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IMPROVING DELIVERY ACCURACY BY INVENTORY CONTROL

– In spare part business

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MASTER'S THESIS (YAMK) | ABSTRACT

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IMPROVING DELIVERY ACCURACY BY INVENTORY CONTROL – IN SPARE PART BUSINESS

The purpose of the present Master's thesis is to improve the delivery accuracy and the service level of spare part deliveries in a case company. The way to do this is to study different inventory control and demand forecast methods. The methods are introduced in the theory section and the most suitable ones are executed in the case company and this is explained in the empirical section.

The demand for items and their variance is studied and analyzed through history data from the case company's ERP system. In addition, the items that have caused most delays are studied and analyzed. Standard deviation is a tool for recognizing which items have a stable demand and the ones whose demand varies randomly. The ABC classification method is a tool for classifying items and it is used to classify the items according to their demand pattern.

The present study concentrates on the inventory control of the items with a stable demand and the items that have caused most delays. Fixed order quantity system with safety stock is chosen to manage the replenishment system of these items. Standard deviation is again used as a tool to count the quantity of safety stock for different service levels for each item.

The history data used for analyzing the start situation is from January to December 2018. The new safety stock limits were updated on the company's ERP on August 2019. The following reports were taken from ERP at the end of November 2019, thus three months follow up was executed to see how the actions had affected the service level and delivery accuracy.

This thesis is an action research and the study describes its first cycle. The results were positive, and the actions have improved both the delivery accuracy and the service level. However, to continue the positive development, new cycles of action research need to be executed in the case company.

KEYWORDS:

Demand forecast, Inventory management, Standard deviation, Service level, Safety stock, ABC classification, Delivery accuracy

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TOIMITUSVARMUUDEN PARANTAMINEN VARASTONHALLINNAN AVULLA - VARAOSALIIKETOIMINNASSA

Tämän opinnäytetyön tarkoitus on parantaa case-yrityksen toimitusvarmuutta ja palvelutasoa varaosaliiketoiminnassa. Tähän tähdätään tarkastelemalla erilaisia varastonhallinnan ja kysynnän ennustamisen työkaluja. Teoriaosuudessa esitellään näitä työkaluja ja niistä sopivimpia otetaan käyttöön case-yrityksessä ja käyttöönottoa selitetään käytännön osiossa.

Varaosanimikkeiden kysyntää ja sen vaihtelevuutta tutkitaan ja analysoidaan case-yrityksen ERP-järjestelmästä otetuista raporteista. Niiden avulla tarkastellaan myös, mitkä nimikkeet ovat aiheuttaneet eniten myöhästymistä tilausten toimituksissa. Keskihajonnan avulla tunnistetaan, millä nimikkeillä kysyntä on ollut vakaata, ja millä kysyntä on ollut vaihtelevaa. ABC luokittelua käytetään jaottelemaan nimikkeitä ja tässä työssä ABC luokittelua on käytetty jakamaan nimikkeet niiden kysynnän vaihtelevuuden mukaan.

Opinnäytetyö keskittyy sellaisten nimikkeiden varastonhallintaan, joilla on vakaa kysyntä, ja jotka ovat aiheuttaneet usein toimitusten myöhästymistä. Näiden nimikkeiden varastonhallintaan on päätetty ottaa käyttöön tilauspistejärjestelmä ja varmuusvarasto. Varmuusvaraston suuruuden määrittelyyn on käytetty kysynnän keskihajonnan laskentamenetelmää.

Alkutilanteen määrittelyyn käytetty data on case-yrityksen ERP-järjestelmästä otetut raportit vuodelta 2018. Uudet varmuusvarastotasot ja tilauspisteet päivitettiin ERP-järjestelmään vuoden 2019 elokuussa. Seurantaraportit otettiin järjestelmästä marraskuussa 2019, jolloin nimikkeiden tilauspisteet olivat olleet käytössä kolme kuukautta. Seurantaraportin avulla voidaan nähdä, miten uudet tilauspisteet ja varmuusvarastot ovat vaikuttaneet toimitusvarmuuteen ja palvelutasoon.

Opinnäytetyö on toimintatutkimus ja sen ensimmäinen kierros on esitelty. Tulokset ovat positiivisia ja tehdyt toimenpiteet ovat parantaneet sekä toimitusvarmuutta että palvelutasoa. Toimintatutkimuksen periaatteita seuraten uusia kierroksia ja tutkimusta tulee jatkaa, jotta toimitusvarmuus ja palvelutaso edelleen kehittyvät paremmaksi.

ASIASANAT:

Kysynnän ennustaminen, Varastonhallinta, Keskihajonta, Palvelutaso, Varmuusvarasto, ABC luokittelu, Toimitusvarmuus

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1 INTRODUCTION

1.1 Is it important to improve delivery accuracy

Improving delivery accuracy is ultimately about satisfying a customer and keeping the promises made. The customers are the ones keeping any business alive and thus are the first and the most important group to consider when doing business and developing processes further. Harrison and van Hoek (2011, 36) state that only the end-customer brings a company profit, growth and security.

Customer's expectations have risen at the same time as the general increase in wealth in developing countries. They expect better quality products and better level of service. Thus, companies need to meet these high expectations by being more customer oriented and responding to the customer rapidly. (Harrison & van Hoek 2011, 37-38; Rushton et al. 2017, 55.)

Customer service is widely recognized as an important aspect of business. There are many factors, that compose to customer service and logistics process and distribution are two of those. Availability of items and delivery reliability are logistical elements of customer service. (Rushton et al. 2017, 33.)

When a company succeeds in satisfying the customer's need, it sets a possibility to improve customer satisfaction and through that customer loyalty. Satisfaction is an attitude towards the company and tells what the customer thinks about the company. Customer loyalty can build up from customer satisfaction and is a behavior towards the company. Loyal customers bring companies large benefits, such as long-term revenue. They also tend to do big purchases and increase them over time. (Harrison & van Hoek 2011, 51-52.)

Keeping the promised delivery date is answering to the customer's expectations and keeping the customer satisfied. Delivery accuracy is one factor in creating possibilities for customer loyalty.

The quantity of items on offer and quantity of inventory are essential from customer service point of view. On the other hand, high level stock means high level costs and the tied-up capital is potentially very high. There is a challenge to balance the costs and the service when keeping a stock. (Rushton et al. 2017, 237.)

1.2 Goals and research problem of the study

The final and main objective of this study is to improve delivery accuracy of the case company's spare part shipments. This objective is divided into smaller, middle objectives, which help to achieve the final goal.

The first middle objective is to find out which items cause delays most. The first measuring point will reveal this. After getting the results from the first measures, the results are analyzed which items have caused delays during the measured period. The data behind the items in ERP also need to be audited on which is replenishment way, safety stock and other details leading how to manage the items in stock.

Second objective of this study is to introduce new ways of managing the items in stock. The goal is to find more proper ways to handle the items so that the components would have a better stock timing, with no lackings nor slow movings.

Changes are made to stock management of item in ERP according to the introduced item management model for the chosen components. After a chosen period of time, another measuring will be executed. The second measuring will reveal if the new way of managing the items has changed the amount of delays and thus if it has had the anticipated effects on delivery accuracy.

This thesis will also show an ABC-analysis of items on offering. This analysis together with the analysis of delay causing items gives a holistic understanding of current status of item and stock management. Thus, the goal is to define the most important components and confirm availability of them always.

In this thesis, I concentrate on examining the delivery accuracy of spare part orders in the case company, not the orders which are produced or assembled. First, because the company management has set spare part business as one of the key strategic points to develop and together with delivery accuracy being one of the key strategic indicators, the business field and the subject are important to the company. Second, there has not been a determined and large examination of items, their influence on delivery accuracy and analysis of items on offer in the company. It is essential from delivery accuracy point of view that stock items are managed in most suitable way.

There are two main research questions in this study and they both aim to reach the study goal. The first research question is

Which items cause delays most?

A report from ERP shows all cases when a shipment has been delayed due to lack of some components. The items and item groups that meet lack of stock most frequently are found by analyzing this report.

Second research question of this study is

Which ways of managing stock suits for each item group best?

The goal is to find more suitable ways to control the items in a way that the components would have better stock timing, no lackings nor slow movings.

1.3 Research methods used in this thesis

This thesis is an action research, which is a process of developing better solutions to everyday problems in companies' real life. The real need for action research comes from inside the companies to find better ways to practice their core business and processes. (Saunders et al. 2016, 189-191.)

The aim and purpose of action research is a change in the situation. The research does not only describe the research object but also affects it by changing it or developing it further. The researcher must know the causal connections in order to know how to interfere to the subject. (Kananen 2012, 37.)

In addition to making a change to the subject, another characteristic of action research is that the researcher is an integral part of the research. The researcher is a part of the research subject, to which a change or development is planned. (Kananen 2012, 38.)

An action research goes ahead like a cycle. First, the research begins by a planning phase, when the subject is defined. This defining phase needs enough time to identify the correct problems and things influencing it. At the same time as defining the research problem, the researcher needs to set goals and how to measure them. Setting a goal without determining how to follow it, makes hard to evaluate success. (Kananen 2014, 35.)

After carefully defining the research problems and turning them into research questions, the research takes a step further and the researcher’s aim is to interfere to the situation with a planned and specific action. The interfering action is something, which the researcher knows has an effect on the subject.

At the end of the cycle, the researcher evaluates and analyses if the actions have had an influence on the subject and if the situation has changed from the original. In action research, the situation is not only analyzed once, but requires constant follow up on the subject. (Kananen 2012, 39.)

A researcher can analyze based on theory or based on collected data. If a researcher bases the analysis based on professional literature, makes assumptions from it and then tests it on his or her own case, it is deductive approach. (Kananen 2012, 36.) This thesis has a deductive approach, as new type of item management systems is studied through literature and applied to case company.

One characteristics of deductive approach is that the set of assumptions, which are tested in the research are very strictly described. The variables that are assumed to influence the subject or the concept are also defined very precisely.

This enables to test how the variables affect the concept and makes possible to repeat the test the same way. Deductive approach uses highly structured methodology and the variables are usually studied by quantitative methods. The research and the relationships between variables and concepts are best understood if the elements of research are made as simple as possible. (Saunders et al. 2016, 146-147.)

Finally, one characteristics of deductive approach is generalization. It is important to identify how widely the researcher can make a generalization according to the research results. The researcher must be careful not to use too narrow sample for too large generalization. (Saunders et al. 2016, 147.)

It needs to be acknowledged that the conclusions made through deductive approach may not be true in reality, but they are logical conclusions. The researcher may or may not approve the hypothesis based on previous studies, theories and literature, so the hypothesis can be approved or rejected. (Ghauri & Grønhaug 2010, 15.)

Quantitative research methods are used in this thesis. In quantitative research the phenomena or the subject is already familiar to the researcher as well as the variables having an effect to the object. This is because a quantitative research cannot be done if the researcher does not know what to study. The quantitative research is often used in business field to show exact data of exact subjects. (Kananen 2012, 30-31.)

1.4 Case company

The case company works in maritime industry as well as power plant industry by offering customers fuel oil supply units with many different functions. The units are made for instance to filter, heat and cool oil before it is supplied to main engine of a ship or a power plant. Many functions may be combined in one unit and a ship or power plant may have several units installed for different functions. The company’s customers are engine manufacturers, shipping companies and shipyards.

The case company has delivered around 15000 units around the world which all need maintenance. Thus, the spare part markets are notable for the company.

2 DEMAND FORECAST AND INVENTORY MANAGEMENT

2.1 Holding stock

Lysons and Farrington (2016, 291) gives a description to the word inventory. According to The Institute of Logistics and Transport inventory means “all the goods and materials held by an organization for sale or use” or “all the items held in stock”. Another definition from the same institute is that inventory means “materials in a supply chain or in a segment of a supply chain, expressed in quantities, locations and/or values (synonym stock).

Different type of businesses hold stock for different reasons and there are many reasons why it is necessary to hold stock. Keeping stock help companies minimize production delays, avoiding bottlenecks and ensures smooth production. Holding stock help companies accommodate to demand variations or changes in supplier’s lead time. Holding stock is also a way to serve both internal and external customers at required service level by being able to satisfy their demand immediately. By buying larger lots and thus keeping more in stock than needed, decreases buying costs as well as transportation costs. Suppliers may also have discounts for larger purchasing lots. These are just a few reasons why companies hold stock. (Lysons & Farrington, 2016, 291; Rushton et al. 2017, 238.)

The stock types are also different according to what purpose they are kept. Raw material stock is kept for keeping production running. In-process stock is also kept for keeping production running but is more than raw material. These are modules or partly finished goods that are needed in next manufacturing phase. Finished products stock are goods that are ready from production. A pipeline stock serves distribution and may be placed in multiple distribution centers. Goods can be delivered to final customer quickly from pipeline stock. General stores consist of different kind of products to support a manufacturing plant for example. A different type of stock is a spare part stock which serves as back up for production machinery or industrial plants where spare parts may be needed very crucially to avoid shutdown. A spare part stock may also be held for servicing purposes, where consumable parts need to be changed at regular basis. (Lysons & Farrington 2016, 292; Rushton et al. 2017, 239.)

2.2 ABC Classification

Pareto Law is a widely known general rule that a small number of things cause the most of results. For example, Richards (2018, 109) and Arnold et al. (2014, 280) explain the Pareto law or 20/80 rule that it states that about 80% of effects are caused by 20% causes. This applies to many fields, also for inventory controlling. The law implies that by concentrating on the few vital ones, one can manage 80% of causes.

Pareto Law is very useful in inventory management for classifying items for many applications. The term for classifying items by Pareto Law is ABC classification. In this classification, Lysons and Farrington (2016, 294) as well as Richards (2018, 110) explains that A items are the most important and which cover 20% of items and which bring 80% of sales revenue. B items cover about 35% and bring 15% revenue and the least important items are classified as C items bringing only 5% of sales although being the biggest group of 45%. Jacobs and Chase (2017, 379) uses slightly different percentages, saying that A items represent 20%, B items 30% and C items 50 %. The percentages can vary but this is roughly the division of classes and applies widely in general.

Often ABC classification is made based on their money value. The item unit cost is multiplied with annual demand of item. This cost is compared to the total cost of items in stock to get the relative cost compared to the total cost. The stock items are organized according to how large percentage they represent from stock value. Those items that hold most of the cost can be calculated by counting the cumulative percentage of costs. Thus, ABC classification is possible by counting which items carry 80 % of stock cost and classify them as A items, which items carry the next 15 % of stock cost and classify as B items and finally, the rest 5 % of items are classified as C items. (Lysons & Farrington, 2016, 294-295.)

For inventory management purposes the traditional ABC classification based on item's money value is not necessarily the most appropriate. Instead, ABC classification that is based on item criticality suits better for this purpose. (Hafnika et al. 2016, 112.) Also, Sarmah and Moharana (2015, 457) criticize the traditional ABC classification in considering which items are the most critical ones to be kept in stock in their research Multi-criteria classification of spare parts inventories - a web-based approach. They introduce a multi-criteria classification for spare part inventories, where they take multiple aspects of item into account when classifying the items. These criteria are criticality, replenishment lead time, cost of item and commonality.

Pareto Law is useful in determining the most important items kept in stock. Often 20 % of stock items represent 80 % of items that are the most fastmoving items. These are thus the items that are wise to keep in stock at high service level. (Rushton et al. 2017, 242.)

2.3 Demand forecasting

Forecasts for item demand can be made for long term purposes and short-term purposes. The long-term forecast is made for strategic reasons and are very high-level forecasts. This type of forecast answers questions like what will be the customer demand for a group of products or services in next few years and how does a company meet that demand. A short-term forecasting meets the demand for a few weeks or months and is tactical forecast in determining the daily processes. This forecast is for example for calculating inventory levels of individual stock items. (Jacobs 2017, 46.)

A short term in business usually means only a few months, under three months, but it is always relative to the context it is used in. A short term forecast on demand is quick to react to random variation and is thus good to determine safety stock levels for stock items. (Jacobs 2017, 50.)

One characteristics of forecast is that it is easier to make for near future than for far future, as the more time is between, the more uncertainty there will be. This aspect is important to understand especially for long lead time items. (Arnold et al. 2014, 240-241.)

The supply planning for stock keeping depends on item demand. The demand of individual stock items differs among different items. Some item's demand is independent meaning the demand does not follow any other item's demand and for some items it is dependent of other items' demand. The forecast is needed for independent items, as the forecast for dependent items already follow the forecast of item for which it is dependent on. Naturally the forecast planning for different type of items according to their demand, should also be different. (Arnold et al. 2014, 240; Rushton et al. 2017, 258-259.)

2.3.1 Risks relating to forecasting

The characteristics of forecast are that usually forecast is wrong. This should be expected in every forecast. The important aspect thus is, how wrong the forecast is. The error in forecast should be always counted with the forecast. This can be presented in percentage of forecast or stating minimum and maximum values. Third characteristics of forecast is that it is easier to make for a group of items than for any individual item. The group forecast is often more accurate than the forecast for one item. (Arnold et al. 2014, 240-241.)

As forecast is often made on historical data, it is important for this data to be as good as possible. When data is collected, it must be understood what needs to be forecasted. This means that data should be taken with the same terms as forecast is made. If forecast is made on weeks or months, the historical data on demand should also be taken in the same time interval. The circumstances relating to data need to be recorded as well. This is to consider sales promotions, weather and other outside actors that influence history demand and thus data collected. Another requirement of collected data is to record the data for different customer groups separately. If a company delivers same products to a small wholesaler and a large retailer, their demand pattern probably differs from each other, so their demand should be recorded separately. (Arnold et al. 2014, 241.)

One risk of wrong forecast is the increase of inventory level and thus the cost of stock. If the forecast error is for example +/- 10%, a company may end up purchasing 10 % of item too much, which increases the money tied in stock. This might also impact the whole supply chain if a company gives its' suppliers a forecast of demand which is 10 % too high. If the suppliers also act on this too high demand forecast, also they react to it by manufacturing 10 % more than actual demand. This is called the bullwhip effect, when the forecast error causes extra stock in every step of supply chain. This leads to extensive increase in inventory level. (Frankl 2018, 93.)

2.3.2 Variation in demand

Counting an average demand to predict future is a simple way and can be used for simple forecasts with short forecast period. The average demand does not however consider variation in demand. Thus, the average demand should be counted with an estimated error. (Arnold et al. 2014, 243.)

There are numerous reasons why demand for individual item can vary. There may be seasonal variation, trend variation, cyclical variation and random variation. In making forecasts about future demand, these variations need to be considered to prevent errors in forecast. The variation may be small or it may be largely scattered around the demand pattern line. (Arnold et al. 2014, 239; Rushton et al. 2017, 271.)

The size of variation is measurable and there are forecasting tools that calculate the demand considering variation. As variation differs among different items, it is good to apply different forecast tools to different type of items. (Rushton et al. 2017, 271, 275-277.)

2.3.3 Standard deviation

When the average demand during a month for example has been counted for an item from historical data, the demand during different months differs from the average. The demand has been close to average on many months, but for some months the demand has been smaller or larger than the average. The closeness or dispersion of demand for different months compared to the average can be illustrated with a normal distribution curve. When the quantities do not differ much from average, the curve is thin, but when the quantities differ largely around the average, the curve shape is wider. (Arnold et al. 2014, 252, 314-315.)

Arnold et al. (2014, 316) introduces three ways to measure the dispersion of demand around the average. One way is to count the range maximum value minus minimum value. Another way is to count the mean absolute deviation, which means the average forecast error. The third way to count the dispersion is standard deviation. The latter way of standard deviation is used in this thesis.

The standard deviation measures how closely or how far the individual demand values are scattered around the average. If standard deviation is low, the demand values are close to each other, but when the dispersion of values is large, the standard deviation is also large. It is counted as follows:

1. Calculate the deviation for each period by calculating the difference between period demand and average.
2. Calculate square for each period’s deviation.
3. Count together the squares of each period.
4. Count the average of squared deviations by dividing the value received in step 3 with the number of periods.
5. Calculate the square root of the average of squared deviations. (Arnold et al. 2014, 252, 316.)

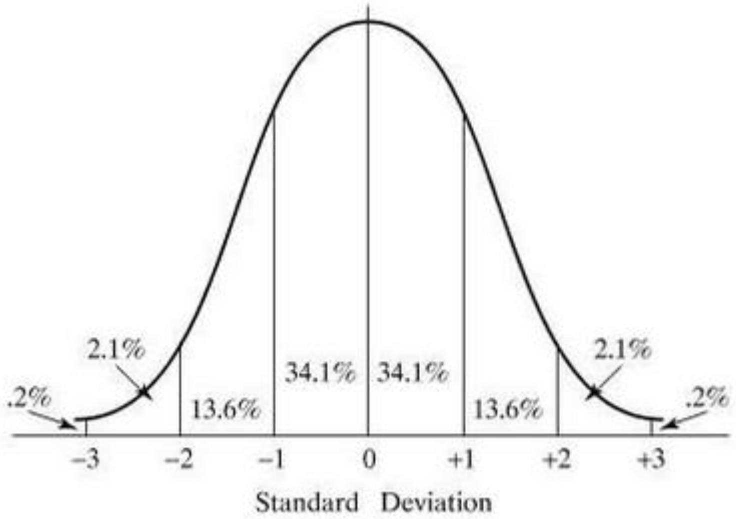

Figure 1. Normal distribution (Chapman et al. 2017, 277).

Sigma, the Greek letter, is the mark of standard deviation. When standard deviation is turned to statistics, in counting the demand, it means that the demand will be within 1 Sigma approximately 68 % of times. 2 Sigma will already cover the demand for 95 % of times and 3 Sigma, the demand is covered 99,7 % of times. The standard deviation and the relative portion it represents is illustrated in figure 1. (Chapman et al. 2017, 279.)

2.4 Forecasting techniques

2.4.1 Qualitative and quantitative techniques

There are both qualitative and quantitative forecasting techniques. Qualitative techniques include tools like scenario planning, brainstorming and Delphi method, where opinions and intuition of experts are collected. Such techniques are subjective and are used for example where historical data is not available. These qualitative techniques can be used to forecasting the demand for a new product for example. (Arnold et al. 2014, 242; Rushton et al. 2017, 270.)

One of the quantitative techniques is to forecast demand for an item based on another factor effecting to demand of the particular item. These factors may be internal or external to the company. External factors having an affect on item demand are weather, time of year, legislation, competitor's acts and such factors for which company has little or no effect on. Internal factors effecting to demand are sales promotions and price and other such factors which the company can control. (Arnold et al. 2014, 242-243; Rushton et al. 2017, 271.)

Quantitative techniques that study internal factors are important for forecasting demand for items. They use historical data and companies usually have plenty of reliable data available. These techniques assume that history repeats itself in item demand. (Arnold et al. 2014, 242-243.) These forecasting models that use history data are called time series analysis. These models use for example past six months sales figures to forecast the sales for the next month. (Jacobs 2017, 49.)

2.4.2 Moving average

A simple way to forecast the near future demand for an item is to look what was the demand in last period, for example during a month. However, this method ignores trends, seasonal variation and random variation in demand. (Arnold et al. 2014, 243.)

Another simple way is to calculate the average demand during a longer period and use that average to forecast next period. This moving average method smooths trends but is not able to respond to seasonal or random variation. This method is suitable for products with stable demand. Another weakness of moving average method is that all data; oldest and newest are considered equal. In reality, demand often changes over time. (Arnold et al. 2014, 243-245; Rushton et al. 2017, 271-272.)

As demand tends to change over time, giving more weight on the newest demand data gives more accurate forecast. This method is weighted moving average where most recent demand data is given more weight than the demand in older time periods. Here also the length of periods affects how fast the forecast reacts to changes. If demand data is taken from just a few months, the forecast reacts to change quickly, whereas if a longer period is viewed, the forecast reacts to demand changes more slowly. (Rushton et al. 2017, 272.)

2.4.3 Exponential smoothing

Exponential smoothing method makes a forecast for next period based on latest actual demand and previous forecasted demand. A smoothing factor, a weight factor is given to previous forecasted demand and thus it considers latest data more important than older data. The smoothing factor is often from 0,1 to 0,3, where bigger the factor, the faster it reacts to changes. Exponential smoothing is a good tool to make short-time forecasting but does not work well for low and random demand. (Arnold et al. 2014, 245-246; Rushton et al. 2017, 272-273.)

2.4.4 Forecast error

The forecast error means the difference between actual demand and forecasted demand. It may differ in two ways; it may be bias, or it may be random. In bias forecast error, the forecast is wrong and when forecast is done for several next periods, the wrong forecast creates cumulative error. Thus, bias is a systematic error, where forecast is always lower or higher than actual demand. Bias error can be fixed by comparing forecast to actual demand and changing the forecast accordingly. Random variation means that actual demand varies around the average demand. It can be small or large variation. (Arnold et al. 2014, 250-251.)

Forecast error can be measured using mean absolute deviation method, where the difference between forecast and actual demand is taken, ignoring whether they are plus or minus, from a period and the average is calculated. The average shows the number of average errors. (Arnold et al. 2014, 251-252.)

The mean absolute deviation gives the number of how far the forecast is from actual demand. Sometimes the average deviation is large and sometimes small. The deviation can be shown in a bell-shaped curve and the mean absolute deviation can be described in normal distribution. The model of curve can be sharply upwards when the difference in demands during a specific period does not vary much. On the opposite, the curve model can be quite low but fat, which means the difference over time compared from forecast to actual varies very much. The bigger the variation, the larger the standard deviation and the bigger the mean absolute deviation, the bigger the error in forecast. (Arnold et al. 2014, 252.)

2.5 Inventory management

For items that have an even and predictable demand, a push system as inventory planning is suitable. The planning and forecast can be made according to data from history demand on individual item and supply is made to ensure adequate stock to prevent stockouts. The opposite system to push system is pull system, where supply is made according to real time customer demand. In this system, a customer demand creates need for supply and no overstock can be built because no extra items are ordered to stock. This is a good system for items that have random and unpredictable demand. (Rushton et al. 2017, 259-260.)

There are two typical inventory systems to guide reordering of items to stock. One is fixed-order quantity system and the other is fixed-time period system. The first means that when inventory level of item drops to a predetermined level, a new order for the item is made for predetermined quantity. The latter means that the inventory level is monitored at specific time periods and a reorder is made then if needed. The quantity of ordered items depends on the inventory level at time of monitoring date. (Jacobs 2017, 363; Arnold et al. 2014, 292, 301; Rushton et al. 2017, 246-247.)

In fixed order quantity system, the reorder point is relevant to determine for inventory management. The reorder point is the quantity to trigger a new order for the item. If this order point is the average demand during lead time, it means there is no safety stock, but if a safety stock is required to prevent stockout, the reorder point is more than the average. The reorder point, demand pattern and safety stock are illustrated in figure 2. The quantity of reorder point is used for demand during lead time (Lysons & Farrington 2016, 310). In fixed order quantity system, the order quantity is predetermined in addition to order point and the time between orders differs depending on actual demand. The formula to count reorder point is below. (Arnold et al. 2014, 311-312.)

$$R = DL + Z\sigma_L$$

R = order point

D = demand

L = lead time

Z = number of standard deviations required for determined service level

σ_L = standard deviation of usage during lead time (Jacobs & Chase 2017, 369).

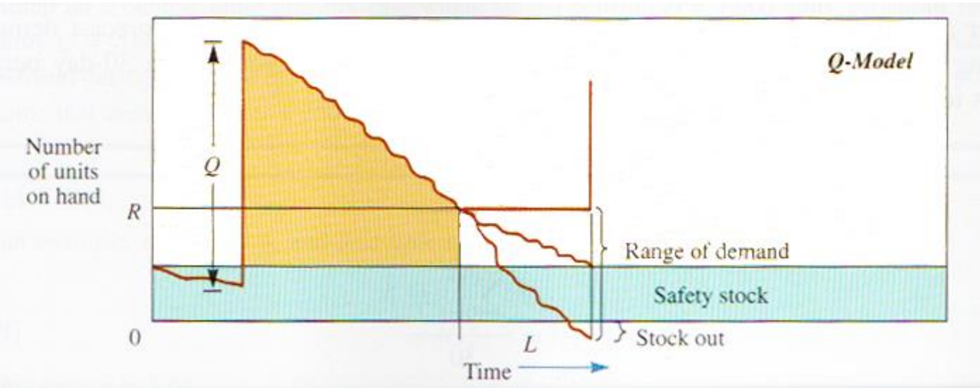

Figure 2. Fixed order quantity model (Jacobs & Chase 2017, 369).

Lysons and Farrington (2016, 314) have compared the advantages and disadvantages of fixed order point and periodic review systems. They state that usually the inventory levels are lower with fixed order system than in periodic review system and reactivity to demand variation is better in fixed order point system. Replenishment orders are generated automatically by reorder point, so the system is more user friendly. Fixed order point system is more appropriate when there are numerous items in stock to manage. However, the disadvantages of fixed order point are that stock may be overloaded if several items reach their replenishment point at the same time and the reordering pattern tends to be random as reorder point is reached at different times.

Advantages of periodic review are that it is easier to notice obsolete items due to systematic review system as well as the stock is replenished more evenly than in fixed order quantity system. The latter also enables company to benefit from larger quantity discounts. (Lysons & Farrington 2016, 314.)

Hafnika et. al. (2016, 111) state in their research on Improvement of inventory control using continuous review policy in a local hospital at Bandung City, Indonesia that a continuous review policy needs to be done regularly to identify which items belong to the most important item group. Also, for effective inventory management, continuous review is needed to prevent excessive stock. Thus, ABC classification also needs to be reviewed at regular time periods to see if there are some changes in item categories and some items have become less or more important.

2.5.1 Service level

There are number of ways and point of views to customer service level. It can mean order fulfilment, order cycle time or gathering all aspects together and meaning the perfect order. Order fulfilment can be measured in different ways. One is counting the quantity of orders fulfilled totally or counting the quantity of orderliness fulfilled totally or it can be measured by counting the value of complete order. In order cycle time measurement, the purpose is to find out how fast an order is completed from customer order to shipment. In measuring the perfect order, all aspect are considered and measured; delivered complete, delivered on time, delivered without defects like shortage, damage or wrong items and delivered with accurate and complete documentation. (Rushton et al. 2017, 50-51.)

Rushton et. al. (2017, 49) states that rising the service level will also rise the cost level. The higher the service level is targeted, the higher the cost. Aiming at 100 % service level means so high costs that it is not profitable for a company to try to reach. Rising the service level from 70 to 72 cost much less than rising the level from 95 to 97. The relationship between the service level and the cost for it is shown in figure 3.

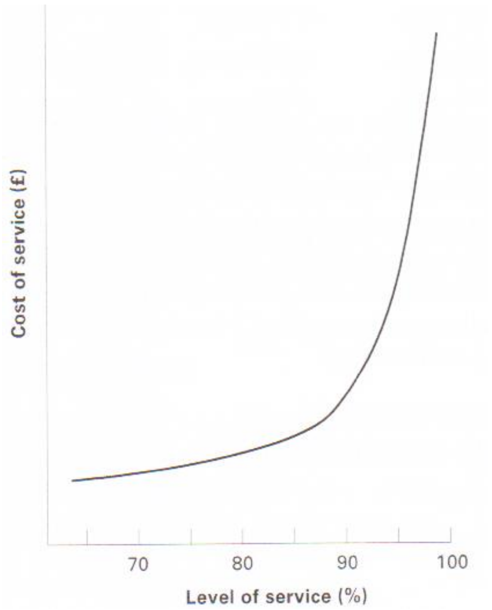

Figure 3. The relationship between the level of service and the cost of providing it (Rusthon et. al 2017, 49).

2.5.2 Safety stock

The service level and safety stock are always related. Safety stock is a way company can try to avoid shortage problems if suppliers' lead times are exceeded or if demand is greater than forecasted. Thus, if a company wishes to serve customers at high service level, they need to have safety stock of items. (Lysons & Farrington 2016, 300.)

Jacobs and Chase (2017, 368) introduce a probability approach to determine the safety stock amount. This approach uses standard deviation to count how much of each item it is good to keep in stock. This approach considers the variability in demand. The main idea of probability approach is that it counts how likely the stock will run out. Figure 4 illustrates the probability of stockout.

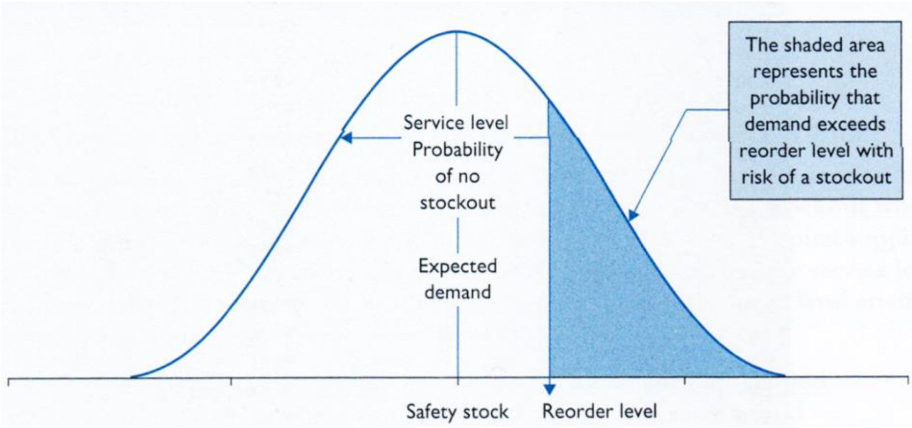

Figure 4. The normal distribution curve (Lysons & Farrington 2016, 301).

The model follows the normal distribution curve, which is discussed in chapter 2.2.2 Standard Deviation. In the middle of the curve, is mean or average of demand. The changes during studied time are spread around the mean, on both sides of the curve. This means that demand has been either lower or higher than average. From probability point of view, it means that in the middle of the curve, the quantity has 50 % of probability to be enough stock to cover demand. However, 50 % of times the stock quantity will not be enough to cover the demand. This means that at 50 % service level, there is no safety stock. If a company wishes to have safety stock, they can add the quantity of 1 standard deviation to stock and this will rise their service level to 84 %. (Jacobs 2017, 368.)

It is earlier discussed in this study how many standard deviations cover 50 or 68 or even 98 % of demand. It means that with one standard deviation to both sides of normal curve, the demand is covered for 68 % of times, when 34 % of times the demand is lower than average and 34 % of times it is higher. However, when determining the safety stock, there is no need to be prepared to lower demand than average, only the demand that exceeds the average. Thus, with one standard deviation of safety stock, a company can have 84 % service level. This is when 50 % of no safety stock is increased by one standard deviation of 34 %. (Arnold et al. 2014, 318.)

In fixed order quantity system, the stock out can happen during item's lead time, which is the time between item is ordered to time it is received in warehouse.

The demand can vary during this time and the quantity of variation could be analyzed through historical data using for example standard deviation as discussed above. (Jacobs 2017, 368-369.) The longer the lead time, the larger the safety stock is required (Arnold et al. 2014, 312). Frankl (2018, 63) also emphasizes the importance of lead time in determining safety stock. Inventory level and thus the costs relating to the level can be increased or decreased by changes in lead time. If a company can reduce the lead time from supplier, they can also reduce the quantity of items kept in stock for preventing stock out.

The quantity of safety stock depends on the service level which a company decides to maintain. The optimal order quantity can be calculated considering demand, ordering cost, holding cost and shortage cost. The reorder point can be calculated by counting together the average demand during lead time and the standard deviation quantity of item as many times as the decided service level requires. The calculation is:

$R = DL + Z\Sigma L$

R = Reorder point

D = Average demand

L = Lead time (lead time and average demand needs to have same timeline)

Z = Number of standard deviations for required service level

ΣL = Standard deviation of usage during lead time (Jacobs 2017, 369.)

2.5.3 Inventory performance measures

There are number of ways to measure how effective inventory management is. The different measuring ways look at the effectiveness from different points of views. One way to measure is to count the lead time of order. The purpose is to calculate how much time it takes for an order requirement to be acknowledged to the time when it is satisfied. Another way is to count the service level by dividing the number of times an item is supplied on demand with the number of times an item has been demanded. A third way to measure inventory management is to count the stock turn. The effectiveness can also be measured by counting the stockouts in a time period. This may be reflected in a percentage from total stock. One measuring type is to count how long the stock will cover the demand if there is no change to demand. (Lysons & Farrington 2016, 299-300.)

3 STUDY ON CRITICAL ITEMS AND DEMAND VARIATION

This study concentrates on the group of items which have an even and stable demand pattern. These are the items that can be kept in stock due to their constant demand, so their circulation is high, and no overstocking takes place. These are also the items that influence the most to service level by decreasing the time of order to delivery. These items also have high influence on delivery accuracy.

Fixed order quantity system is used for items that have even demand in the case company and this is handled in this study. Proper safety stock levels are calculated per item by considering the lead time and cost.

Service level and number of stockouts will be used in this thesis to evaluate if planned actions have affected the delivery accuracy in the case company.

3.1 Delivery accuracy in the case company

The case company operates with sailing vessels, so the type of stock needed to serve customers is spare part stock. For a company selling spare parts for sailing vessels, the most important reason is to be able to sell and deliver parts rapidly from stock.

The case company has been following its own performance from delivery accuracy point of view for a few years. Management team has set high level of on time delivery as one key strategic indicator. As one of the key values in the company is reliability, delivery accuracy is one way to bring it to reality.

As the first step the company needed to determine the time lines, when an order is delivered on time and when it is delivered late. To set the standard, the company compared how one of their biggest customers calculated the delivery accuracy. According to customer's system, an order was delivered on time, if it was delivered within 2 days of confirmed date. The case company set the time line to be 1 day.

The system is simply to compare the actual delivery date to the confirmed delivery date. The sales department sets the confirmed date when they send a confirmation of order to customer and the logistics department sets the actual date when they deliver the order to customer. The delivery terms are considered when setting the dates.

The delivery accuracy is reported each month in the case company. The report includes all sales orders delivered to customers. All orders which are delivered to customer within the confirmed delivery date are reported as delivered on time. All orders that are delivered with longer delivery time as confirmed are reported as late.

According to the report, the average delivery accuracy in 2018 was 84 %. The accuracy varied from 74,6 % to 89,1 % between different months in 2018. In 2019, the average delivery accuracy from January to August was also 84 %. The lowest delivery accuracy has been 80,8 % and the best delivery accuracy has been 86,2 %.

3.2 Item delays in picking process

The research will be executed in two phases. First is data collection from the case company's ERP-system. All the shipments are affected in ERP-system, so also all the delays are shown there. The first step shows the current state of orders' delivery time as well as the problematic items, that cause delays the most.

In the delivery process in case company each shipment and each item to be picked from stock have a requested picking date. Salespeople set the picking date according to customer's wishes and checks from ERP-item register when the item is available. The salesperson creates a picking list for each shipment to warehouse and they pick and pack the shipments according to picking lists.

When an item is picked from stock, warehouse people also update it in ERP-system. This date is then compared to the requested picking date when measuring the delivery accuracy.

All the items that have been picked later than on requested date can be seen from the report. In the first step, the report is taken from twelve months period to gather as objective data as possible. The item offering in the case company's spare part business is quite large, but within 12 months period, the report will show the tendency of which items or item groups often cause delays.

The nature of business is quite stable and there are no seasonal fluctuations or marketing promotions, which would affect some items to have extra demand and which would then cause bias demand patterns. However, the end users are various, so the need for different items differs largely. Also, new techniques and technologies are developed all the time in the markets, which creates development in the case company's offering as well. This development in item offering is slow, so it will not show in short term reports, but will show in longer period. Thus, there are irregularities in demand and this makes the item offering very large. Nevertheless, there is a group of items which formulate the most common items sold and delivered to customers.

In the section Theoretical framework, different types of warehouse managing and item classifying systems are introduced. Through theory, the best solutions for warehouse and stock managing in the case company spare part business are chosen. These solutions will be applied to the most common items.

After the new managing system have been guiding the stock balance for three months, another data collection will be executed. This second data collection will be done the same way as the first one to achieve comparable results.

3.3 Data collection and analysis

The background data for this research is a report from case company's ERP-system of all the sold, physical items in spare parts during year 2018. The report includes each happening of each individual item being sold to a customer and item’s stock value price and replenishment time. There were totally 1362 different items sold in 2018. The final analysis and actions to ERP were executed six months later than the end of reported period, thus I took the same report for these six months in 2019 to notice if there were remarkable changes in demand.

Some of the items sold to customers consist of set of different components. These component sets are transferred to the report so that the individual components are calculated to get info of their real demand.

Another report was also run for the same period and for the same content, but this one also included information on whether the item was picked from stock on time or late. The picking date was compared to the requested date set by sales department. Late pickings may be caused by various reasons, such as sales choosing too early picking date for items not at stock or human resources at warehouse but the most common reason behind late picking is lack of component. Thus, this report shows which items cause late pickings the most.

I started my analysis work from the report of late pickings and from there moved to the other report with all the sold items. After I had analyzed which items cause late pickings the most, I moved this data to the other report by coloring all items red that had caused delay to picking. Thus, this data followed all the way analyzing the second report.

3.3.1 Items causing most delays

The report showed each picking happening separately, so first I needed to count together all on time pickings and all late pickings of each item. Through this I was able to find out how many percentages the item had been picked late from stock compared to total quantity of demand. The percentage varied from zero to one hundred between items. There were 1362 items.

I started analyzing and handling the data by first moving out the items that had never been picked late. Second, I moved out items that were only sold and delivered to customer fewer pieces than ten pieces. Third group of removing items were the ones that had been picked late only under ten % of times. All these groups of items were not significantly causing delays to pickings. The process of excluding item groups is shown in table 1 below.

Table 1. Process of finding items causing significant delay.

	Quantity	Percentage of items
Causing delay 0 times	737	54 %
Volume sold under 10 pieces	390	29 %
Causing delay under 10% of times	103	7 %
Causing delay 90% of times	132	10 %

This process of excluding not significant items follows Pareto's Law. 90 % of items are not important from the point of view of causing late picking to customer orders. The 10 % that were left only covers 132 items and these have caused orders to be delayed more than 90 % of times.

3.3.2 Variance in demand and standard deviation

After the delay analysis, I continued the analysis of the study with the other report by counting the total quantity of each item sold. The total quantity of each item sold was summed for each month of the year. This was done to see how variant the demand for individual items had been between different months. Thus, the study shows if an item had a predictive and even demand or if the need varied much during the period.

The next step of the study was to count the average demand from twelve months for each item. After this, the difference between the demand for each month and the average was counted. This helped to find out how largely the demand varied from average. Through this way, the standard deviation for each item was counted.

I used standard deviation of item's variance in demand to make an ABC classification of items. I counted how many percentages the standard deviation differed from average for each item. The percentage is a functional figure, which shows how small or large the deviation is from the average. The difference in percentage offered comparable figures and allowed me to organize items into classified groups. Through this, I was able to identify the most common items for which demand was most stable. The standard deviation percentage varied from -315 % to +80 %.

3.3.3 ABC Classification

Pareto Law is useful in determining the most important items kept in stock. Often 20 % of stock items represent 80 % of items that are the most fastmoving items. These are thus the items that are wise to keep in stock at high service level. (Rushton et al. 2017, 242.) This is also the group of items which this thesis concentrates on.

Again, I used the tool of excluding to find the items that had the most even demand. I removed the items which demand was low. To find out the appropriate level, I chose the level of low demand, where delay causing items did not appear. This level was ten, so I removed all items which yearly demand was ten pieces or under. This group of items has the most unstable demand and is not the focus of this thesis. In ABC Classification this group is classified as D items, as shown in table 2.

After this removal, 32 % of items were left. They represent classes A, B and C. The demand for class C items was unstable, but the group included items which had caused serious delays in reported period, so their demand needed to be analyzed in this study. The items in classes A and B had stable enough demand to make predictions for future demand based on their demand over the period examined. The standard deviation percentage varied from -20 to +20 % for A items and from -50 to + 50 % for B items.

Table 2. Classification of items according to variation of demand.

	Quantity	Percentage of items	Demand class	Items causing delay
Random demand	950	68 %	D	0
Unstable demand	224	16 %	C	34
Fairly stable demand	130	9 %	B	60
Stable demand	94	7 %	A	38

As stated above, there were no delay causing items in class D, but they appeared in classes A, B and C. As much as 36 of 94 A items were items that had caused delays in picking during the reported time. This is 38 % of A items. In B class there were 103 delay causing items and represent 29 % of B items.

Although ABC classification done in this study is based on historical item demand, also criticality, lead-time and cost are considered. They are taken into account when counting the re-order point and quantity of safety stock to keep decided service level.

3.3.4 Knowledge about items

This was the first time when history data of item demand was purposefully used to predict future demand. Thus, there was reason to be cautious in predictions, because wrong calculations may lead to too high inventory level. Also, as stated before, although item demand does not change along with seasons or sales promotion, there are items which demand changes gradually because of new technologies. The change is so slow that it does not show in a yearly report.

I interviewed one of the sales persons in the case company about the items. We looked through all the items from report and he pointed out the special attention items to me. These items were the structural parts, which consisted of multiple items. Also, items which were older technology and for which new item with updated technology has been introduced and customers are slowly changing into. In addition, there were some item codes which were supplier-connected and the case company had recently changed the supplier, so the demand for that item needed to be transferred into the new supplier item. Some items also needed to be purchased with extra data given to supplier, thus these items could not be kept in stock.

3.4 Service level

The demand for items that have a stable and continuous demand can be illustrated through normal distribution or normal curve, where the demand is predictive. For these items standard deviation can calculate how much safety stock covers for certain amount of service availability.

I counted how much of each item should have as safety stock with different levels of standard deviation. With zero standard deviation, the quantity is zero, because there is no safety stock. With one standard deviation the quantity was how much demand differed from average demand by taking into safety stock one difference in normal curve. And taking into safety stock two differences in normal curve, the quantity is the standard deviation by two levels.

By calculating the standard deviation and demand accordingly, I was able to see how much of each item should be kept in stock for different service levels. In addition to quantity, I calculated the value of each item with different service levels. This shows how much more money is invested in stock if service level is set higher.

The lead time of each item in ERP is calculated in days but the demand data in background report is in months. Thus, the lead time of each item needed to transfer into months to have comparable data. This is calculated by dividing the lead time by 30,42, which is an average number of days in one month.

To find out the demand for different service levels, I counted the demand during lead time for each item. Second, I counted what was the standard deviation quantity during lead time. With these calculations I was able to count how much was the demand for different service levels. For 50 % service level, the quantity was only the demand during lead time, for 84 % level, the demand is one standard deviation added to quantity during lead time. For 98 % level the standard deviation is added two times to quantity during lead time. This means that with the lowest service level, the quantity of an item is enough for 50 % of times of demand, the second service level, the quantity is enough for 84 % of times and the best service level, the quantity at stock is enough almost 100 % of times.

I also counted how much each service level would cost for each item. This way, I could notice the most expensive items and how much it would cost to keep the highest level of service for them. For low price items which have a stable demand, it is reasonable to have the best service level, because their circulation is high and customer demands will be satisfied. However, for high price items the cost of keeping them in stock is so high, that even though the circulation is high, the stock value remains at very high level, it is not good to keep the highest service level. For those items a lower service level is better.

The service level in this thesis means that a customer order is completed fully in requested time. Order is fully completed when all the order lines are picked from stock within the time set by sales person. Another meaning of service level in this thesis is how fast an order can be fulfilled from time of ordering to time of delivering. The smaller the time between ordering and delivering, the better the service level. The time from ordering to delivering can be within one day in the best case, but it can be months for orders including items that have long supply time and which are not kept in stock but are ordered from supplier per order. As this thesis concentrates on items that have stable demand pattern and actions are targeted to keep those items in stock, this thesis aims to improve the service level for orders which are delivered straight from stock.

To count the service level of case company I used another report from ERP. This report included all orders delivered in 2018 and showed the time of ordering and the time of delivering to customer. I counted how many days was between ordering date and the delivering date. As described before, the number of days varies from zero to some months. As this thesis concentrates on items that are kept in stock to serve customers fast, the most relevant is to count how many orders can be delivered straight from stock.

A normal time frame for processing the customer order is one to two days in the case company. Thus, I counted how many orders have been delivered to customer within two days from ordering. 59 % of orders had been delivered within two days in 2018.

3.5 Actions to ERP

After I had calculated the quantity and price for each item with different service levels, I took another report from ERP with same data but with recent period. The first report was for the whole year 2018. The second report consisted of demand information during the first six months of year 2019. I used this recent data to compare the demand and see if it had changed dramatically recently.

The total sales of spare parts have gradually increased during the past 5 to 10 years. Thus, keeping in mind this growth, I calculated the quantity and price for different service levels adding 15 % growth to them.

3.5.1 Safety stock

I went through the items in classes A and B one by one. In principal, I chose 98 % service level for these items, as the demand was stable and so many of them had caused delays according to the report. However, I lowered the service level to 84 % and even to 50 % if the demand had decreased significantly in the most recent demand report showing 2019 demand figures. Also, I chose the lower service level of 84 % if the item was very expensive causing too high stock value. On the contrary, I increased the quantity even over 98 % service level for items whose cost was very low. I particularly paid attention to the items that had caused delays.

For items in C class, where demand was unstable, I only went through the items that had caused delays and for most of them, I chose 98 % service level. But again, for the most expensive items, I lowered the level to 84 or even 50 % to prevent too high stock value due to randomness of demand.

The chosen quantities for safety stock were updated to ERP item register's minimum stock quantity. Some items already had a safety stock limit similar to the calculations of this study, so they remained the same, but most items did not have this data before or the data had outdated. The changes were made to 196 items, where 154 items had 98 % service level and 42 items had 84 % or lower service level. Thus, 79 % of changed items would have almost full-service level after update and 21 % would have a lower service level after update.

3.5.2 Minimum purchasing lot

Minimum purchasing lot is not directly the topic of this study, as it does not affect the stock quantity. However, it is an essential part of making reasonable purchases to suppliers, so this data was also updated to ERP item register. I had a team of experts from purchasing, warehouse and sales with who we checked this data for the same above items.

4 RESEARCH FINDINGS

4.1 Items causing delays

The second phase of this study included taking a report from ERP about late pickings. The report was run with the same settings, so the results would be comparable to the first report. The period was three months for the second delay report.

The first report showed 132 items that had caused significant delays. The second report showed that 105 of those items caused no delay during the second period. Thus, the actions made to ERP for safety stock and minimum purchasing lot had the anticipated affect on item availability for 80 % of items that had caused delays the most.

There were still delays for 27 items during second reported time. This is 20 % of items that had the most serious delay problems in the first report. The delays had decreased for 18 items, so improvement can be seen for these too. The delays had increased for 9 items. In total the actions had not been sufficient for 7 % of delay causing items. Table 3. below show how the actions have affected the items that had caused delays in the first reported period.

Table 3. Effects of safety stock to item availability.

	Quantity	Percentage
Items with no delay	105	80 %
Items with decreased delay	18	13 %
Items with increased delay	9	7 %

In the ERP update for safety stock and minimum service level, there were 196 items that were updated. Almost full-service level, 98 % was chosen for 154 items which is 79 % of items and 84 % or lower service level was chosen for 42 items which is 21 % of items. It was a decided decision to allow out of stock situations for these 21 % of items. In calculations, these items would not be available for sales at 16 % of times. Also, 2 % of not availability was allowed for items with 98 % service level. Table 4. represents the delays in 98 % service level and 84 % or lower service level. There were 17 items from 154, which represents 11 %, in 98 % service level that still had delays in the second report. The delay per item varied from 3 to 33 %. In the items with lower service level, there were 8 items from 42, which represents 19 %, that had delays in the second report and the delay varied from 2 to 33 %. However, 89 % of items with highest service level had not faced delays and 81 % of items with lower service level had not been late at time of picking for sales order.

Table 4. Delays per service level.

	Updated items	Delays in 2nd report
Items with 98 % service level	154 / 79 %	17 / 11 %
Items with 84% or lower service level	42 / 21 %	8 / 19 %

As stated before, 2 % of delays was acceptable for items with 98 % service level. For all 17 items that had faced delays, the delay was more than the acceptable 2 % as can be seen in table 5. In the lower service level 16 % of delays was acceptable. In this group, the delays varied from 2 to 33 %, where 3 % of delay was expected and allowed but 33 % was not. There were 8 items that still had faced delays in this item group and 7 of them had delays from 2 to 14 % of times and this is demonstrated in table 5. Thus, only 1 item had faced more delays than acceptable.

Table 5. Expected delays per service level.

	Acceptable delays	Delays too often
Items with 98 % service level	0 / 0 %	17 / 100 %
Items with 84% or lower service level	7 / 88 %	1 / 12 %

4.2 Effects on delivery accuracy and service level to customers

In 2018, 59 % of orders had been delivered to customer within two days of ordering. After the actions executed to ERP system of case company, the service level has risen to 66 %.

The delivery accuracy has been 84 % in average in 2018 and also during the first eight months of 2019, when the actions on safety stock and minimum order quantity were not yet updated to ERP system. The actions were updated to case company’s ERP system at the end of August 2019. Thus, to see if the actions have affected the delivery accuracy, the results for September, October and November 2019 needs to be studied. The delivery accuracy for September 2019 is 91,1 % and for October 92,1 %. November results were not yet available.

4.3 Conclusions

Holding stock is essential for a company like case company who sells spare parts to customers. Serving customers with short delivery time is a key factor to win orders and keep the customers satisfied. It would not be possible to have good service level for customers without keeping items in stock. Without stock, all customers’ orders would need to be ordered from supplier and delivery time would extend significantly and it would change according to supplier's ability to supply. Thus, keeping stock is essential also to smooth delivery problems with suppliers. (Lysons & Farrington, 2016, 291; Rushton et al. 2017, 238.)

What to keep in stock is the important question. Keeping stock ties capital and does not add value to business, thus it is important to have the right items in stock and not items which customers do not order or order only seldom. There were over 1300 different items that were ordered by customers in 2018 in case company. It would be impossible and not wise to keep all of them in stock. Thus, the items and their demand by customers are studied and analyzed in order to find out which items should be kept in stock.

ABC classification is widely used to classify items. In inventory management it is a useful tool to separate the most important items from a wide range of items. (Sarmah & Moharana 2015, 457; Hafnika et al. 2016, 112; Rushton et al. 2017, 242.) In spare part business the most important items are the ones that customers order regularly. ABC classification is used in this thesis from the demand pattern point of view to identify the items whose demand is regular and stable. Those items are the key to reach the goal of this thesis, to improve delivery accuracy.

History demand data is used to investigate each item's demand pattern, whether it is regular and stable or if it is random. History data regarding items' demand in case company suits well to make forecasts for near future as the operational environment is quite stable and there are few outside factors to influence demand. The demand stays the same during different seasons and there are no marketing actions or similar to affect to demand. Thus, history data in this case offers reliable data for forecasting.

For inventory management, there are two opposite systems, push system and pull system (Rushton et al. 2017, 259-260). Both are needed in a company like case company, where the total offering is very large, and the demand varies largely between different items. As said above, there were over 1300 different items that were sold to customer in 2018. A push inventory system is suitable for the group of items that are delivered regularly, and a pull inventory system is suitable for the item group that are only sold occasionally (Rushton et al. 2017, 259-260).

Fixed order quantity system is a push system as inventory management way meaning the items are pushed to be sold instead of pull system where each sold item is ordered from supplier. Fixed order quantity system is suitable for items which have stable demand and high circulation in stock. Safety stock levels and order points are the details with how the system works. (Arnold et al. 2014, 292, 301; Jacobs 2017, 363; Rushton et al. 2017, 246-247, 259-260.) This is the system that is used for the items for which safety stock levels are updated in this thesis. Also, the company's ERP system supports fixed order quantity system.

In analyzing the history data of item demand, the purpose was to find the items with stable and even demand pattern to share the items into groups and divide them into push inventory system and pull inventory system. Standard deviation was used to recognize these items from the whole offering. Standard deviation shows how narrow or how wide the demand is spread around the average during different time periods. (Arnold et al. 2014, 252, 316.) In this thesis, the demand data was for each month of 2018. The result the standard deviation gave was in pieces per item. To make the results comparable and to make items comparable, counting the relative standard deviation was a good solution. If an item's standard deviation percentage was high, its demand was random, but if the percentage was low, the demand was stable.

The forecasts made in this study are short term forecasts with target on near future. The near future forecasts can be used to manage inventory on daily basis, for example to determine safety stock levels. The forecast made in this thesis are made for that purpose exactly. In order to maintain good level of forecast and to prevent forecast errors, latest demand data should always be included when checking the forecast whether it is correct or wrong. The safety stock levels can then be updated according to the latest forecast. However, long enough time from history should be kept in making the forecast so that forecast would not react to random changes. (Arnold et al. 2014, 241; Jacobs 2017, 46, 50.)

Regular forecasting should not only be used in company's internal purposes but also for outside communications as one way of inventory management. Forecasted demand for different items based on history data, could be communicated to suppliers on regular basis, for example for six months ahead. This would help suppliers to prepare their production or their supply chain to meet the company's needs. The replenishment order could still be placed according to fixed order point. This type of communication could be a good additional tool to manage inventory for items with stable demand pattern.

Giving suppliers forecast demand information helps to prevent unexpected delays in lead time. With forecast data, the lead time could even be shortened. As stated before, a key to decrease the amount of safety stock, is to be able to shorten the lead time (Arnold et al. 2014, 312; Frankl 2018, 63). Giving forecast data to suppliers and planning roughly replenishment orders beforehand enables a company to have the right timing of stocking, with the right items in stock at the right time.

There are risks relating to forecasting future demand and communicating the data to suppliers of course. The risk of creating excessive stock to own or to suppliers' warehouse is one risk. (Frankl 2018, 93.) To prevent this from happening, it is very important to have a regular forecasting system with current demand data and changes in demand pattern are communicated to suppliers on time.

Forecasting can be used as an inventory management tool also for items which are not held in stock. For this group, a different forecasting tool is more convenient. History data does not necessarily give useful information if demand has been irregular or if the item is new and there is no history data available. For this group of items, qualitative forecasting tools should be used. These are for example brainstorming or Delphi method where experts give their opinion or outlook on item's demand in the future. Another qualitative method is to follow and analyze the demand for another item, which is related to another item. This is a way to analyze dependent items. (Arnold et al. 2014, 242; Rushton et al. 2017, 270.)

The case company does have this kind of qualitative information available as it also designs the main machinery where the spare parts handled in this thesis are used. If some regular component in the machinery is changed due to technological development or change in supplier or some other reason, this will affect to spare part offering after a while. At the time of changes in machinery, forecasting can be made for future spare part needs according to the volume of machinery. This allows the company to prepare to manage their inventory for these items. Forecast can be communicated to supplier well ahead of actual need and lead time, price and other details can be negotiated already.

For items with irregular demand, forecasting is difficult. History data is not useful, because there is no pattern and qualitative methods does not work if there is no dependence to any other item or there are no known changes behind to predict the future demand. For these irregularly sold items, pull system as inventory management is the suitable way. When a customer orders this kind of item, it is ordered from supplier and then delivered to customer directly. In this method the item only goes through the warehouse and is not held in stock. As a result, inventory management for these items is to not keep them in stock.

Standard deviation was a very good tool to count the quantities for safety stock. The required service level per each item was easy to count with this method. One standard deviation means the item is available in stock at 84 % of times it is demanded by customer, two standard deviation means the item is available at 98 % of times. (Jacobs 2017, 368.) Counting the standard deviations for the case company, I added data about price per item also. Thus, the price per 84 % service level and the price per 98 % service level was visible all the time. This way I was able to consider also the effect on stock value when determining safety stock levels.

The results from delay reports show that the actions made to ERP for item’s safety stock and minimum purchasing lot have affected positively to 93 % of items that had availability problems in the first reported period. This means following delay reports and counting and forecasting item demand are effective ways to improve item availability.

As the results show, there were still 7 % of items for which the actions had not been enough and which had still caused delays significantly. The demand history should be examined for these items to find out if demand has increased significantly since the first demand data report. The demand may also be the same as before, but there may be serious supply problems from supplier. Studying these items’ latest history on demand and supply reveals if changes should be made to item’s inventory management.

The second delay report showed that the 17 items, which were 11 % of items with 98 % service level still faced delays. The decided decision was to allow 2 % of not availability for these items, but the report showed some of the items had even 33 % of delays. In total, all these 17 items had faced delays more than 2 % of times. Thus, these items should be examined for update demand data, because it seems the safety stock for these items it not enough. However, 89 % of items had faced no delays, so updated safety stock levels have affected availability for most items.

Regarding items with 84 % or lower service level, 8 items had faced delays in the second report. The delay was lower than the acceptable 16 % for 7 of these items and higher than acceptable for only 1 item. In conclusion, the results were as expected for these items.

The service level is improved if more orders can be delivered to customer faster than before. This means that the right items are available in stock with help of safety stock. During September, October and November 2019 the company has been able to process 12 % more orders within two days than in 2018. The safety stock for the chosen items have had a positive affect also to service level.

The delivery accuracy has not increased at all from the beginning of 2018 until the end of August, but it has stayed at average 84 % level. After the actions represented in this study were executed, the delivery accuracy has increased significantly. The delivery accuracy has not been over 90 % before the actions has been executed, but during the three months after the actions, the level has stayed at over 90 % delivery accuracy level. The delivery accuracy has improved 8,5 % from 2018. Thus, the actions of this study have had the expected, positive effect on delivery accuracy.

In a conclusion, the delay report and demand history report should be made regularly to have a current view always about the most important items in terms of service level. The regularity will help to prevent keeping high stock for items that have decreasing demand and will notice new items for which a safety stock should be established. A suitable time for making a demand history report could be rolling 12 months. A shorter time would distort the data by ignoring the random variation. This could affect demand for an item would appear extensive or lesser than in reality. The delay report could be taken in monthly cycles to follow up critical items from supply point of view.

As the theory of action research suggests, multiple research cycles are completed on the subject. At the end of the first cycle, the researcher evaluates and analyses if the actions have had an influence on the subject and if the situation has changed from the original. In action research, the situation is not only analyzed once, but requires constant follow up on the subject. (Kananen 2012, 39.)

The cycle of action research is iterative. After finishing the first round of defining the problem, setting the goals, planning and executing the interfering action and finally evaluating the results, the research starts again from the beginning. The researcher diagnoses the situation and defines it. Now, there may appear a new set of research questions, as the situation has changed through the first cycle of actions and interference. Thus, there must be new set of actions to change the situation. The cycle iterates like this as long as the researcher sees it valuable. (Saunders et al. 2016, 191.)

4.4 Validity and reliability

The researcher needs to have a critical way of working through the whole research project. This means all the information and data needs to be evaluated with a critical mindset all the time asking if this is relevant or if this is valid. This does not only apply to other researchers' studies and literature, but also for the researcher's own decisions, analysis and conclusions. (Saaranen-Kauppinen & Puusniekka 2006.)

When the researcher seeks information, earlier studies and literature on the subject, the researcher needs to view the information critically. Evaluating the info, at least the background and reliability of author and possible commercial ties needs to be considered. Another important aspect is to consider what is adequate amount of data. A special attention should be put to online data, as everyone can write and publish in internet and the data may change. Also, no one supervises the data published online, so it has no scientific reliability. (Lapin korkeakoulukonserni.)

The literature studied to build the theory for this thesis is from recent years, thus it represents the current view of supply chain management and inventory management. The authors are experienced in their field and have published multiple studies and books through well established publishers. Many of the authors describe the subjects introduced in this thesis, thus the theory is not based only on one or two author's views.

Case studies regarding convenient forecasting tools, item classification systems and stock replenishment ways are also implemented. This shows the subject is not only important to this thesis' case company but is a wide and common subject to develop in any company or institute that holds stock.

One ultimate aim in research is that it is reliable and valid in order it to be taken seriously. Research validity means the findings are checked to be accurate by using specific procedures. Reliability means the research is executed in a consistent matter. (Creswell 2014, 201.)

The reports that are used for item analysis in this thesis are taken straight from case company's ERP, so the data shows exactly what the reality is, thus the data is reliable. The first report that creates the foundation for this study is from one-year period. The case company's business field is quite stable and there are no seasonal changes in demand. Thus, the report is reliable with regards to broadness of data. In addition, a comparison report is taken exactly with same specifications for another six months after the first report to notice differences at time of inputting new safety stock limits and replenishment quantities. Also, the second report that is made for analyzing the results of the actions made, are run from ERP with the same specifications to have comparable results.

One way to achieve validity is to use triangulation, using multiple data sources and building a coherent theme of them. Other ways to increase validity of research is to ask for comments from participants of analysis or conclusions and clarify how researcher's own background and culture may affect the results. Describing opposite thoughts and views proves the research is realistic and thus brings validity to study. (Creswell 2014, 202.)

A researcher can add reliability to the study by describing the steps of the study and documenting the procedures in detailed and clear way. Any obvious transcription errors need to be checked and definitions needs to remain the same throughout the study. (Creswell 2014, 203.)

The reports and the process of analyzing the data are described in detail to allow readers to be able to follow the study from starting point to the end.

5 SUMMARY

The subject of this thesis is about inventory management. There are plenty of ways to manage inventory and the used management way depends on the type of stock it is used for. The stock type in this thesis is a stock for spare parts which is used for delivering orders to customers straight from stock.

A suitable way to manage this kind of inventory, is fixed order quantity system, where safety stocks are used to prevent out of stock situations. To have the right quantity of items in stock, the management requires deep knowledge of item demand pattern, lead time and cost.

Historic demand data is useful information to study items' demand pattern and to recognize critical items. Analyzing the history data, a company can find out which items are the ones that are ordered by customers most often. Using history data is a way company can make forecasts for future demand of items and determine safety stock levels.

Counting the average item demand and how much demand varies over time is a useful tool to categorize items according to their demand pattern. Standard deviation helps to recognize the items that have stable demand. The items with stable demand are items with high circulation so they are also safe to keep in stock, because they are used from stock regularly. These items are the ones to keep in stock all the time to serve customers rapidly with high service level.

The item offering in case company is very large. By using the standard deviation, it was possible to recognize the most critical ones in terms of usage and high circulation. According to Pareto Law, a few vital items affect the most of causes. In this case a few vital items were chosen to have safety stock and fixed order point to improve the delivery accuracy and service level.

The aim of this study was to improve the delivery accuracy of spare parts in case company. By above analysis and actions, the delivery accuracy was improved significantly by 8,5 % and the service level improved 12 %. This study shows that by concentrating on the few vital items and implementing suitable inventory management on them, a company can improve its performance towards customer.

This study is an action research with specific targets and specifically described methods to gain the objects. The aims and ways are described in detail. However, this study only includes the first cycle of action research. Following the principles of action research, multiple cycles are required. Thus, analyzing the demand of items and changes in them, must continue in the future to keep improving the delivery accuracy and service level further.

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