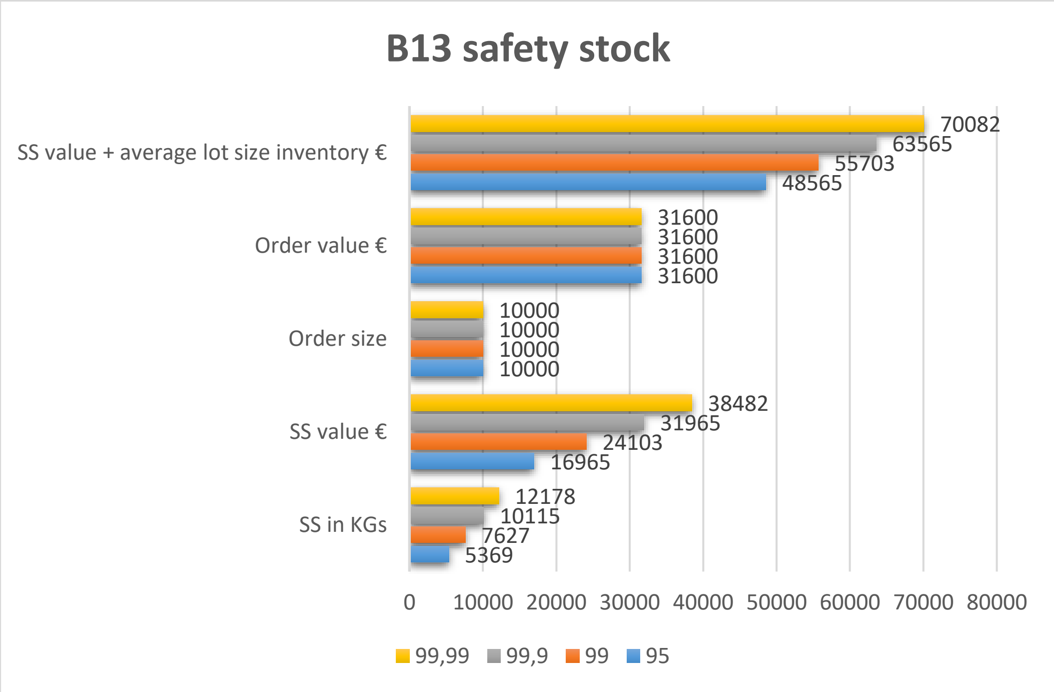


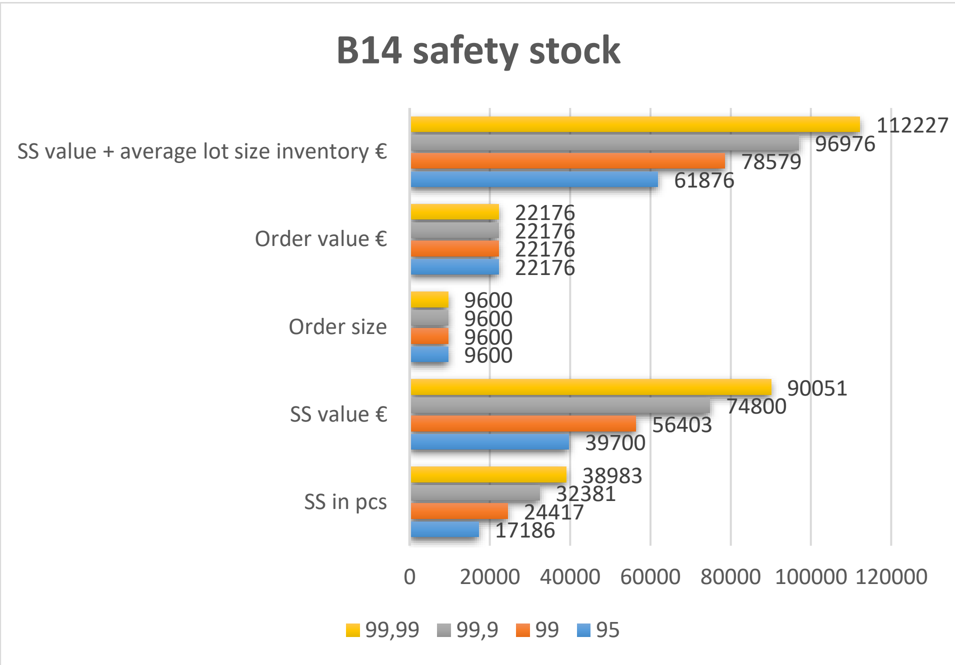
Appendix 42. average inventory value of material B11 and B12 for desired service level



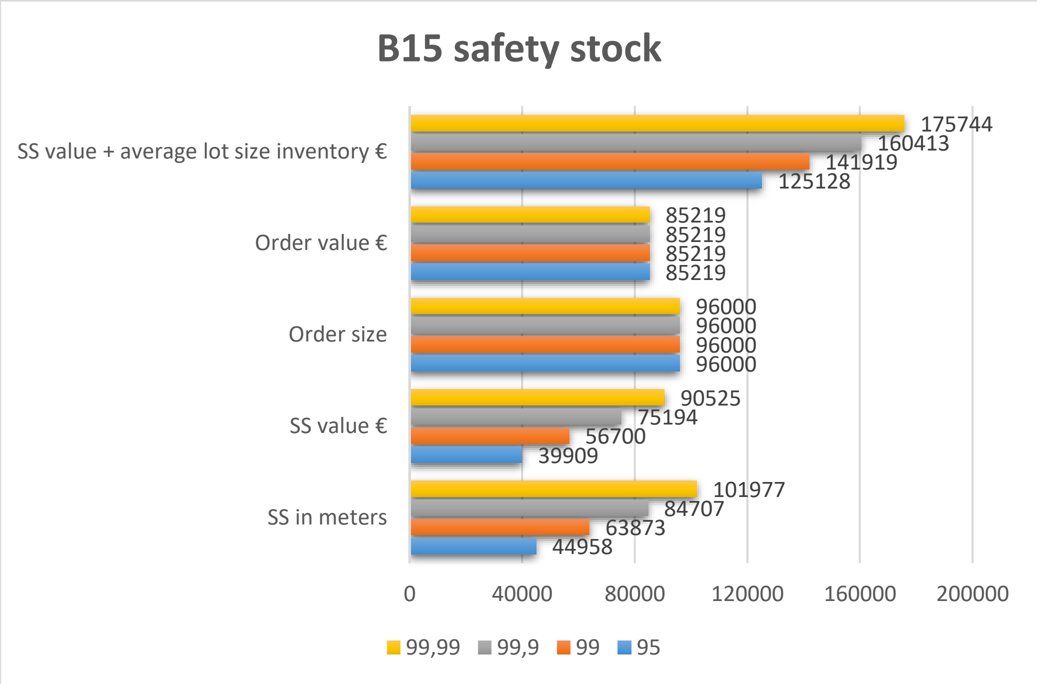


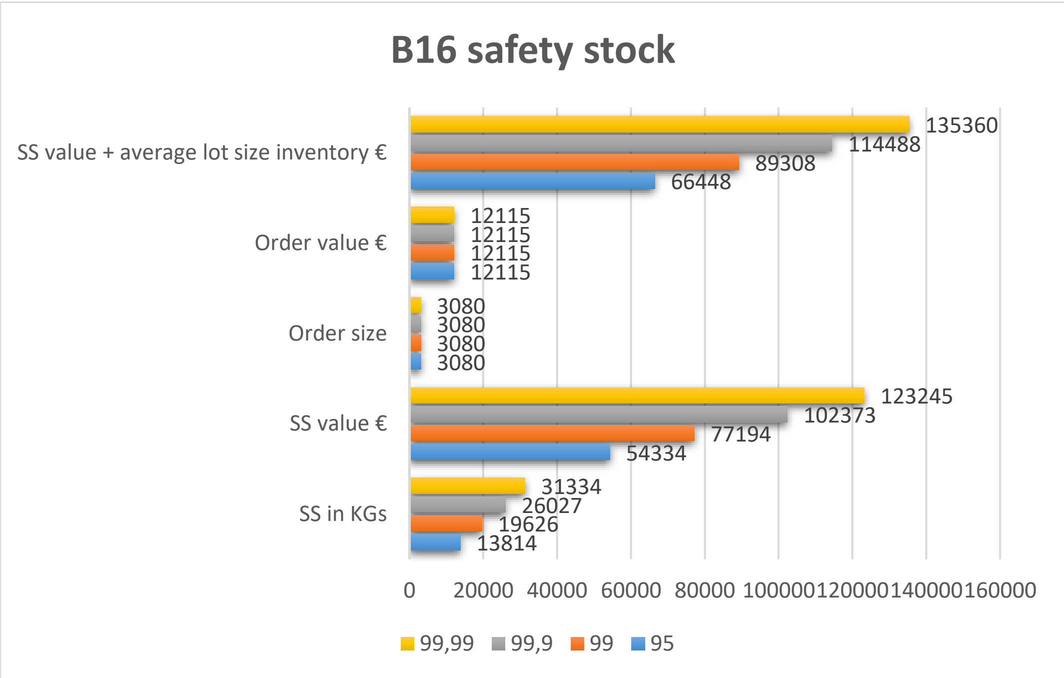
Appendix 43. average inventory value of material B13 and B14 for desired service level



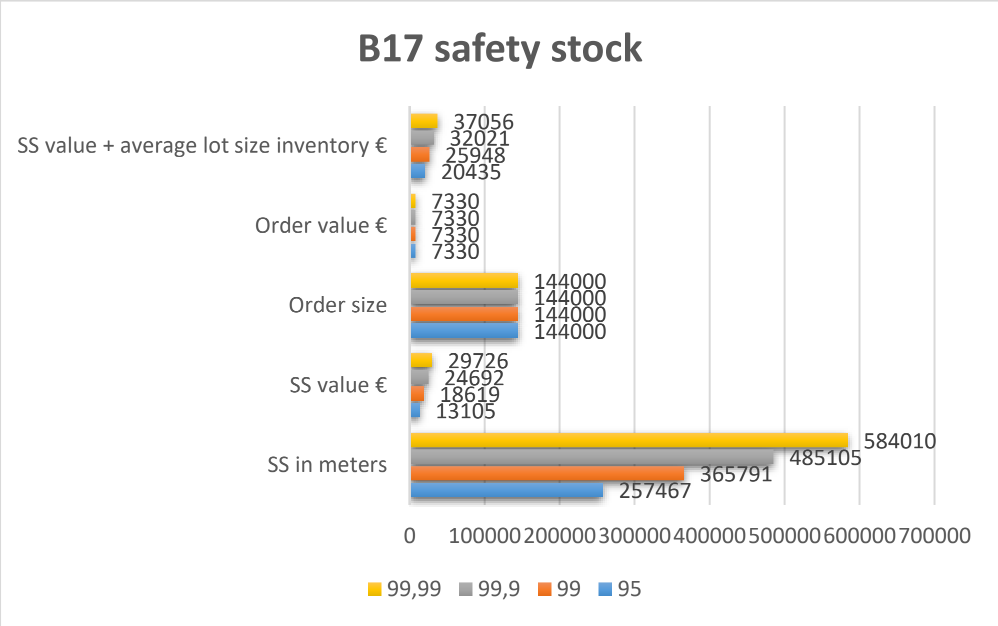


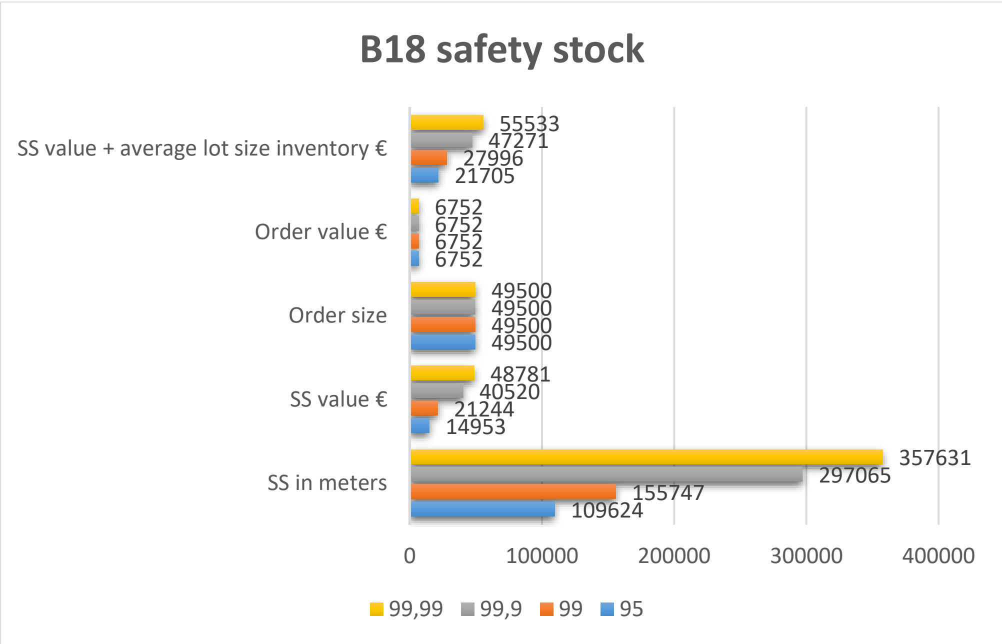
Appendix 44. average inventory value of material B15 and B16 for desired service level



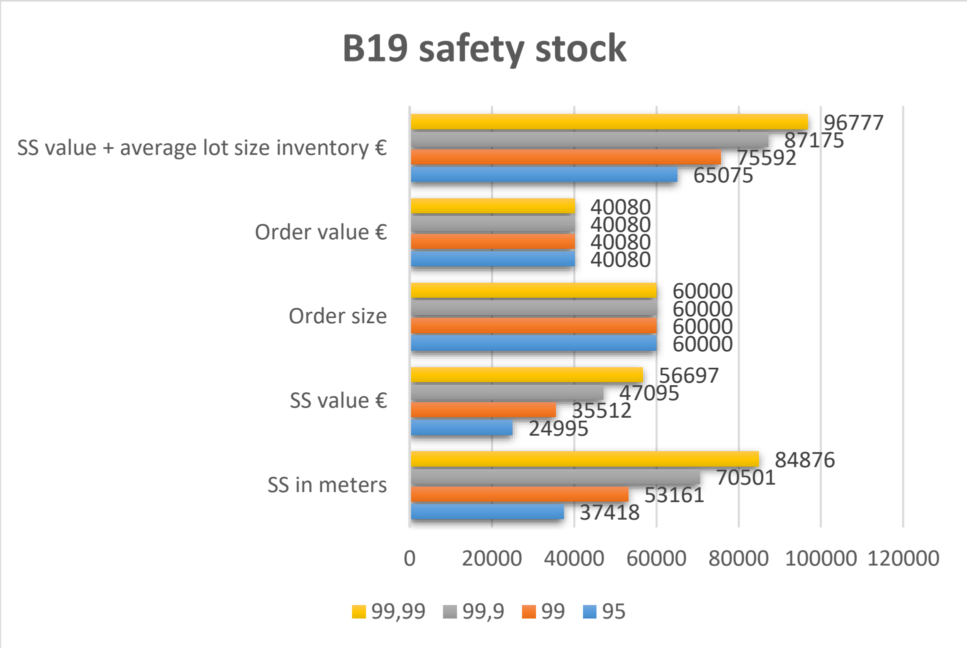


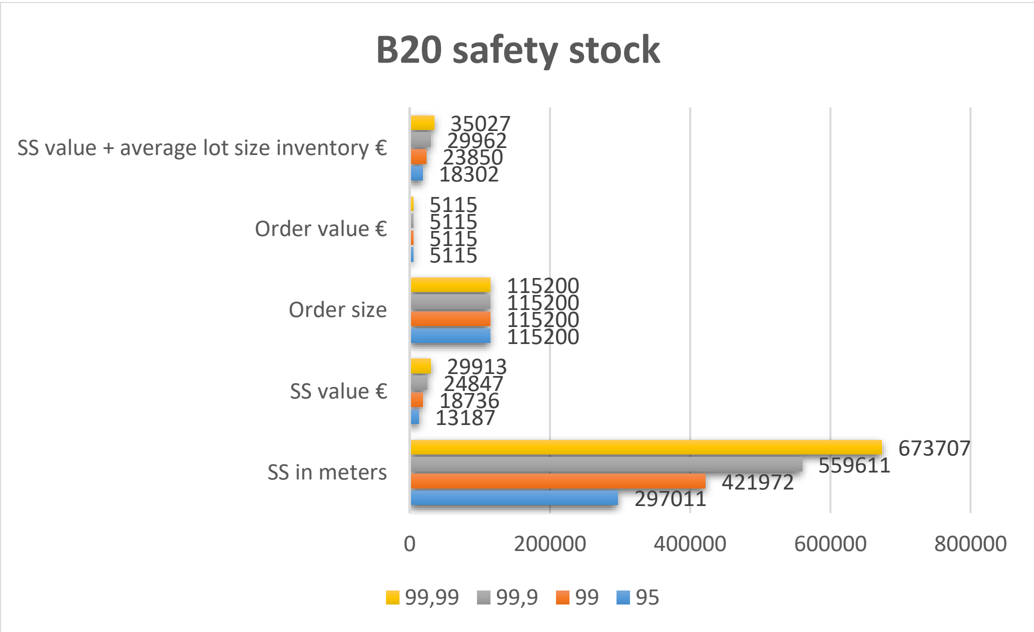
Appendix 45. average inventory value of material B17 and B18 for desired service level



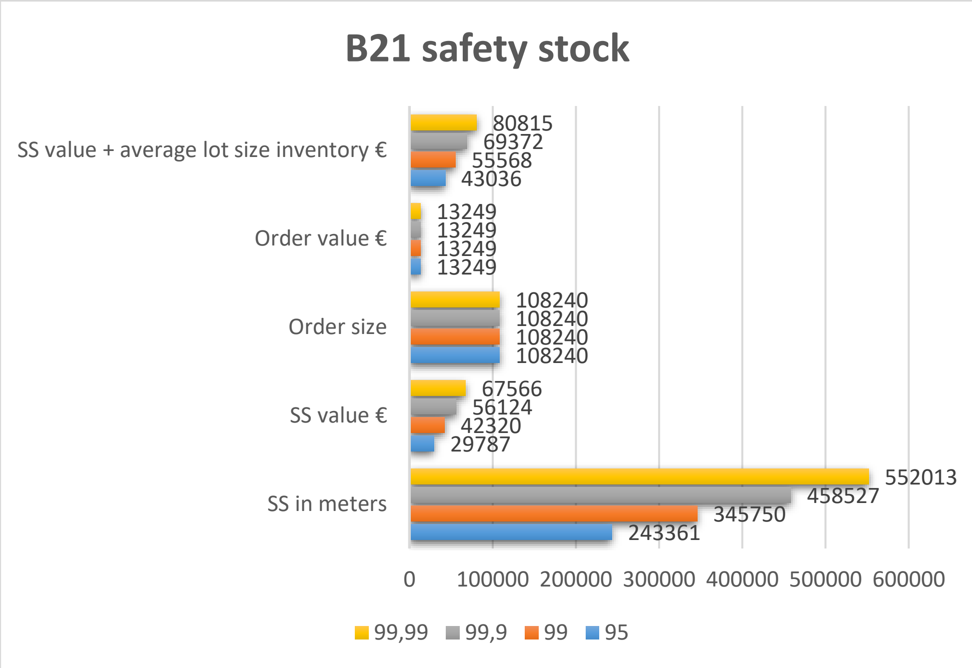


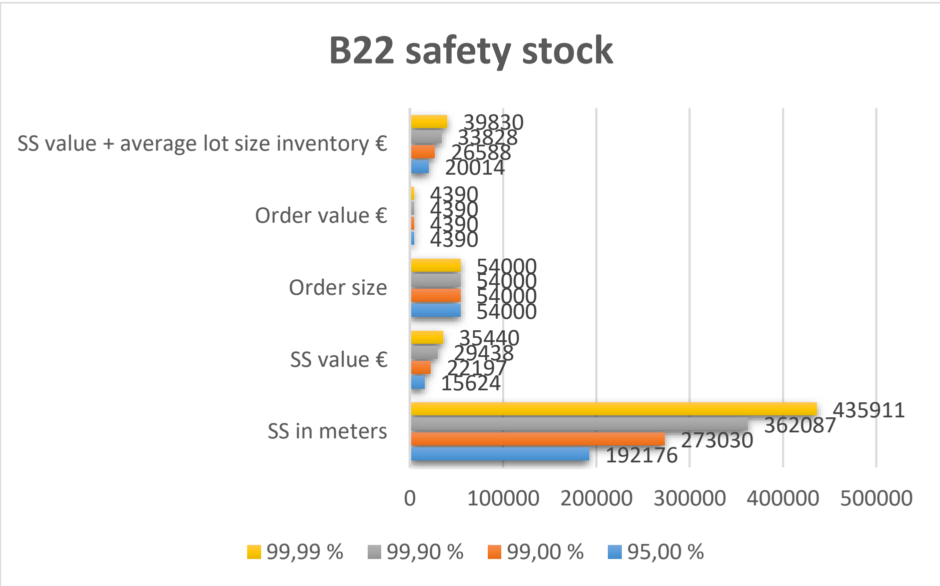
Appendix 46. average inventory value of material B19 and B20 for desired service level



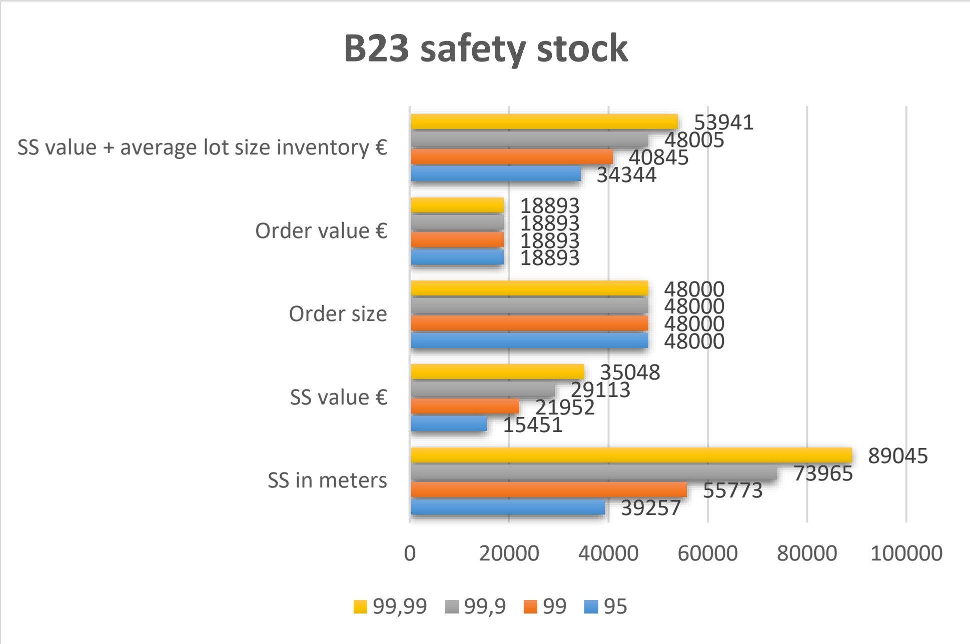


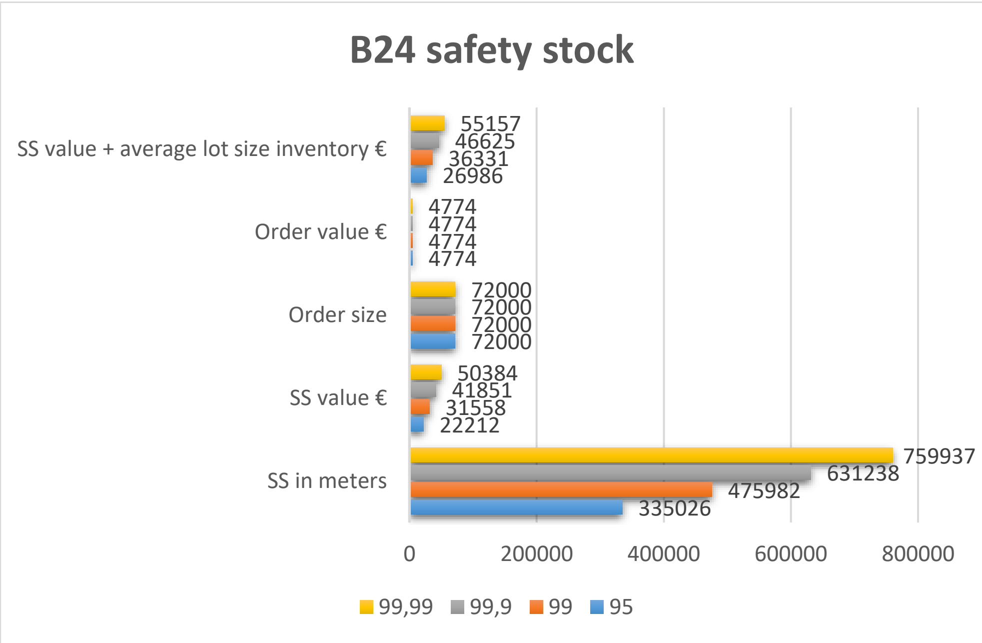
Appendix 47. average inventory value of material B21 and B22 for desired service level





Appendix 48. average inventory value of material B23 and B24 for desired service level





Appendix 49. average inventory value of material B25 for desired service level