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Optimization of a Laundry's Garment Stock and Ordering

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Abstract

The object of the thesis is to improve the efficiency of a laundry's garment stock by optimizing the order points and order quantities. The thesis is a part of larger project to implement the stock and purchasing modules of an ERP system.

Based on theory the used mathematical models were decided and the needed parameters identified. To find the optimal order quantity stock value, holding cost percentage, order costs and transportation and handling were calculated. For the order point definition the lead times per supplier and service level for the safety stock were studied. The current situation on stock was analyzed by XYZ – analysis. Based on an analysis the test products were chosen. For the test products the monthly demand and standard deviation of demand was examined.

Based on the data collected, order points and optimal order quantities for test products were calculated. The impact of variation of stock valuation and holding cost percentage on order quantity was also analyzed. Based on the analysis, the parameters to be used for all the products on stock were chosen.

As a result of the thesis the products which have no demand and need to be removed from the stock are defined. When the order quantity and order point are set and in use for all the products on stock the efficiency of the order process will improve, the stock value will reduce and stock service level improve.

Keywords
Inventory control, ordering, order point, order quantity, laundry

Miscellaneous

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Tiivistelmä

Opinnäytetyön tarkoituksena oli optimoida tilauspisteet ja ostojen tilauskoot teollisen pesulan työvaatevaraston toiminnan tehostamiseksi. Opinnäytetyö oli jatkoa pesulan toiminnanohjausjärjestelmän varasto- ja ostomoduulin käyttöönottoprojektiin.

Teorian perusteella määriteltiin käytettävät matemaattiset mallit, joiden käyttämistä varten määriteltiin tarvittavat parametrit. Ostojen tilausmääriä varten laskettiin varaston kustannusprosentti, ostotilauksen hinta sekä kuljetus- ja käsittelykustannukset. Tilauspisteitä varten määriteltiin toimittajakohtaiset toimitusajat sekä varmuusvarastoja varten käytettävä palveluaste. Työssä on tutkittu nykytilannetta XYZ -analyysin avulla. Analyysin perusteella valittiin testituotteet, joiden tuotekohtainen kulutus varastosta ja kulutuksen hajonta tutkittiin.

Näiden tietojen perusteella laskettiin esimerkki-aineistolle uudet tilauspisteet ja ostojen tilauskoot. Varastonarvon ja varastonkustannusprosentin muutosten vaikutusta lopullisiin tilauskokoihin analysoitiin. Näiden analyysien perusteella löydettiin parametrit, joita käyttämällä kaikille varastossa oleville tuotteille on helppo laskea tilauspiste ja tilausmäärä.

Työn perusteella on määritelty tuotteet, joiden tarve on niin vähäistä, että niistä kannattaa pyrkiä eroon mahdollisimman pian. Suunnitellulla varaston-ohjauksella tullaan jatkossa saavuttamaan lisätehokkuutta ostoprosessissa, nopeampi varaston kiertonopeus, pienempi varastonarvo ja parantunut varaston palveluaste.

Avainsanat (asiasanat)
Varasto-ohjaus, ostot, tilausmäärä, tilauspiste, pesula

Muut tiedot

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1 INTRODUCTION

1.1 Objective of the Thesis

The objective of this thesis is to find a working mathematical inventory control method for the inventory management of a modern laundry. With the chosen inventory control method the answer for two questions, **when to order** and **how much to order,** are to be found for all the items on garment stock. The optimization ought to reduce the number of items in stock as well as the stockout situations. With the help of defined re-order points and order quantities the ordering process will work more efficiently in the future.

The thesis consists of four parts:

- Introduction and background: Definition of what this thesis is about, what is studied in later chapters and how the laundry operates.
- Theory: The main theoretical points needed for this study are discussed.
- Implementation: The defined theoretical points are applied for the activities of commissioning company.
- Results and Discussion: The results of the applied theory are reviewed and discussed.

1.2 Background information

1.2.1 Laundry Industry in Finland

The annual laundry markets in Finland are worth about €300 million. 90% of these markets are for business customers and only 10% for private customers. The markets have faced steady 2–3% growth during the past few years. In Finland's laundry markets, Lindström Ltd has the dominant position in all areas except the hospital sector, with almost 90% of the market share. Other companies in the markets only have a percentage of 1 to 2%, and most of them have only local operations. (Räsänen, 2011)

Over the years Lindström has been able to purchase many small competitors and to achieve its position (Aaltonen, 2009).

The laundry industry has some seasonal fluctuation. During spring many companies hire a lot of summer workers for whom the garments have to be acquired beforehand. These garments also return to stock after the summer when the summer workers end their contracts. The mid-summer is usually quiet due to long holidays, when there is less garments to wash. Some industries, where the production peaks just before Christmas, also need garments for seasonal workers in October and November.

1.2.2 Pieksämäki Laundry

The laundry is situated in Pieksämäki, at the heart of Finland and it currently has about 50 employees. The laundry has five main product groups: walk-off-mats, garments (work clothes), hotel textiles, industrial wipers and hygiene products. (Rusanen, Marketing brochure, 2011a) The facility has been taken into use in 2009 and it is a highly automated laundry with four laundry lines, one for each product category excluding hygiene products which are not washable. The laundry has low water and detergent consumption, half of the amount permitted for a Nordic eco-label.

The laundry was owned by Rusanen Tekstiilipalvelut Ltd, part of Etola group, from 2009 till the end of September 2011. On 1st of October 2011 it was acquired by Lindström Ltd.

1.2.2.1 Garments

Process Description for garments

Generally the garment process has four main activities: receiving and sorting, washing, finishing and delivery.

On receiving and sorting the dirty garments are first sorted by delivery routes and customers and marked as received for the system. After this the clothes are sorted by their material and color to wait for their washing turn.

After the washing the garments are put on a hanger and blown dry in a drying tunnel. After the drying the condition of the garments is checked. If the garment is okay it is directed to the automated sorting line, but if it is not okay it is either directed to the sewer for repair or to the stockroom to be changed for a new garment.

From the sorting line the garments are packed in sacks and roll containers according to the department, customer and delivery route and then delivered to the customers by an outsourced delivery company. (Rusanen, Process description for garment service, 2008) A detailed process description can be found from appendix 1.

1.2.2.2 Stock process

The garment stock is a support activity for the garment rental. The reason for keeping stock is that the worn garments can be replaced immediately and for the new wearers the garments can be issued immediately. The stock is needed since the lead time for garments from the suppliers is from 3 days to 6 weeks and the demand fluctuates. In general, the worn garments have to be replaced within three days and the new wearers usually need new garments within two weeks.

Garment stock has six main activities;

1. Replacement of worn-out garments
2. Issue of new garments for existing customers
3. Issue of new garments for new customers
4. Returning of the garment from a wearer whose employment has ended
5. Change of garment for different size or model and
6. Receiving of purchase orders.

On top of this the stock personnel maintain the stock inventory and inventory data on an ERP-system. A detailed process description for garment stock on a chart can be seen in appendix 2.

During the past 8 months the stockroom and purchasing modules of the ERP-system *ABS laundry solutions* have been implemented to improve the inventory control and ordering at the laundry. The stockroom gives up-to-date information about items in stock and stock values, and the purchasing module gives automated purchase recommendations according to specified minimum values (order-points). When implementing the modules the order-points were just set to some random values, according to the circulating amount of each product, to make the module work.

The stock amounts in August 2011 were at an extremely high level. There were about 37,000 items in stock, which is about 45% of circulating rented inventory. The optimum percentage ought to be around 10%. The aim for the inventory control is to meet this target percentage with the help of redefined order points and order quantities.

2 THEORY

2.1 Inventory Management

Inventory management is a broad concept of controlling *stocks* within an organization. Stocks can be anything from paperclips to knowledge. For banks stocks are cash reserves, for an office one form of stock can be spare pencils and for a car manufacturer stocks can be metal sheets used for the body of the car. In general, stocks are materials which are not needed immediately. The listed *items* in stock are called *inventories*. Single products in stock are called items and a *unit* is a standard size or quantity of an item. Some quarters use the term *stock keeping unit (SKU)* for the items in stock. (Waters, 2003, 4-7)

The demand of a single item changes due to production runs, the market situation, faults, weather and so on, depending on an organization and products. The organizations try to meet the changing demand by having some items in stock, so that when there is a need for the item, the demand can be fulfilled. If organizations do not have stocks they cannot (usually) meet demand as fast as needed because it takes time to manufacture or for the supplier to deliver the needed items. Some other reasons for holding stock are to reduce the risk of delayed or incorrect delivery, reduce the transportation costs of a single item, gain discounts on larger order quantities and avoid an expected rise on price. (Walters, 2003, 8) According to Silver, Pyke and Petersen (1998, 27), the type of demand can be different according to the way items are issued from stock; the items may be issued item by item, by the dozen, by hundreds.

In the modern manufacturing industry organizations have different types of stock in order to meet the demand and internal and external variations. According to Waters (2003, 9) there are typically five different types of stocks:

- raw materials
- work in progress
- finished goods

- spare parts
- consumables

One of an inventory manager's main tasks is to control the flow of goods to the stock so that the combined costs of inventory and purchasing are minimized as illustrated in Figure 1. To find the optimized solutions there are two common questions to be answered:

When to order?

The timing of ordering is important since if the order is placed too late there is a stockout situation and if the order is placed too early there probably are some items in stock when the new order is delivered to the stock. If the re-order point is too high the average inventory value increases, which causes more capital costs.

How much to order?

The right order quantity on the other hand is the trade-off of the inventory holding costs and purchasing costs.

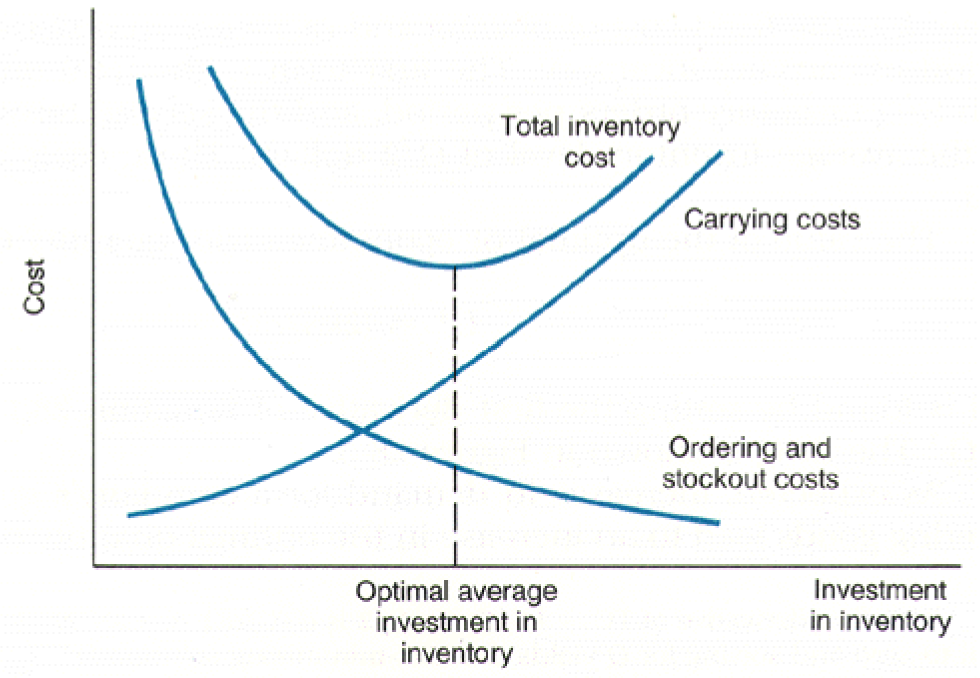

FIGURE 1 - Trade-off between stock costs and order costs. (Shapiro & Barbirer. 2009)

Figure 2 illustrates the typical stock cycle. The figure is an example of how the stock quantity reduces over time according to its usage. At a certain point a purchase order is placed to avoid the stock running out.

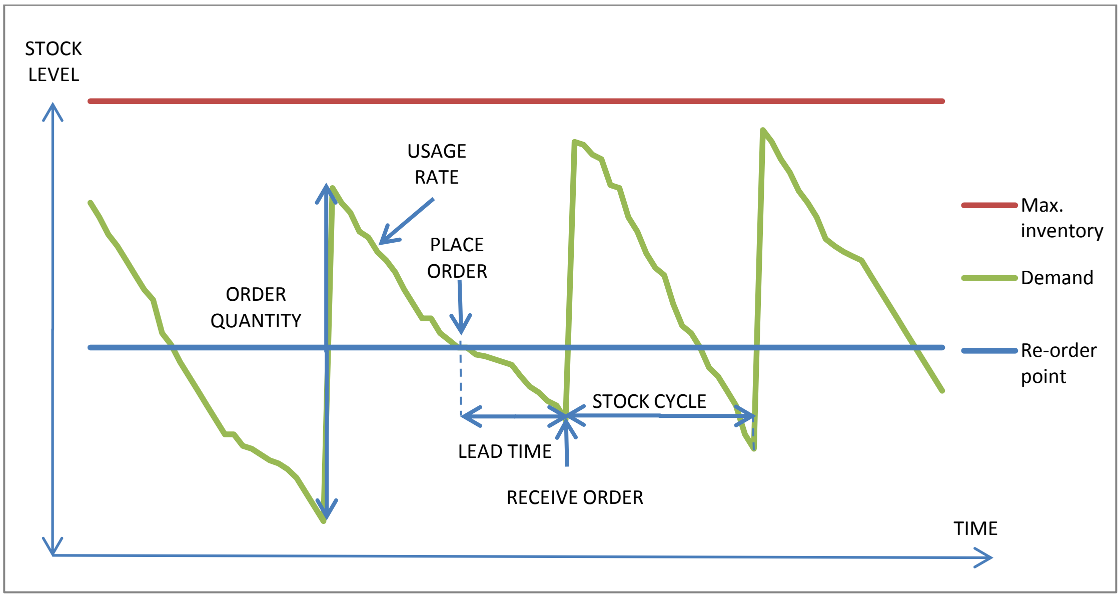

FIGURE 2 - Typical stock cycle.

The important concepts shown in Figure 2 are defined as:

Re-order point (s) - The point when a new purchase order is placed. (Slater, 2010, 11)

Order Quantity (Q) - The amount ordered after the re-order point is reached. Sometimes order quantity is also known as lot size. (Slater, 2010, 11)

Maximum inventory (S) - The maximum level of units of a product in stock. Used for the order quantity specification for min-max ordering systems. (Slater, 2010, 11)

Lead time (L) - The time from ordering to receiving of the order is called lead time. Lead time for each supplier and product may, and probably will, be different.

Cycle Time - The time from order to re-order of a single item is called the cycle time.

Usage rate (D) – The amount of products that are needed from the stock. The term demand is often used for the same meaning.

Inventory turnover (T) - Rating that tells, in theory, how many times in a year the inventory is used. If the average annual inventory value is €500,000 and the annual usage from the stock is €3,500,000 the inventory turnover is 7 (3,500,000 / 500,000 = 7). Higher turnover figures mean that on average less capital is tied to the stock. The inventory turnover rating is a useful target figure for inventory control. (Waters, 2003, 54) (Slater, 2010, p.11, 15, 30)

2.2 Purchasing

2.2.1 General

Purchasing is an important function for a company for acquiring the needed products (Rauhala, 2011, 11). Before the actual purchasing can start, an organization has to select the type of products provided and find the most suitable suppliers for these products. The product and supplier selection are important parts of a company's strategy which have to be considered thoroughly. Once the strategic decisions have been made, the actual purchasing can be started. Purchasing can be done in different ways depending of the type of need of the products required. Often purchasing is just the ordering of defined products from the defined suppliers with defined prices. For the ordering of defined products and prices, it is important to find the optimal ways and quantities to do the actual order process. (Waters, 2003, 52)

It must be noted that when suppliers are selected, besides product quality and price, also ordering methods, lead times and supplier service level should be taken into account. These factors may increase the inventory holding costs more than the achieved savings with a low-cost supplier.

2.2.2 Ordering costs

The fixed ordering costs when placing an order are called order costs. These costs include everything that is independent from the quantity of the placed order. The fixed telephone, IT and office costs are part of ordering costs. The time used to place an order, follow up and for invoicing is considered as fixed order costs although they vary a bit according to the order quantity. (Waters, 2003, 52; Muckstadt & Sapra, 2010, 12; Silver et al. 1998, 46) In practice the easiest way to define the order cost is found by dividing the annual purchasing personnel costs by the sent orders (Waters, 2003, 52). There are different arguments over whether the actual shelving and transportation costs should be part of the order costs. Waters (2003, 52) mentions that sometimes these costs are included in the ordering costs and sometimes not.

2.2.3 Ordering methods

There are four common methods for the ordering of stock products. The difference between these methods depends on the review method and the definition of order quantity. Different methods are commonly used for different product classes. During the past twenty years the use of computers has changed the method of reviewing and for most IT solutions the review method is automated to give the order request on a status quo principle. The methods are described below.

s, S -method

The order point and maximum inventory are fixed. The stock is continuously reviewed and when the stock level meets the re-order point (s) a purchase order up to the maximum inventory level (S) is generated. This method is also called the min-max method. (Silver et al. 1998, 238)

s, Q –method

The order point and order quantity are fixed. The stock is continuously reviewed and when the stock level meets the re-order point (s) a standard sized purchase order (Q) is placed. (Silver et al. 1998, 237)

Silver et al. (1998, 238) note that the above mentioned two systems would be the same if the usage from the stock is only one unit per transaction and the order is placed before the next transaction. In reality the usage is often more than one unit per transaction and there is a short period between when the re-order point is met and the purchase order is generated, which differentiates these two methods from each other.

R, s, S -method

The order interval, order point and maximum inventory are fixed. The inventory level is checked periodically (R), if the level is under the re-order point (s) a purchase order is placed up to the maximum inventory (S), if the level is not under the re-order point no order is generated. (Silver et al. 1998, 240)

R, S -method

The order interval and maximum inventory are fixed. The inventory level is checked periodically (R) and a purchase order is then placed up to the maximum inventory (S). (Silver et al. 1998, 239)

2.3 Inventory value

For accounting and material management purposes the value of inventory is needed at a specific time. The stocks organizations hold are usually acquired over a long time period and usually products in stock are bought at different times at different prices. This causes a dilemma about how to value the stock. The main principle is to multiply the purchase prices with the amount of inventory. The valuation of the products in stock at a certain time can be done in four different ways: (Waters, 2003, 48)

Actual cost

In the actual cost method the purchase price for each SKU is known and the inventory value is the sum of all SKUs. This method gives the exact value of the stock, but this can be an extremely laborious method for inventories that have thousands of items in stock. This method is usually used for inventories which have only a few expensive items in stock, like car showrooms. (Waters, 2003, 48-49)

First-in-first-out (FIFO)

The FIFO –method is based on the assumption that the oldest items in stock are sold or used first. In this method the amount in stock is calculated based on the purchase price of the latest order for the quantity of the latest order and then the price of the previous order for the quantity of that order and so on, as long as there is a price for all of the items in stock at that moment. FIFO is the standard method in many countries. The method illustrates quite well the actual costs, but in case the prices rise quickly the value can be overestimated if the products are actually not sold or used in the same way the method assumes. (Waters, 2003, 49)

Last-in-first-out (LIFO)

The LIFO –method is based on the assumption that the items that arrived most recently to the stock are used first. The value is calculated similarly as for FIFO, except the opposite way; the earliest order price is set for the same number of items than in the earliest order and so on. The LIFO –method tends to underestimate the stock value if the prices are rising. (Waters, 2003, 49)

Weighted average cost

Weighted average cost is the simplest method for large inventories. The average unit cost is calculated of all the purchases over a certain period of time and the average cost is multiplied with the units in stock. The downside is that this method can underestimate the inventory value when the most recent prices rise. (Waters, 2003, 49)

2.4 Inventory cost factors

2.4.1 Holding costs

Holding or carrying costs are the costs of keeping items in stock. There are various fixed or semi-fixed costs for carrying items in stock. Usually the holding costs are calculated per annum. According to Silver et al. (1998, 45), these costs are:

- Cost of money. In other words the capital cost percentage defined by the organization's upper management, which is the cost of capital needed for acquiring the items in stock. This cost is the interest rate paid for money borrowed or the possible return of investment rate from another possible investment (opportunity cost).
- Storage space cost. This includes the annual rent plus the interest or the annual depreciation value of the building.
- Handling costs. This includes the cost of needed machinery, their maintenance and electricity and the depreciation value.
- Utility costs. Containing needed lighting and heating.
- Administration costs. Containing needed computers, licenses, printers, paper and so on.
- Cost of loss, which are due to damage, pilferage and theft of the items in stock or the depreciation value of items in stock.
- Personnel costs.

Some studies calculate the stock personnel as a cost factor for holding costs and some overrule it. The amount of personnel at stock may be fixed and thus considered as part of holding costs. Some state that the shelving procedures should be part of the item costs and the picking procedures should be part of sales costs. Such thinking would consider only the time used for inventory calculation, data maintaining and cleaning as inventory holding costs.

2.4.2 Unit cost

Unit cost is the cost of getting the needed units to stock. If an organization manufactures the products itself complicated calculations may be needed to identify the unit cost, but if the product has been purchased the unit cost is the price of the unit from the supplier and the possible freight cost. (Waters, 2003, 52; Silver et al. 1998, 44) Silver et al. (1998. 44) state that the inspection of delivery and shelving costs should also be included in the unit cost.

2.4.3 Shortage cost

Shortage cost is the cost from many actions that happen or do not happen because there are no items in stock when needed. The cost of a shortage may be the lost sales for a customer, reduction in customer satisfaction, extra administration needed, loss of reputation, needed substitute product, rescheduling of operations, emergency delivery or even because of a lost customer and so on. It is hard to estimate the actual cost since the effect of shortage is something that normally would not happen or extra work is needed. (Waters, 2003, 53; Silver et al. 1998, 48)

Silver et al. (1998, 48 & 241-247) show different ways to evaluate the shortage cost, but they state that there is no precise way to model the costs and it is often more beneficial to reduce the probability of disservice than model the costs of disservice. One way to avoid shortage costs is to increase the safety stock and thus the re-order point.

2.5 Product categorization

General

In order to find the best practices for inventory control, one must first familiarize themselves with the products held in the inventory (Hoppe, 2006, 53). The list of inventories is a useful tool for an inventory manager. From it all the items in stock can be found, but it can be also used in decision making by helping to focus on the right things. When each individual SKU is defined one can categorize the items in stock and find the most important ones. (Silver et al. 1998, 32-33)

ABC analysis

It has been noticed that typically around 20% of products account for 80% of total usage value, 80% of investments in stock account for 20% of items and 80% of items come from 20% of the suppliers (Rauhala, 2011, 151; Silver et al. 1998, 32; Sakki, 2009, 90). This is usually the basis of product categorization and implies that not all the items should be managed the same way. The categorization can be made, for example, for three different classes according to the cumulative usage value. For example, class A for 0−50% of cumulative usage value, B for 51−80% and C for 81−100%. This classification is typically called an ABC-analysis. In an ABC analysis the importance of an item depends on its usage value. (Silver et al. 1998, 32-35) The classification should be done continuously to have the real-time classification for the basis of the optimization. The common mistake of not continuously categorizing the stock items tends to lead only to short-term success. (Hoppe, 2006, 53)

Class A

The class A products should be given the most attention since they constitute the most of the usage value and can be only 5−10% of product volume. This class should have as high an inventory turnover rate as possible in order to have the average stock value minimized. (Rauhala, 2011, 155; Hoppe, 2006, 57) According to Rauhala (2011, 154), the stock of "A" products must be kept as low as possible, while ensuring that they never run out. Rauhala's rule of thumb is that "*A-products should be in every arriving purchase delivery*".

Class B

Hoppe (2006, 57-58) states that B materials often represent 15−20% of the number of products and 15−20% of usage value.

Class C

The group C consists of the products that have a low usage rate. They often represent less than 10% of usage, but more than 50% of the different products. According to Rauhala (2011, 151-152), it is useful to add one to two classes to the analysis since group C tends to be too large to be managed.

It must be noted that an ABC analysis evaluates the criticality of the products only according to the demand, not according to the nature of the product. Some of the products may be critical for the sales or production even though their consumption is low. These so called “goodwill” products from B and C groups must be identified and given attention and even categorized in a different way. (Rauhala, 2011, 155)

XYZ analysis

Another classification method is the XYZ analysis. This is used to categorize the products in stock according to their consumption in units, whereas an ABC analysis is based on the consumption value in euros (Hoppe, 2006, 53).

2.6 Forecasting demand

2.6.1 General

The main point of inventory management is often not to present the current situation, but to plan the future stock levels. It is therefore important to forecast the future demand and costs. The forecasts give important information for the planning of the future activities, but they also need initial information. (Waters, 2003, 230-231). The needed information and information flow for a forecast can be seen in Figure 3.

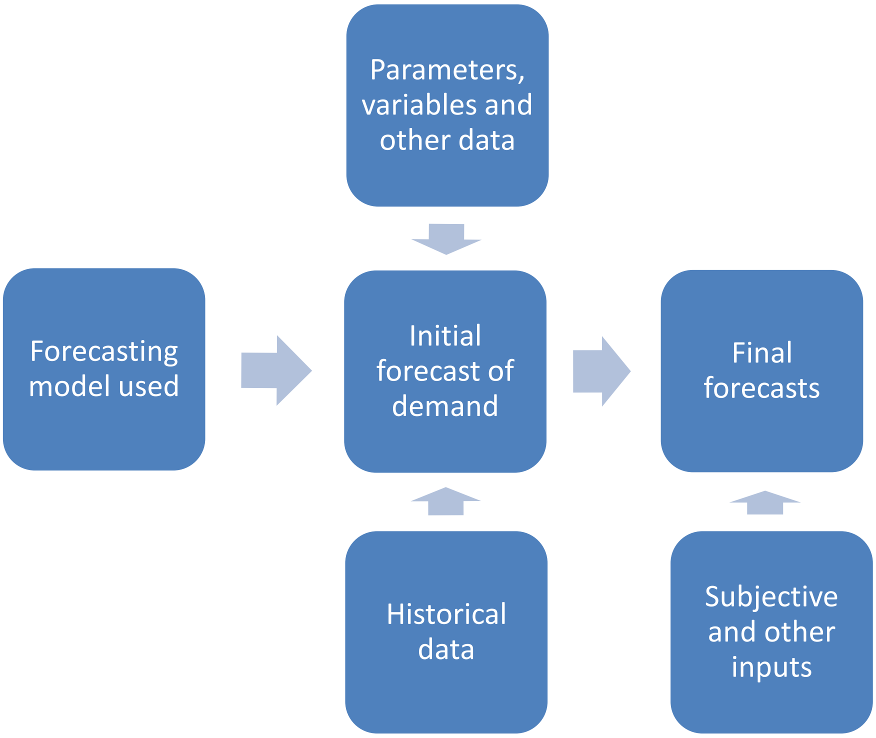

FIGURE 3 - Needed information for forecasts (Waters, 2003, 231).

The data for forecasting is collected from the different sources of the company. It is important that the accuracy of the data has been verified, the forecasting errors observed and the final forecasting model critically questioned and updated from time to time. (Silver et al. 1998, 75)
There are several different ways for forecasting depending on the time, type of product and availability, and the accuracy and relevancy of data. The purpose of the forecast defines the time horizon needed for the forecast; for strategic decisions the horizon ought to be long-term (several years), for tactical medium-term (three months to a year) and for operational level short-term (few weeks). Inventory control, according to Waters (2003, 233), generally requires the forecast to be for a few weeks ahead. According to Sakki (2009, 135), for inventory controlling, the forecast is needed for the period of the lead time, but usually a forecast is done for one to three months ahead.

In inventory management judgmental forecasting is used for new products, but for products with historical data the quantitative method can be used. According to Waters (2003, 233), in the projective method the historical data is looked at and the data is extended to the future. The causal method looks at the factors affecting demand. In Figure 4 different forecasting approaches are shown.

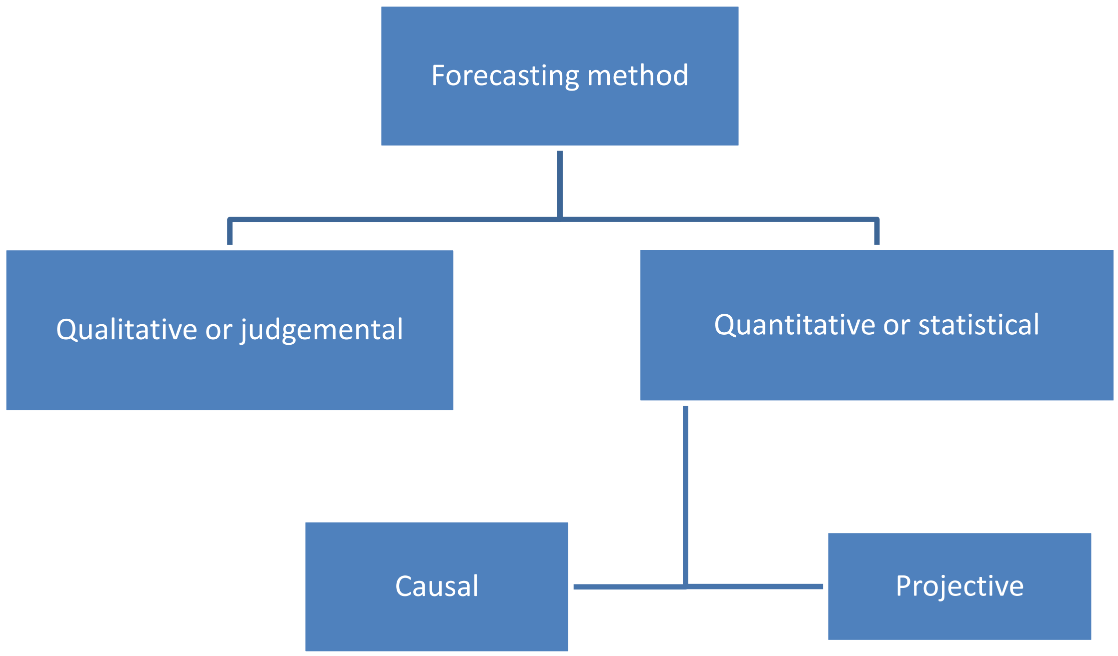

FIGURE 4 - Approaches to forecasting (Waters, 2003 234)

Sakki (2009, 135, 139) points out that the projective method that has a basis on historical data should be used for the items in stock that have a regular usage rate, since the technique is quite easy. Regular use of forecasting can lead to reduced inventory levels in the long run.

2.6.2 Time series

Time series are forecasting methods in which statistical usage data, which is collected for every certain standard time period, is analyzed. With the graphical presentation the usage patterns can be easily seen. (Sakki, 2009, 135-135) In reality the usage fluctuates. This not only shows that the simple average is not always the best way to forecast future need, but also that other ways are used to find a method that could better forecast the future demand. Some commonly used methods are:

Simple average

Simple average is the simplest way to forecast future demand. If the demand is stable simple average is a usable method for the forecast.

Simple average = (sum of demand over N periods) / N

$$\bar{x}_{t,N} = \frac{(x_t + x_{t-1} + x_{t-2} + \cdots + x_{t-N+1})}{N} \qquad \text{(Formula 1)}$$

x_t = usage

N = number of periods

t = period

Trend

Trend is an easy method to illustrate how the usage has changed in the long run. Trend describes whether the average usage is increasing or decreasing over a long period of time. The difference in the trend of different time periods can also show the maturity of the product. (Sakki, 2009, 136)

Moving average

In moving average the forecast is the average of the decided number of previous periods. For the next period the oldest usage figure is removed and the most recent number is added. Moving average usually follows the actual usage better than simple average. (Sakki, 2009, 137)

Average = (sum of demand over previous N_p periods) / N_p

$$\bar{x}_{t,N_p} = \frac{\sum_{t=1}^{N_p}(x_t + x_{N_p - t})}{N_p} \qquad \text{(Formula 2)}$$

x_t = usage

N_p = number of previous periods

t = period

Exponential smoothing

New forecast for next period = previous forecast + α * (previous period usage – forecast for previous period)

$$a_{t+1} = a_t + \alpha * (x_t - a_t) \qquad \text{(Formula 3)}$$

a_t = forecast made at t-1 for period t

x_t = usage

α = constant, $\in [0,1]$

t = period

2.6.3 Forecasting errors

The forecasts always contain errors when the demand fluctuates. This is why it is important to evaluate the errors and take them into account for a final forecast. There are a few ways to illustrate an error. The two most commonly used are mean squared error and mean absolute error. (Silver et al. 1998, 109; Sakki, 2009, 138-139)

Mean squared error (MSE)

Mean squared error is the average squared for the value difference of the forecast and actual usage over a certain time period. Silver et al. (1998, 109) recommend to use MSE for defining a forecasting error because of its easy usage and close relation to the standard deviation of errors.

MSE = [sum of $(\text{forecast} - \text{demand})^2$ over N periods] / N

$$MSE = \frac{\sum_{t=1}^{N}(a_t - x_t)^2}{N} \qquad \text{(Formula 4)}$$

x_t = usage

a_t = forecast made at t-1 for period t

N = number of periods

t = period

Mean absolute deviation (MAD)

MAD is the average of the absolute value for the difference of the forecast and actual usage over a certain time period.

MAD = [sum of | (forecast – demand) | over N periods] / N

$$MAD = \frac{\sum_{t=1}^{N}|a_t - x_t|}{N} \qquad \text{(Formula 5)}$$

x_t = usage

a_t = forecast made at t-1 for period t

N = number of periods

t = period

2.7 Order point

One of the most important parts of inventory controlling is the definition of when to order. For most of the systems the inventory is controlled according to the inventory situation. For this kind of method the need of replenishment is triggered by the stock module of an ERP system according to the inventory position and defined order point. To define the order point the lead time of each supplier, standard deviation of lead time and usage over lead time have to be found and the wanted service level needs to be decided to calculate the order-points. In theory if the lead time from the supplier would be zero the order point could be set so that when the last product leaves the stock a new product is immediately ordered and delivered to the stock. In a reality the lead time is at least few hours and also the lead time fluctuates for each supplier. According to Sakki (2009, 123), a common formula is used to define the re-order point.

On continuous review methods

Re-order point = forecasted usage on lead time + safety stock

$$s = D * L + B \qquad \text{(Formula 6)}$$

s = order point

D = demand

L = Lead time

B = safety stock

On methods with periodical review methods

Order point = forecasted usage over L * (lead time + half of the review period) + safety stock

$$s = D_L * (L + \frac{P}{2}) + B \qquad \text{(Formula 7)}$$

s = order point

D_L = demand over L

L = Lead time

B = safety stock

P = Review period

2.7.1 Lead time

Lead time, from a customer point of view, is the time from the moment the order point is reached until the new order is delivered to the stock and ready for use (Sakki, 2009, 120). It consists of the following steps:

(1) Customer makes an order

(2) Order is received and confirmed by the supplier

(3) Products are manufactured

(4) Order is packed and shipped

(5) Order is transported

(6) Order is delivered

(7) Products are checked, shelved at the customer and the data is updated

To reduce the lead time, improvements to one or more of these steps should be made. (Sakki, 2009, 121)

2.7.2 Safety stock

Safety stock is the stock needed to ensure the desired service level for fluctuating usage.

$$B = k * s * \sqrt{L} \qquad \text{(Formula 8)}$$

B = safety stock

k = safety factor

s = standard deviation of demand over L

L = lead time

Safety factor

TABLE 1 -Safety factor for service level

K - safety factor	0,5	1	1,5	2	2,5	3
Cumulative %	69,15 %	84,13 %	93,32 %	97,72 %	99,38 %	99,87 %

2.8 Order Quantity

2.8.1 General

How much to order? That is a question that most purchasers have to answer in order to succeed. The optimal order quantity can be defined with expert knowledge about the need and consumption of an item over a certain period of time, but not many experts can do this for all the products in stock. This is why it is more convenient to use some type of mathematical model. The most used method is the economic order quantity (EOQ) method, which is also known as Wilson's formula. (Rauhala, 2011, 193)

2.8.2 Economic Order Quantity

Economic order quantity is a wildly known method used to optimize the order quantities so that the combined costs of ordering and holding stock are minimized (Sakki, 2007, 116). This trade-off is illustrated in Figure 1.

$$Q_e = \sqrt{\frac{2*D_t*O}{U*H}} \qquad \text{(Formula 9)}$$

$Q_e =$ Optimal order quantity
D_t = demand over time period t
O = order cost
U = unit cost
H = holding cost percentage over time period t

EOQ Assumptions

The basic EOQ model includes the following assumptions (Waters, 2003, 67):

- the demand is known and it is constant over time
- all costs are known and do not vary
- no shortages are allowed

- there is no lead time
- orders and deliveries are done for single items
- no quantity discounts, so the unit and order cost do not vary
- the whole order is delivered once, no part-deliveries accepted

The mentioned assumptions simplify the basic formula so that it can be easily used in many industries. The purpose of the formula is not to give accurate results in a strict mathematical sense, but to simplify the actual circumstances. The formula has been proved to be accurate enough for many purposes. (Waters, 2003, 67)

2.8.3 EOQ Sensitivity analysis

In reality the demand and costs are not known for certain. To identify the effect of change in cost parameters or demand it is useful to analyze the sensitivity of the formula. (Waters, 2003, 87)

3. IMPLEMENTATION

3.1 Research working methods

On the basis of the theory the needed formulas were defined for order point and for order quantity. The needed cost parameters for the formulas were defined and the basic cost values were collected from the accounting, maintenance and production managers of the laundry. The values were calculated to resolve the accurate holding cost percentage and ordering costs. The information of holding costs is from the year 2011 and the information of the order quantities from the first nine months of 2011.

The information about order quantities as well as lead times was collected from the delivery notes of the suppliers and from Etra’s purchasing department. The information about orders and deliveries is from the first nine months of 2011.

The information about usage of test data was collected from the ERP system and calculated with Microsoft Excel. The test data was selected based on an XYZ-analysis about stock usage. Altogether twelve test products were selected; five from category A and three from both categories B and C and one product from category D. The period of the information is from the beginning of June 2011 till the end of September 2011.

The order points and quantities for test products were calculated and analyzed. Based on these analyses the definition of a final model was decided and the needed information for later purposes for creating an automated report are pointed out.

3.2 Used terminology

The garment stock at the laundry has 415 product codes with 1 to 24 different sizes per product in stock at the moment. Later on the following terminology is used: a single piece held in stock is called an **item** and a certain product with a certain size is called a **product.** For example, product WS1466/52 means product WS1466 (Trousers, Etra Rocket+), size 52. The product with many sizes is later called **product code**.

3.3 Stock conditions

In this case the products in stock are rather homogeneous; all the garments are made out of cotton, polyester or a mixture of the two. All the products need similar storing conditions; normal indoor humidity and temperature. All the products are quite similar sizes and all are rather light (50g to 1.8 kg). Most importantly, the products have quite the same price; from €2 to €87.

The inventory includes both new and used items. The reason for used garments in stock is because of the wearers who have left the customer or changed the size of their clothing. The biggest reason for the returning of used items to the stock is the seasonal workers of the customer companies who only work for a few months. The need of used items from the stock is also taken into account for the definition of the usage quantity of a product, since the usage of new and used from the stock is the actual usage of the product for a certain time period. If the used items would not be taken into account the calculated usage rate would be too low. This would lead to low order points and occasional stockout situations. In Figure 5 an example of the usage method is illustrated. New items come to the stock from the purchase orders and the used items from the ended customers or from the wearers whose employment has ended. By default the used garments are issued from the stock before new garments.

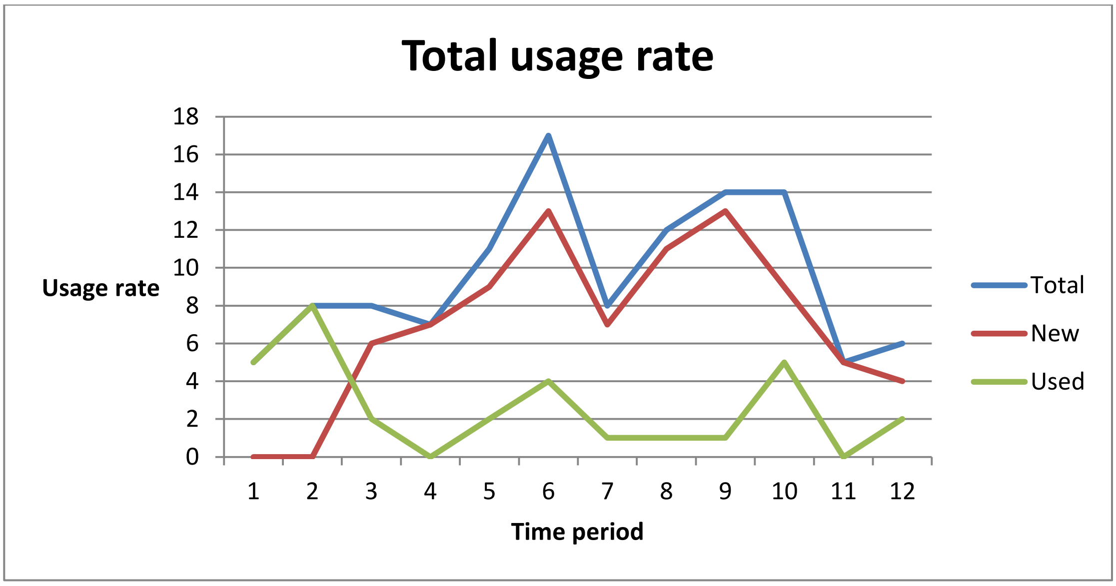

FIGURE 5 - Comparison of usage of different quality grades

3.4 Current ordering methods

The operational purchasing at the laundry has earlier been done mainly by one office person. In the case of a stockout or if the purchasing person is on vacation, the sales and customer service have also ordered items. The order has been placed when the stock employees have informed the purchasing personnel that some products are out or there are only a few items left in stock. The purchase person has then ordered 5 to 40 items of the product based on her experience of how important the product is. No product categorization or criticality analyses about the products have been done. These unprofessional actions have led to the current situation, where the inventory turnover rating is extremely low (1.18 for the time period 2/2011 – 6/2011 and 0.89 for the time period 6/2011 – 9/2011). There have been daily stockouts for some products, which means that the investments were made for the wrong products. The most important reason for bad inventory control has been the fact that the items on inventory had not been inserted to the stock module of the ERP-system prior to the beginning of 2011.

As mentioned earlier, in the stockroom and purchasing, modules of the ERP-system have been taken into use during 2011. With the help of these modules the up-to-date stock quantities can be seen and the purchase requests are made according to the order-point (minimum). The system is set by default to create purchase orders up to the maximum order quantity, which can be defined for each product separately. For products the minimum amount per order can also be defined.

For the ordering method the system sets a limitation. Since it does not have a feature for setting the maximum limit of product in stock, the order quantity has to be set for the system by using the Q-method.

3.5 Cost parameters

3.5.1 General

It is important to define the cost parameters as well as possible since if the parameters are not accurate enough the final order quantities may change from the optimal. In the following chapters the parameters have been calculated and discussed. Later it is shown how the change of the ordering cost and inventory cost percentage affect the economic order quantity.

It must be noted that there are different ways to accumulate the costs, since the same cost can be seen as fixed cost and as variable cost. In this thesis the costs that are fixed are calculated into the order cost and inventory holding costs.

3.5.2 Stock valuation

The inventory value for items in stock on 22 August 2011 is €765,529.07. This figure is not calculated from the average annual amounts of the stock as it should be since there is no data about the previous stock amounts. As the valuation method is used the latest purchase price per item for 65% of items and the average price of €22.95 for 35% of items is used.

3.5.3 Ordering costs

Defining the actual ordering cost is essential for the optimal order quantity definition. For ordering costs only the average cost of purchase order, cost of IT and possible order cost from supplier are considered to be fixed ordering costs. Shelving and inspection time and the cost of orders vary according to the delivery quantity and are therefore considered as part of item cost.

During the time period 1/2011–9/2011 there were 334 purchase orders for garments. The majority of purchase orders were from Etra. In the future the aim is to order mainly from Etra. The only exceptions are certain customer related items. In Table 2 the number and the distribution of orders for each supplier can be seen.

TABLE 2 - Purchase orders per supplier on 1/2011–9/2011

Supplier	Orders	Order-lines	Items on orders	Average order lines on PO	Average items on PO	Percentage of orders	Percentage of Items
Etra	266	1613	12024	6	45	80 %	77 %
Meira Nova	3	11	81	4	27	1 %	1 %
Image Wear	12	29	333	3	28	4 %	2 %
Kwintet Leijona	13	48	274	4	22	4 %	2 %
Kwintet Hejco	17	56	422	4	25	5 %	3 %
Standa	11	138	2104	13	192	3 %	14 %
Dimex	7	13	169	2	25	2 %	1 %
Fristads	5	16	119	4	24	1 %	1 %
Total	**334**	**1924**	**15526**	**6**	**47**	**100 %**	**100 %**

It has been estimated that in the laundry one fifth of one person’s working time is used for the purchasing of garments, and thus the average purchase cost per purchase order is €12.35. On top of the fixed purchase cost the cost of IT and office utilities for purchasing personnel is €0.90.

TABLE 3 - The ordering costs.

Average cost of actions per PO	€12.89
Average cost of actions per order line	€2.15
Average cost of actions per item	€0.27

It must be noted that the ordering costs are calculated for the time period when the purchase module of the ERP-system has mainly not been in use. The proper use of the purchasing module and the reduced number of the suppliers will reduce the time used for ordering.

3.5.4 Inventory costs

The data for inventory carrying costs is collected from the finance, maintenance and IT personnel of the company. A big issue when defining the inventory carrying cost percentage is whether the personnel costs of stockroom should be included or not, since most of the tasks in the stockroom are not associated with the ordering. The only personnel costs that should be considered for the inventory carrying costs is the time used for the inventory inspection, cleaning and data management (Model 2). If the personnel cost is taken into account as a whole (Model 1) the percentage will increase which will lead to reduced order quantities. However, if the personnel cost is not taken into consideration the inventory amounts may increase due to the increased order quantities. Later the sensitivity of the EOQ is tested and the impact of personnel cost is studied.

In Table 4 the values of each carrying cost component is calculated and in Tables 5 and 6 the percentage of each component respectively for Models 1 and 2 are illustrated.

TABLE 4 - Value of each inventory cost component

INVENTORY CARRYING COST VALUES FOR EACH COMPONENT			
* Inventory value		765 529,07 €	
1.	**Capital costs**	**61 242,33 €**	
	percentage	8 %	
2.	**Space costs**	**16 864,11 €**	
	Space	6,1 %	of whole building
	Rent	241 667,50 €	for whole building
	Interest	8 %	
	Insurance	943,06 €	
	Fire and accident	14 800,00 €	for whole building
	Environment	190,00 €	for whole building
	Others	470,00 €	for whole building
3.	**Handling costs**	**2 500,00 €**	
	Machines	2 500,00 €	
	Maintenance	1 500,00 €	
	Electricity	1 000,00 €	
4.	**Utilities**	**2 900,00 €**	
	Lighting	650,00 €	
	Heating	2 250,00 €	
5.	**Administration**	**6 570,92 €**	
	Computers	4 575,00 €	3 computers in use in stockroom.
	Depreciation	300,00 €	1500€ / pcs, write-off period 5 years
	ABS License	875,00 €	
	Maintenance	350,00 €	
	Printers	1 795,92 €	1 printer in use in stockroom
	Others	200,00 €	
6.	**Cost of loss**	**20 138,23 €**	
	Damages	250,00 €	Estimation of 10 items a year
	Theft	250,00 €	Estimation of 10 items a year
	Pilferage	500,00 €	Estimation of 20 items a year
	Depreciation	19 138,23 €	Estimation that 5% of items is sold for half price
7.	**Personnel**	**82 478,70 €**	Model 1
	Model 2	12 371,81 €	15 % of workforce at stockroom is used for data maintenance and inventory calcula-tions
	Model 1	82 478,70 €	3 persons
	Salary	22 600,00 €	
	Additional cost	21,65 %	
Total		**192 694,29 €**	

TABLE 5 - Inventory carrying cost component percentages (Model 1)

Inventory carrying cost percentage (Model 1)		
* Inventory value		765 529,07 €
1.	**Capital costs**	**8,00 %**
2.	**Space costs**	**2,20 %**
3.	**Handling costs**	**0,33 %**
4.	**Utilities**	**0,38 %**
5.	**Administration**	**0,86 %**
6.	**Cost of loss**	**2,63 %**
7.	**Personnel** (Model 1)	**10,77 %**
Total		**25,17 %**

TABLE 6 - Inventory carrying cost component percentages (Model 2)

Inventory carrying cost percentage (Model 2)		
* Inventory value		765 529,07 €
1.	**Capital costs**	**8,00 %**
2.	**Space costs**	**2,20 %**
3.	**Handling costs**	**0,33 %**
4.	**Utilities**	**0,38 %**
5.	**Administration**	**0,86 %**
6.	**Cost of loss**	**2,63 %**
7.	**Personnel** (Model 2)	**1,62 %**
Total		**16,01 %**

It must be noted that the stock value at the moment is extremely high, which leads to an underestimated inventory cost percentage. If the inventory value reduces the inventory carrying cost percentage will increase and cause reductions in optimal order quantities. Figure 5 shows the effect of inventory value reduction on the cost percentage. For example, a value reduction of 40% will increase the cost percentage by 9.8% from 25.17% to 34.95% for model 2. This is a 39% increase to the percentage figure.

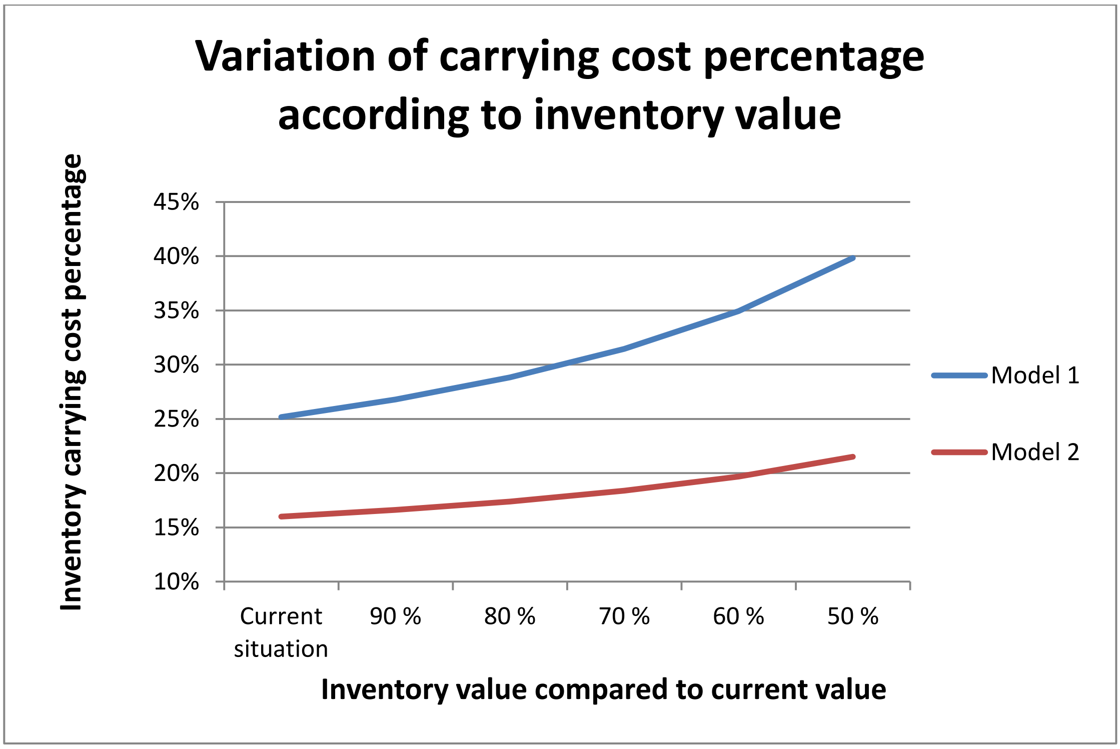

FIGURE 6 - Effect of inventory value on inventory carrying cost percentage

3.5.5 Unit cost

Unit cost is the cost of an item from the supplier. On top of the actual item cost the average transportation, inspection and shelving costs have to be considered. The cost of inspections and shelving were calculated from nine deliveries made in September 2011. For these deliveries the average time for inspection was 8 seconds per item and the average time for shelving was 16 seconds per item. The average hourly wage for a stock person with the overheads is €15.41. So the combined cost of inspection and shelving of single item is €0.10.

The average size of an order during the period 1/2011–9/2011 was 47 items and the average transportation cost for Etra was €15. This means that the average transportation cost of an item was €0.13.

The actual unit cost = the unit cost + €0.10 + €0.13

3.6 Product categorization

As of 30 September 2011 there were 37,377 items in stock, of which 77% were new and 23% used. 54% of used items in stock were unique which means that they have historical data on them, and 46% are non-unique, without data about the age of the product. Because such a big number of used products were non-unique and 33.04% of the issues are for the used items the items on stock have been categorized by an XYZ-analysis. This categorizes the products by the number of issues, not according to the issue value, during the time period 6/2011–9/2011.

During the period 11,161 items were issued from the stock of which 66.96% were new and 33.04% used. The inventory turnover rate was 0.89 for the whole stock, 0.78 for new stock and 1.29 for used stock. The analysis is illustrated in Table 7 and on Figures 6 and 7.

TABLE 7 - XYZ –analysis

Category	issued	% issued	products	% of products	Category lower limit no. issued per product
A	5615	50,31 %	107	3,82 %	25
B	3978	35,64 %	347	12,39 %	5
C	1309	11,73 %	407	14,53 %	1
D	259	2,32 %	259	9,25 %	0
E	0	0,00 %	1681	60,01 %	
Sum	11161	100 %	2801	100 %	

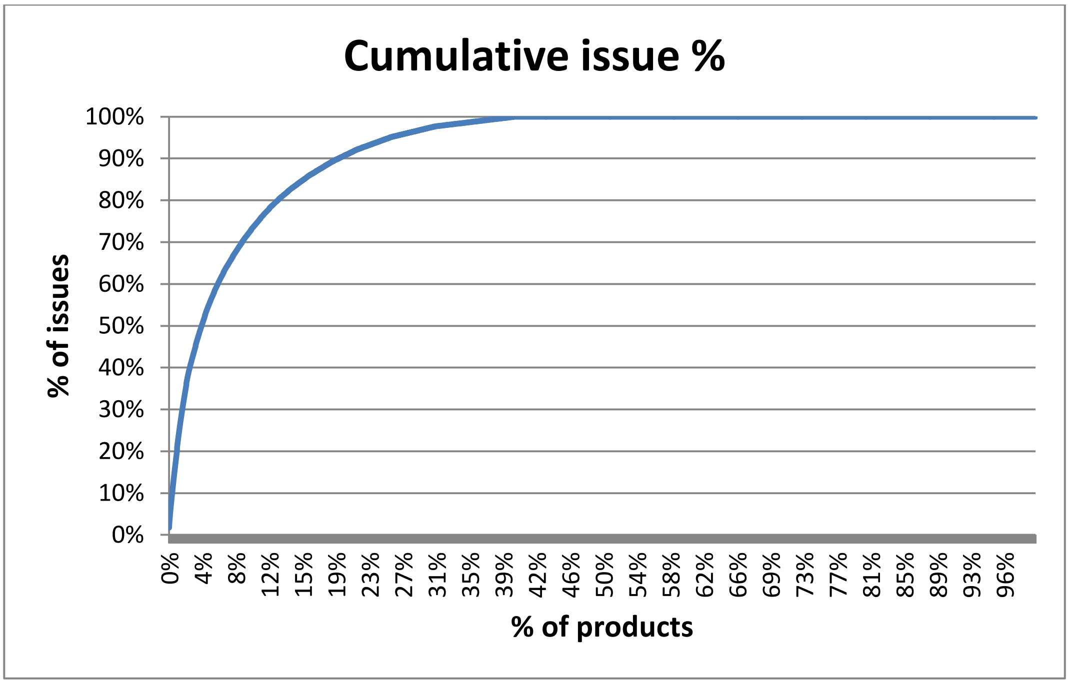

FIGURE 7 - Distribution of issues from the stock

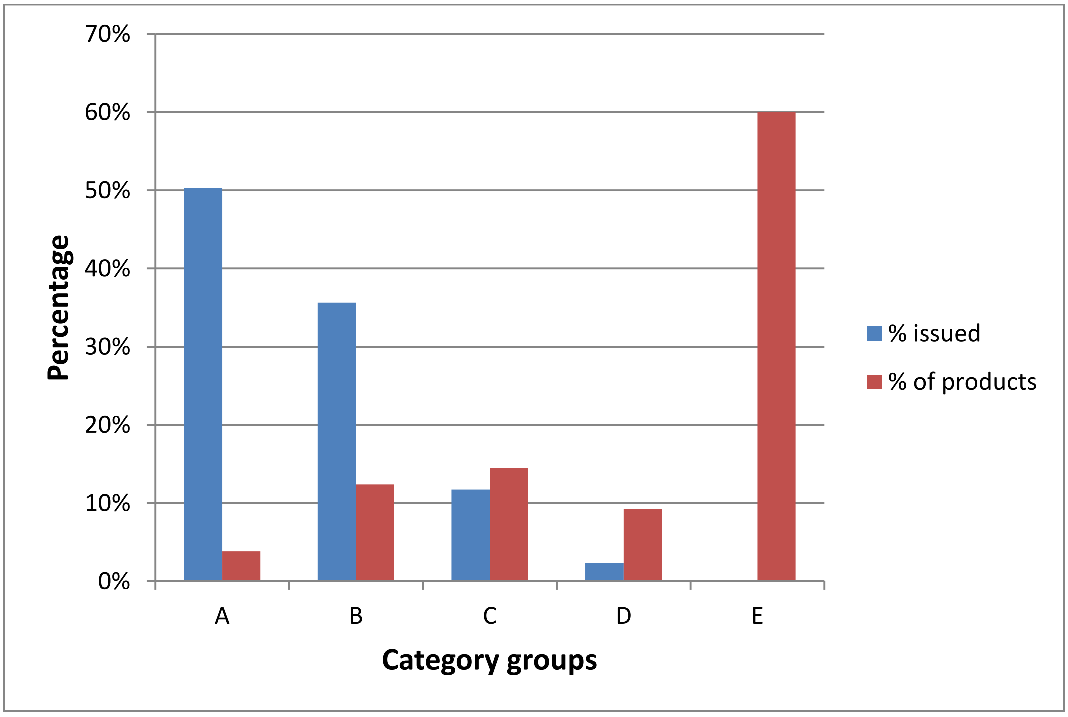

FIGURE 8 - XYZ categorization

From Table 7 and Figure 7 it can be seen that more than 50% of issues are from 107 products and actually only from 46 product codes. All the issues are for 40% of products. 60% of products do not have any issue history in the time period 6/2011–9/2011 and actually there are 188 product codes that do not have issue history for any size. It must be noted that the time period in which the data is collected is the summer season which is the quietest time of the year for the laundry industry.

3.7 Demand and forecasting

The demand from the stock for the commissioning company is due to four different reasons; (1) change after an old garment is worn out, (2) change for a different size, (3) issue for new employee of old customer or (4) issue for new employees for new customer. Due to this fact the demand has three basic models. When the new garment is needed, because the old garment is worn out, the need is usually by item and the demand is rather normally distributed. In case of a new employee or change of size, 2 to 6 items of a product for 1-5 product codes (shirt, trousers, jacket, overall etc.) is withdrawn from the stock. In case of a new customer the need cannot be estimated beforehand since the demand can be even hundreds of pieces and that's why all the garments for new customers are purchased separately. In fact, the garments of new customers are held in a different stockroom (106 starting inventory) and are also issued from that stock. The demand for new customers can be overruled from this thesis because of the nature of its demand.

The demand of a stock is not related to sales as much as in normal retail business. This is because the garments for new customers are bought separately and the demand of garments from the stock depends mostly on the wearing of a product and the amount of circulation of a product.

In order to find the best forecasting model 5 products from A, 3 products from B and C and 1 product from category D are chosen as test data. In Figures 9 and 10 the demand and time series for the demand are illustrated for products test A1 and test A2.

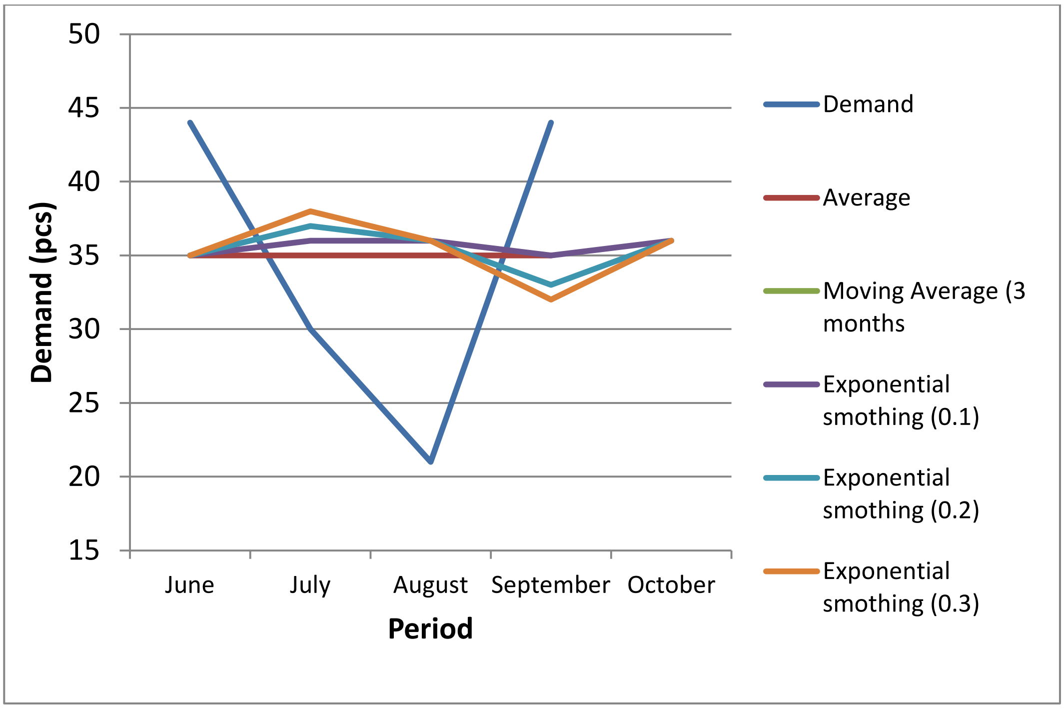

FIGURE 9 - Demand of test product A1

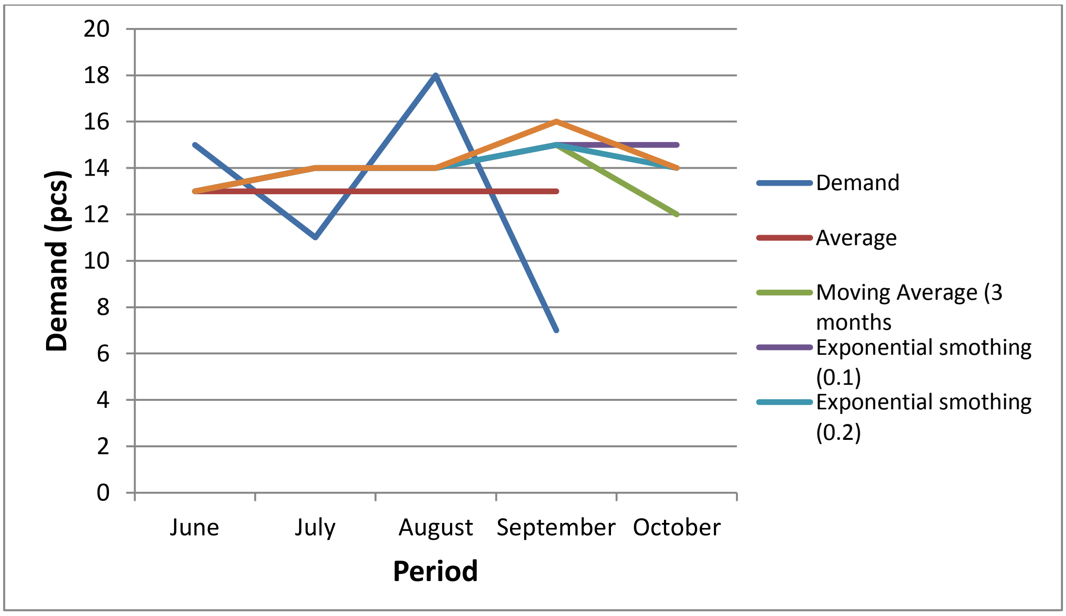

FIGURE 10 - Demand of test product A2

The monthly demand data of the test products was collected and different forecasting methods were tested in order to find the most suitable method to forecast the future demand. As can be seen in Figure 9, however, the demand varies a lot and it is hard to find a working model to follow the demand curve. For test product A2 (Figure 10) the change in demand during the test period was reasonable compared to the average demand.

For category B test products the average monthly usage was from 3 to 7 pieces and the most common (mode) monthly usage for these test products was zero.

Since there is test data available only for four months, the time series do not really give any further help for the forecasting of the future demand. Later the average monthly demand of the test period (4 months) is used as a demand rate for test products. The future demand forecasting has to be studied more in-depth when there is enough test data.

3.8 Order point

The order point is calculated with the widely used formula:

$$s = D * (L + \frac{P}{2}) + k * std_L * \sqrt{L}$$

For the formula the average usage during the review period and lead time is calculated and added to the safety stock. This is calculated by multiplying the decided safety factor with the standard deviation of lead time and square root of lead time.

3.8.1 Review method

When selecting the review method the ERP-system's limitations have to be considered first. The ABS Solute's purchasing module gives up to date purchase requests for all the products that have the economic amount (= on stock – reserved + ordered) equal or less than the order point. In reality it is not wise to order the products from the same supplier each day, but to combine the orders of one week per supplier as one purchase order. That is why the review period is calculated to be one week (five days).

3.8.2 Safety stock

Service Level

Customer service and satisfaction is extremely important for this industry since the rent prices on products are quite low. This means that every customer reclamation and administrative action may cause the loss of profit from that customer for months ahead. Also, the product unit prices are reasonably cheap. The average cost per item at the moment is about €25. That is why the service level of the stock can be set quite high in order to minimize stockout situations and customer complaints. At this point the service level is decided to be 97.7% which equals k factor 2.

3.8.3 Lead time

Rusanen has only 7 suppliers for the garments; Etra, Standa, Kwintet Hejco, Kwintet Leijona, Fristads, Meira Nova and Nybo Jensen, the most important being Etra. In Table 8 the lead times given by the supplier and the actual lead times on 1/2011–9/2011 are illustrated. The given lead times from the suppliers are on 5/2011 when the suppliers were asked for the product catalogues and supplier information for the implementation of the purchase module.

TABLE 8 - Lead times for suppliers

Supplier	Given lead time (working days)	Actual average lead time (working days)
Etra	3	5
Meira Nova	21	32
Image Wear	5	12
Kwintet Leijona	5	14
Kwintet Hejco	5	8
Standa	5	-
Dimex	14	6

To define the order point, the average lead time of each supplier is calculated in Table 8. From the table it can be seen that only Dimex has been able to supply the orders on time. For the other suppliers the average lead time will be used when calculating the order point.

3.9 Order Quantity

The order quantity is calculated according to the basic EOQ formula. As mentioned the basic formula has some assumptions which can be overruled. Some of the assumptions of basic EOQ formula, which can be overruled, are:

- The demand is known and it is constant over time. This factor can be overruled by re-calculating the order quantities after a certain time period according to the usage data.
- All costs are known and they do not vary. This factor can be overruled by reviewing the cost parameters frequently.
- No quantity discounts taken into account. At the moment only a few of the purchased items have quantity discounts. For these products the order quantity can be calculated separately.

The needed parameters for economic order quantity are for Model 1: Inventory cost percentage 25.17%, Order cost €12.89, cost of transportation, inspection and shelving €3.23. For Model 2 the inventory cost percentage is changed to 16.01%. For Model 3 the cost of transportation is not taken into consideration. For all the models the usage is calculated for the average of usage for time period 6/2011–9/2011.

For all the test products the order quantity for Model 1 is 20% less than for Model 2. In Model 1 the inventory turnover figure for test products from category A is from 5.8 to 8.2, for Model 2 it is from 4.5 to 6.6 and for Model 3 from 5.3 to 7.5. The order quantities for Model 1 can be seen in Table 10.

4. RESEARCH RESULTS

4.1 Order method

The ordering method to be used in the future for the laundry will be R,s,Q –methods. The order point and order quantity will be fixed for all the products and the orders will be done weekly for all the suppliers according to the purchase recommendations generated by the system according to the inventory position of each product. The case of a stockout can be overruled with the principle of one order per week.

4.2 Order Point

The order point for each product is calculated according to the following formula

$$s = D * \left(L + \frac{P}{2}\right) + k * std_L * \sqrt{L}$$

s = order point
D = demand (per day)
L = Lead time (days)
P = Review period (days)
k = safety factor
std_L = standard deviation of demand over L

The needed usage data and each supplier's average lead time are collected from the system when the order points are reset. In Table 9 the order points for test products have been calculated. The effect of high standard deviation can be seen on the order point of test product A3 and test product B6.

TABLE 9 - Order points for test products

Product	Supplier	Lead time (L)	Monthly average demand	Monthly standard deviation	ORDER POINT
Test A1	Etra	5	35	11,30	**24**
Test A2	Etra	5	13	4,79	**10**
Test A3	Etra	5	25	20,17	**30**
Test A4	Etra	5	20	13,20	**21**
Test A5	Etra	5	12	5,38	**10**
Test B6	Etra	5	7	12,50	**16**
Test B7	Etra	5	6	5,80	**8**
Test B8	Etra	5	3	4,36	**6**
Test C9	Standa	5	2	2,50	**4**
Test C10	Etra	5	1	1,41	**2**

4.3 Order Quantity

The order quantity will be most suitable when Model 1 is used. The order quantity for all the products will be set according to the economic order quantity with the following parameters:

- Annual inventory cost percentage 25.17%
- Order cost €12.89
- Cost of transportation, inspection and shelving €0.23 (added to the unit cost)

The usage data to be used will be the monthly average of the past four months until there is data for more than one year, at which point the seasonal index should be taken into use.

$$Q_e = \sqrt{\frac{2 * (3 * D_{4\,months}) * 12{,}89}{(U + 0{,}23) * 25{,}17\%}}$$

U = unit price of a product

$D_{4\,months} =$ Average demand of product for past 4 months

The order quantities for each test product can be seen in Table 10. In Table 11 the combined cost of ordering and holding items in stock is calculated. It can be seen that there ought to be 5 to 8 orders in a year for category A products and 3 to 4 orders for category B products.

TABLE 10 - Order quantities for test products

Product	Unit price	Transpor-tation etc.	Monthly average demand	Order cost	Holding cost %	Order Quantity
Test A1	13,80 €	0,23 €	35	12,89 €	25,17 %	**56**
Test A2	39,12 €	0,23 €	13	12,89 €	25,17 %	**21**
Test A3	15,78 €	0,23 €	25	12,89 €	25,17 %	**44**
Test A4	12,48 €	0,23 €	20	12,89 €	25,17 %	**44**
Test A5	20,64 €	0,23 €	12	12,89 €	25,17 %	**27**
Test B6	16,50 €	0,23 €	7	12,89 €	25,17 %	**23**
Test B7	19,32 €	0,23 €	6	12,89 €	25,17 %	**20**
Test B8	21,62 €	0,23 €	3	12,89 €	25,17 %	**13**
Test C9	21,90 €	0,23 €	2	12,89 €	25,17 %	**11**
Test C10	18,32 €	0,23 €	1	12,89 €	25,17 %	**9**

TABLE 11 - Total costs for test products

Product	Order Quan-tity	Order point	Aver-age stock	Annual orders	Order costs	Holding cost	Total costs
Test A1	56	24	52	7,5	96,68 €	183,63 €	**280,31 €**
Test A2	21	10	21	7,4	95,75 €	203,04 €	**298,79 €**
Test A3	44	30	52	6,8	87,89 €	209,55 €	**297,43 €**
Test A4	44	21	43	5,5	70,31 €	137,56 €	**207,87 €**
Test A5	27	10	24	5,3	68,75 €	123,45 €	**192,19 €**
Test B6	23	16	28	3,7	47,08 €	115,80 €	**162,88 €**
Test B7	20	8	18	3,6	46,40 €	88,57 €	**134,98 €**
Test B8	13	6	13	2,8	35,70 €	68,75 €	**104,44 €**
Test C9	11	4	10	2,2	28,12 €	52,92 €	**81,04 €**
Test C10	9	2	7	1,3	17,19 €	30,35 €	**47,54 €**

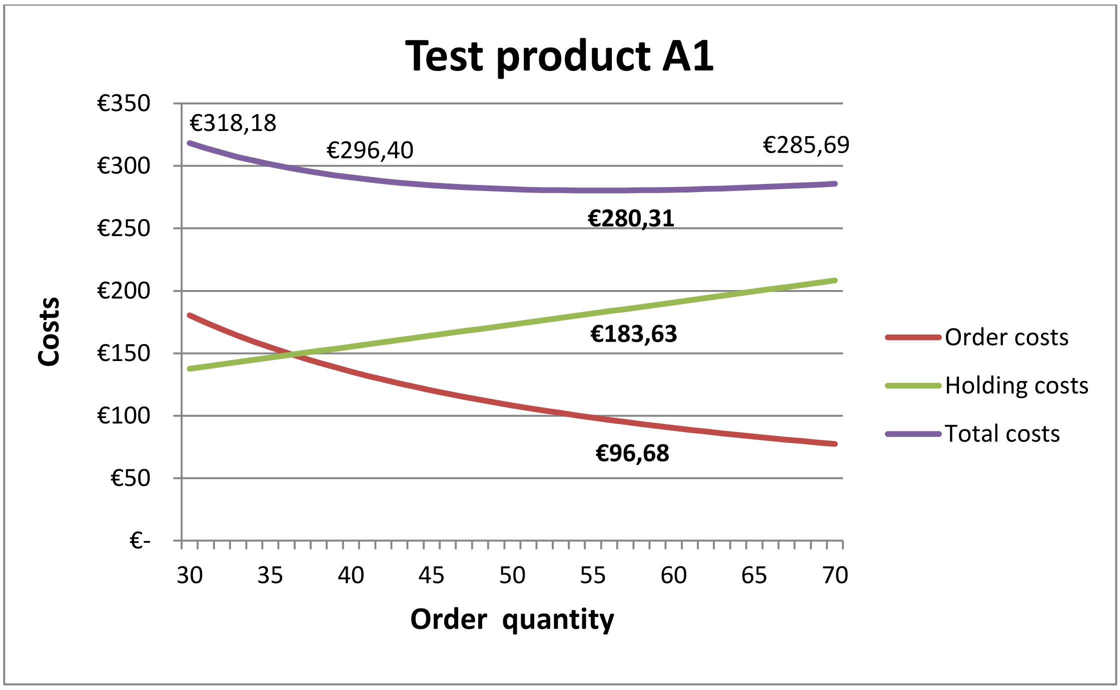

FIGURE 11 - Cost comparison for test product A1

4.4 Action recommendations

Automated updating of the parameters

Inventory controlling is a time sensitive activity where the components change continuously because the usage and supply vary. In order to make the best out of the study it is important to build automated processes to update the examined parameters. One way to do the update is to collect the needed data with a BI-tool like SAP Crystal Reports, sort and calculate the data and input the new values for the system. To set the updated parameters the following data has to be collected from the ERP-system:

For each product:

- Monthly issue history for past months (as many as possible)
- Current unit cost
- Actual lead times from the suppliers

The needed general information:

- Inventory value. To redefine the inventory cost percentage

Elimination of E-items

A rapid way to improve the stock value situation is to get rid of the E-items as fast as possible. These items hold valuable space in stock and increase the stock value. Also, the role of D items could be questioned. It should be considered whether there should be an outlet for the organization that would sell all the products that have been removed from the product catalog.

Product catalogue

On a higher level the number of suppliers and wide range of the product catalogue should be questioned. At the moment it seems that there are only a few customers for each product code.

Key performance indicators

Other improvement ideas for inventory management that could be made are the utilization of important KPI's such as inventory turnover ratings, percentage of products in different ABC –classes and the number of stockout situations. With the right indicators the inventory development can be more easily monitored.

5. DISCUSSION

The reliability of the research results can be questioned since there are a lot of variables that are defined according to the best knowledge practice, not according to precise data since there is no data on hand. It is also useful to question whether in this thesis the fixed and variable costs are defined the right way. A single matter that may be done differently in the future is the definition of whether the stock personnel should be part of inventory carrying costs or not. Stock personnel should probably not be part of holding costs, but since the inventory value is at the moment high, the inventory holding percentage would be quite low without this kind of “data manipulation”.

The order cost is now set according to the best practice policy not according to a thorough study, which may lead to a variation in the order quantity from the actual optimal quantity. At the time of the study however, the purchase module of the ERP was still in a test and implementation phase and there was no point to accurately calculate the workload, since the workload will change once the system is properly in use.

After all, the output of the thesis is useful, since without the mathematical inventory control method the current situation of high stock value and numerous stockouts would probably continue. The benefit of defined order points will hopefully make the purchase person’s work faster and easier and gradually reduce the stock value and increase the inventory turnover rating.

The cost parameters defined in this thesis can be later important information for the management for defining the amount of stock personnel and workloads of the personnel. The cost parameters could also be used as a benchmark for the industry for defining the stock holding cost percentage.

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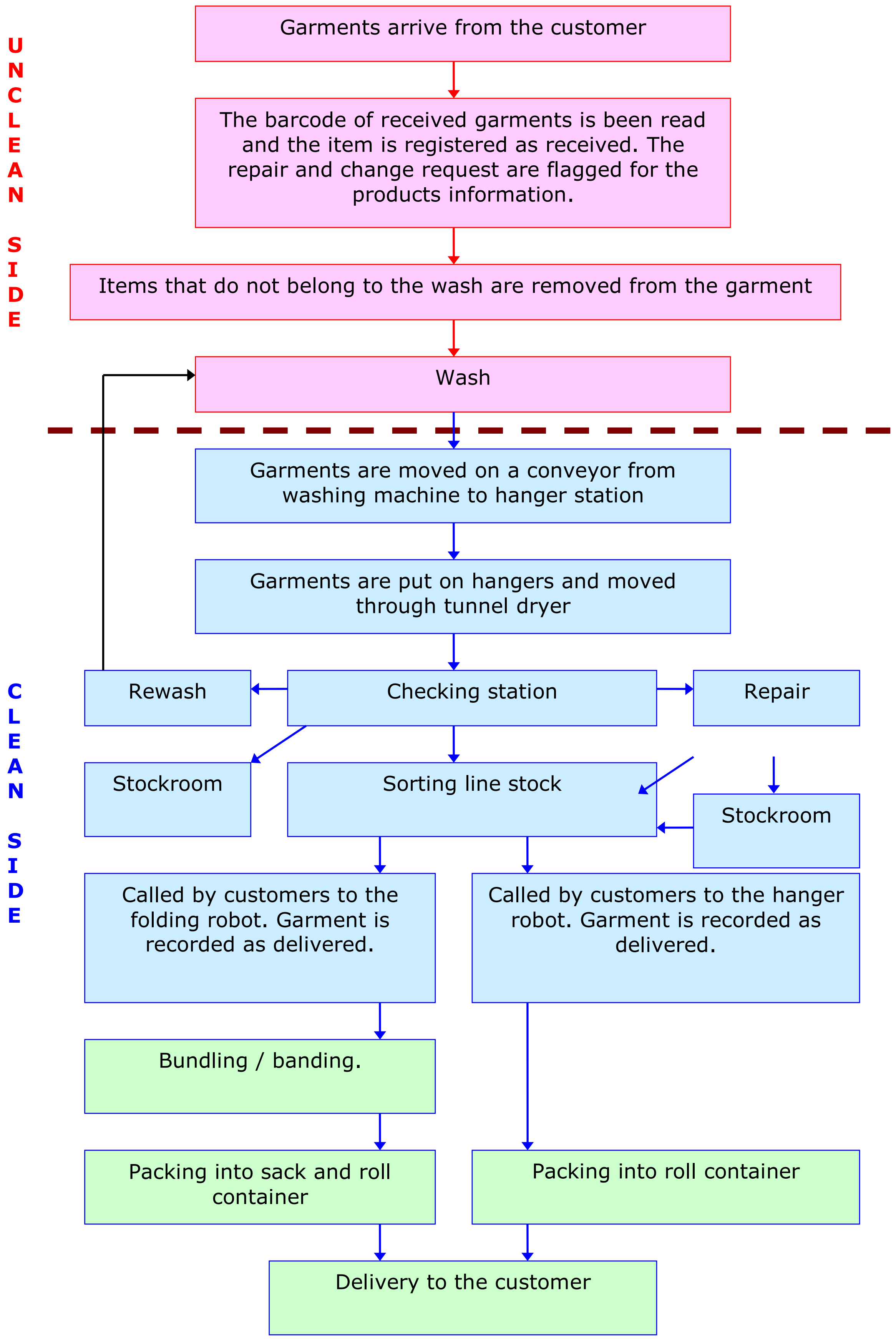
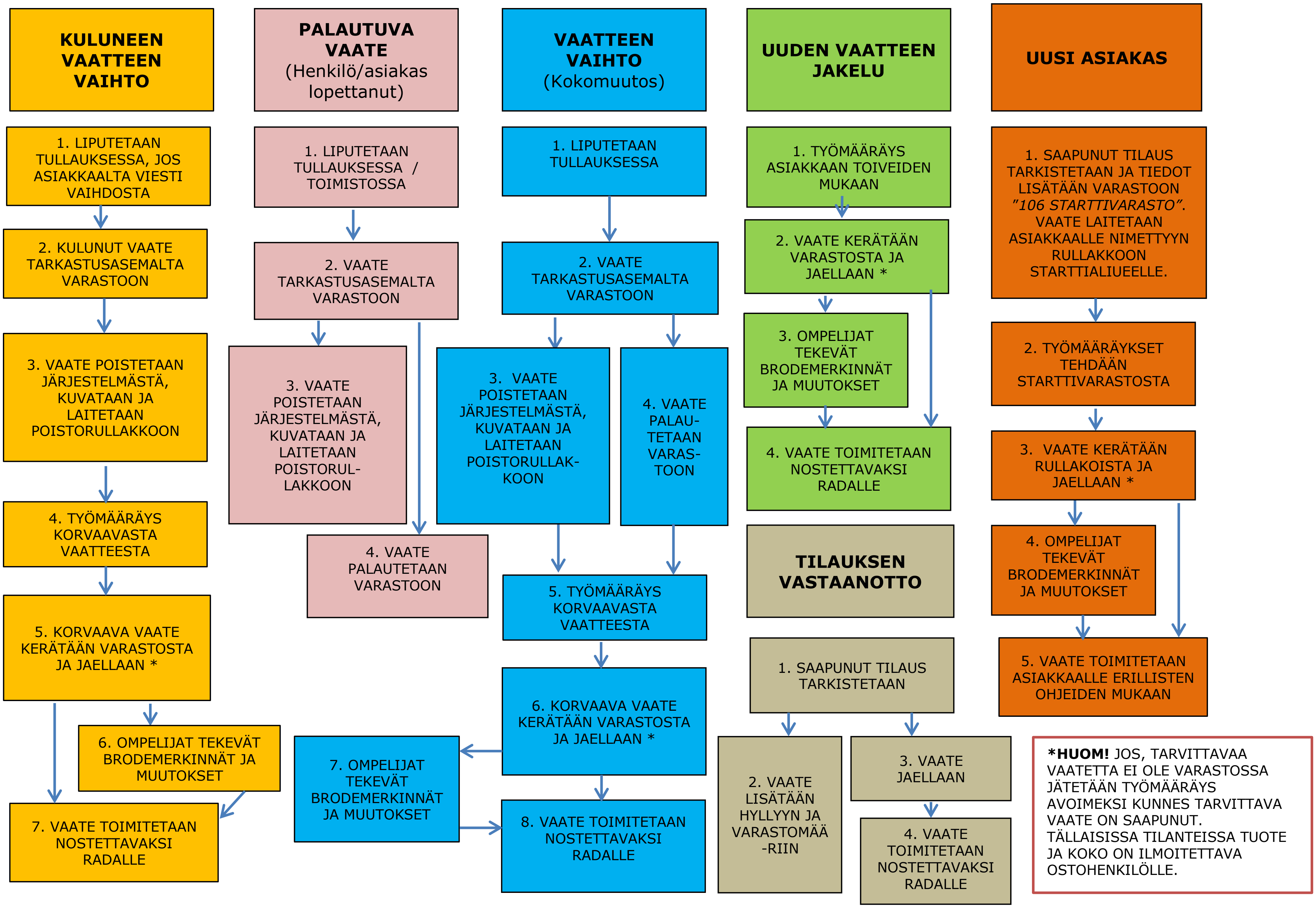
APPENDICES

Appendix 1. Process Description for Garments




KULUNEEN VAATTEEN VAIHTO
1. LIPUTETAAN TULLAUKSESSA, JOS ASIAKKAALTA VIESTI VAIHDOSTA
2. KULUNUT VAATE TARKASTUSASEMALTA VARASTOON
3. VAATE POISTETAAN JÄRJESTELMÄSTÄ, KUVATAAN JA LAITETAAN POISTORULLAKKOON
4. TYÖMÄÄRÄYS KORVAAVASTA VAATTEESTA
5. KORVAAVA VAATE KERÄTÄÄN VARASTOSTA JA JAELLAAN *
6. OMPELIJAT TEKEVÄT BRODEMERKINNÄT JA MUUTOKSET
7. VAATE TOIMITETAAN NOSTETTAVAKSI RADALLE
PALAUTUVA VAATE (Henkilö/asiakas lopettanut)
1. LIPUTETAAN TULLAUKSESSA / TOIMISTOSSA
2. VAATE TARKASTUSASEMALTA VARASTOON
3. VAATE POISTETAAN JÄRJESTELMÄSTÄ, KUVATAAN JA LAITETAAN POISTORUL-LAKKOON
4. VAATE PALAUTETAAN VARASTOON
VAATTEEN VAIHTO (Kokomuutos)
1. LIPUTETAAN TULLAUKSESSA
2. VAATE TARKASTUSASEMALTA VARASTOON
3. VAATE POISTETAAN JÄRJESTELMÄSTÄ, KUVATAAN JA LAITETAAN POISTORULLAK-KOON
4. VAATE PALAU-TETAAN VARAS-TOON
5. TYÖMÄÄRÄYS KORVAAVASTA VAATTEESTA
6. KORVAAVA VAATE KERÄTÄÄN VARASTOSTA JA JAELLAAN *
7. OMPELIJAT TEKEVÄT BRODEMERKINNÄT JA MUUTOKSET
8. VAATE TOIMITETAAN NOSTETTAVAKSI RADALLE
UUDEN VAATTEEN JAKELU
1. TYÖMÄÄRÄYS ASIAKKAAN TOIVEIDEN MUKAAN
2. VAATE KERÄTÄÄN VARASTOSTA JA JAELLAAN *
3. OMPELIJAT TEKEVÄT BRODEMERKINNÄT JA MUUTOKSET
4. VAATE TOIMITETAAN NOSTETTAVAKSI RADALLE
TILAUKSEN VASTAANOTTO
1. SAAPUNUT TILAUS TARKISTETAAN
2. VAATE LISÄTÄÄN HYLLYYN JA VARASTOMÄÄ-RIIN
3. VAATE JAELLAAN
4. VAATE TOIMITETAAN NOSTETTAVAKSI RADALLE
UUSI ASIAKAS
1. SAAPUNUT TILAUS TARKISTETAAN JA TIEDOT LISÄTÄÄN VARASTOON ”106 STARTTIVARASTO”. VAATE LAITETAAN ASIAKKAALLE NIMETTYYN RULLAKKOON STARTTIALIUEELLE.
2. TYÖMÄÄRÄYKSET TEHDÄÄN STARTTIVARASTOSTA
3. VAATE KERÄTÄÄN RULLAKOISTA JA JAELLAAN *
4. OMPELIJAT TEKEVÄT BRODEMERKINNÄT JA MUUTOKSET
5. VAATE TOIMITETAAN ASIAKKAALLE ERILLISTEN OHJEIDEN MUKAAN
*HUOM! JOS, TARVITTAVAA VAATETTA EI OLE VARASTOSSA JÄTETÄÄN TYÖMÄÄRÄYS AVOIMEKSI KUNNES TARVITTAVA VAATE ON SAAPUNUT. TÄLLAISISSA TILANTEISSA TUOTE JA KOKO ON ILMOITETTAVA OSTOHENKILÖLLE.