Utilizing Data in Inventory Management

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Tiivistelmä

Yritykset tuottavat jatkuvasti suuria määriä dataa. Toimitusketjun hallinta on yksi alue, joka hyötyy merkittävästi kertyneestä datasta. Ymmärtämällä yrityksen toimintaan liittyvän kysynnän ja tarjonnan perusteet, yritykset voivat parantaa toimintaansa ja vapauttaa pääomia tehokkaamman varastonhallinnan avulla.

Yrityksen kysynnän ja tarjonnan ymmärtäminen aloitettiin analysoimalla transaktioista syntyvää dataa. Tarjontaan liittyvän datan pohjalta esitettiin mittareita, joiden perusteella toimittajien toimintaa tulisi seurata. Kysynnän suhteen pyrittiin löytämään säännönmukaisuuksia, joiden avulla voidaan laskea yrityksen varastoon sitoutunutta pääomaa. Kun kysyntään ja tarjontaan liittyvät asiat ovat selvillä, tehtiin niiden pohjalta toimenpide ehdotus, miten tietoja voitaisiin hyödyntää varastonhallinnan parantamiseksi.

Tuloksena onnistuttiin löytämään yksinkertainen tapa kehittää varastonhallintaa. Varastonhallintaan liittyy suuri määrä muuttujia, eikä niitä kaikkia voi ottaa huomioon. Käytetyn menetelmän avulla pystyttiin löytämään säännönmukaisuuksia, jotka todennäköisesti löytyvät useista yrityksen tuotteista. Käytetty menetelmä mahdollistaa myös tiedon hyödyntämisen edelleen kehittämisen. Muuttujia lisäämällä ja teknologiaa hyödyntämällä kehitystyötä voidaan automatisoida ja sitä olisi siten mahdollista hyödyntää paremmin kaikissa yrityksen tuotteissa.

Avainsanat (asiasanat)

Varastonhallinta, Toimitusketjun hallinta, Data

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Abstract

Companies are constantly generating a large amount of data. In companies, supply chain management is one area that benefits significantly from the accumulated data. By understanding the supply and demand related to the company's operations, companies are able to improve their operations and free up capital through more efficient inventory management.

Understanding the company's supply and demand began by analyzing the related data generated from transactions. In relation to supply-related data, metrics were presented on the basis of which suppliers' activities should be monitored. In relation to demand, I try to find regularities, with the help of which it is possible to reduce the capital committed to the company's inventory. When the issues related to demand and supply are clear, an action proposal was made based on them, how the data could be used to improve inventory management.

As a result, I managed to find a simple way to develop inventory management. Inventory management involves a large number of variables, and it is not possible to take them all into account. With the method used, it was possible to find regularities that are likely to be found in several of the company's products. The method used also enables the further development of data utilization. By increasing variables and utilizing technology, development work can be made more automated and thus it would be possible to better utilize it in all the company's products.

Keywords/tags (subjects)

Inventory Management, Supply Chain Management, Data

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1 Introduction

Data analysis has been a rising trend in the business world in recent years. Companies strive to use data to develop their business to be more efficient and productive, thereby gaining a competitive advantage in the market. Data refers to unprocessed information accumulated by the company. For example, sales and purchase orders, goods receipts and production completions accumulate data in the company's ERP system. With the help of data analytics, the purpose is to transform the accumulated raw data into such a form that it can be used in decision-making. This means, for example, visualizing data and finding different trends and regularities.

The purpose of the thesis is to find ways for the client, Oy SKF Ab, how to use the data accumulated from the company's operations to develop procurement and inventory management. The goal is to find regularities in the data, which would make the operation smoother and easier to predict. The possible findings are supposed to be translated into action proposals, which would be used to release capital tied to inventories and reduce costs from procurement.

Companies mainly collect data in their own ERP system. However, this information is often siloed behind different departments, and it is not utilized across the company's entire supply chain. This siloing often leads to inefficient and expensive decisions when departments do not know precisely the effects of their activities on other departments of the company.

Commissioner

Oy SKF AB's Muurame factory is the client of the thesis. SKF started its operations in Finland in 1908. In Finland, the company has a factory manufacturing industrial lubrication systems in Muurame and a sales office in Espoo. The company employs about 160 people in Finland. (SKF, n.d.)

Ab SKF, Svenska Kullagerfabriken is a Swedish industrial company founded in 1907. It is one of the world's best-known industrial brands and a leading player in the bearing business. In addition to bearings, the company also manufactures, for example, seals and lubrication systems. SKF employs approximately 42,000 people worldwide in 129 countries. SKF has a total of 77 factories. (AB SKF, 2023)

2 Data

2.1 Data in Supply Chain

In a competitive industrial sector, the importance of material management is increasing in terms of the company's competitiveness. Approximately half of the company's turnover goes to material purchases, so managing them has a significant impact on the company's cash flow and ability to make a profit. Although the demand may seem random, with the help of data it is possible to find recurring events, as a result of which the operating environment becomes clearer and easier to predict.

Data has long been talked about as the new oil. In 2018, Forbes reported that the world produces 2.5 quintillion bytes of data per day, and the pace is only accelerating with the spread of the Internet of Things. In terms of the company's operations, the supply chain is one of the most significant sources of data. Supply chain data can be estimated to come from three different sources, the company's master data, demand-driven data and supply-driven data. (Oracle, n.d.)

With the information obtained from the master data, it is possible to define, for example, individual products, work steps and their unit costs. From the data coming from the demand, we can find out, for example, the order and delivery history of products and customers. From the data coming from the supply, it is possible to examine the performance of the suppliers, the stock quantities of the parts and the performance of the own production. (Oracle, n.d.) By combining and analyzing the obtained data, it is possible to detect items in the company's supply chain that are not working efficiently and to focus development measures on these items.

2.2 Data analysis

With the help of data analysis, companies are able to learn from past events and strive to develop their operations based on them. With the help of data, it is possible to find regularities, recurring events and trends. The results obtained by data analysis can be divided into four categories; descriptive, diagnostic, predictive and prescriptive. (Stevens, 2022)

Descriptive data analytics tells what has happened. With its help, it is not possible to find answers to problems, nor to find cause-and-effect relationships for events. (Stevens, 2022) The company's key figures and data from ERP are a good example of this kind of result.

Diagnostic analytics digs a little deeper with the help of data. It answers the question why something has happened. The purpose is to focus on anomalies found in the data. For example, large changes in order quantities or delivery accuracies are such anomalies. In diagnostic analytics, you have to use other data sources in order to be able to understand what causes the changes. (Stevens, 2022) It is possible that the reason for the weakened result is revealed to be a machine failure or even a deficiency due to a single component at some point in the supply chain. Analytics should not only focus on finding problems. Positive observations, such as increased sales or delivery reliability, should also be taken into account and try to understand what caused these changes. These lessons can potentially be used in other phases of the supply chain.

With the help of predictive analytics, the aim is to find out what is likely to happen in the future. It takes into account the results of two previous analytics, what has happened and why it has happened. This is especially useful for companies when they are trying to plan their future operations. Predictive analytics uses relationships between different variables to form predictive models of the future. (Stevens, 2022) For example, it may be possible to predict customers' ordering behavior based on previous ordering behavior, which makes it possible to facilitate the company's production planning and procurement.

The purpose of prescriptive analytics is to show how the company should act in anticipated situations. Prescriptive analytics takes into account the final results of the previously described analytics methods, which aim to get a picture of what should be done next. Prescriptive analytics is the most complex form of analytics, as it seeks to find solutions for all possible decisions and outcomes that a company can make. This is achieved by using, for example, algorithms, machine learning and statistical methods. With the help of analytics, different scenarios can be seen, how different events lead to different results. Based on these scenarios, the company can decide how it should proceed. (Stevens, 2022)

3 Supply Chain

3.1 Supply Chain Management

The supply chain includes all parties that are directly or indirectly fulfilling the customer's needs. In addition to manufacturers and suppliers it includes transport companies, retailers, warehouses, and customers. All operations of each organization are also part of the supply chain. These include, for example finance, product development and customer service. The supply chain is dynamic and constantly moves information, products and money. Many supply chains can be considered as networks so it would be more reasonable to talk about supply network. (Chopra & Meindl, 2013)

The purpose of every supply chain is to maximize the value it produces. Value can also be referred to as surplus, which corresponds to the value produced for the customer minus the costs caused by the supply chain. Productivity of the supply chain can be calculated by subtracting the total costs caused by the supply chain from the price received from the customer. (Chopra & Meindl, 2013)

Each supply chain has its own customer needs, which they should be able to meet. The subject can be examined through three points. The company must understand the market in which it operates. The company must be able to define its own core competence areas. And the company must have the ability to develop its supply chain. (Hugos, 2018)

By understanding the market in which the company operates, it is able to facilitate its balancing between cost efficiency and service level. The supply chain should support the company in implementing its strategy. The company's strategy is based on customer needs. A company whose supply chain enables it to meet customers' needs most efficiently will gain market shares at the expense of its competitors. (Hugos, 2018)

Understanding the market can be started by finding out what the current customers are like and who their customers are. It is important for the company to understand what kind of supply chain they are involved in. Based on the information received, the company can make a decision whether it should focus on responsiveness or efficiency. (Hugos, 2018)

It is also important for the company to understand its own core competence areas. Each company can operate in several markets and in several supply chains. Some of the activities may be unique to a certain sector, while in relation to other markets, activities can be combined to achieve financial benefits. (Hugos, 2018)

When the company has found out what kind of market it operates in and what its core competence is, what remains is the development of operations so that it can fulfill its own role in the supply chain. Operations can be developed through five supply chain drivers. The drivers of the supply chain are production, warehouses, location, transportation and information. (Hugos, 2018)

The supply chain consists of a number of companies that participate in getting the product on the market. The main goal is to increase sales while reducing inventories and expenses. In the modern supply chain, each company focuses on its own core competence and networks with other companies in order to get products to the world. Companies must focus on developing their core competencies in order to remain competitive. Companies must be able to align their supply chain with market requirements. (Hugos, 2018)

Decisions related to the supply chain play a significant role in the company's success. In order to stay competitive, the company must be able to adapt to changing requirements, both in terms of technology and customer needs. Decisions related to the supply chain can be divided into three main categories. These categories are strategy, planning and execution. (Chopra & Meindl, 2013)

In the strategy phase, activities are planned for several years ahead. At this stage, decisions are made, for example, between buying and manufacturing products. In the planning phase, the timeframe is from a quarter to a whole year. The goal is to maximize the surplus of the supply chain. At this stage, companies should think about inventories, for example. Uncertainties related to deliveries should also be taken into account at this stage. The end result is methods of operation that can be used to run daily operations. In the implementation phase, the time interval is from days to a week. At this stage, operations are focused on individual customer orders, which are aimed at being fulfilled as efficiently as possible. When the time interval for decisions shortens, the uncertainty about future events also decreases. Within the same day, there are rarely significant changes to plans, while within the same month, the fluctuations can be large compared to what was anticipated. It can be said that a good strategy enables good planning, which enables good daily operations. (Chopra & Meindl, 2013)

The company achieves its goals related to the supply chain through three levels. These include understanding the uncertainty associated with customers and suppliers, as well as understanding the capabilities of the supply chain. Customer needs usually depend on where the final product goes. Urgent spare parts orders are usually smaller in quantity, while quantities for production lines or large construction projects are larger. The company should also understand what kind of delivery times the customer can tolerate. Small rush orders are usually needed immediately, while larger orders going into production allow for longer delivery times. In spare parts orders, the customer may place a high value on getting all parts from one place, while in construction projects it may not be necessary. Urgent orders should be received with a short delivery time and the customer may be looking for another supplier to meet their needs, in construction projects the service level may be weaker even in the short term. (Chopra & Meindl, 2013)

3.2 Forecasts in Supply Chain

Demand forecasting is at the heart of all supply chain management. All push processes are based on anticipating demand, while pull processes react to demand. In this case, resources should be able to be foreseen. In both cases, you have to anticipate the demand created by customers. (Chopra & Meindl, 2013)

There are a few things to remember about forecasts. They are always imprecise and should always include both an expected value and a margin of error. Companies should take into account the possible margin of error when making forecasts, as it helps to better allocate resources. Even if two forecasts have an average demand of 1000 units, the operation must be different if the range of one forecast is 100–1900 units and the other is 900–1100 units. Long-term forecasts tend to be less accurate than short-term forecasts. The further the company is in the supply chain in relation to the customer, the more distorted forecasts they get. This distortion in the supply chain can be described by the term bullwhip effect. (Chopra & Meindl, 2013)

In the bullwhip effect, a small change in demand leads to a greater variation the further along the supply chain you go (Figure 1.). The phenomenon can be seen especially in industries that are growing rapidly. At first, as the demand grows explosively, companies increase production to meet the increased demand. At some point, a level is reached where supply exceeds demand. When demand starts to stabilize, many companies notice the change too late, which leads to excessive production volumes and, in the longer term, production downtime. The costs resulting from the effect are felt everywhere in the supply chain. Companies have to increase production capacity and material purchases. Additional transport has to be organized in order to be able to meet the demand. Inventories are increased so that fluctuations in demand would cause fewer problems. Increased demand can also lead to problems in terms of sales. Products do not get to the shelf early enough, which can lead to lost sales. (Hugos, 2018)

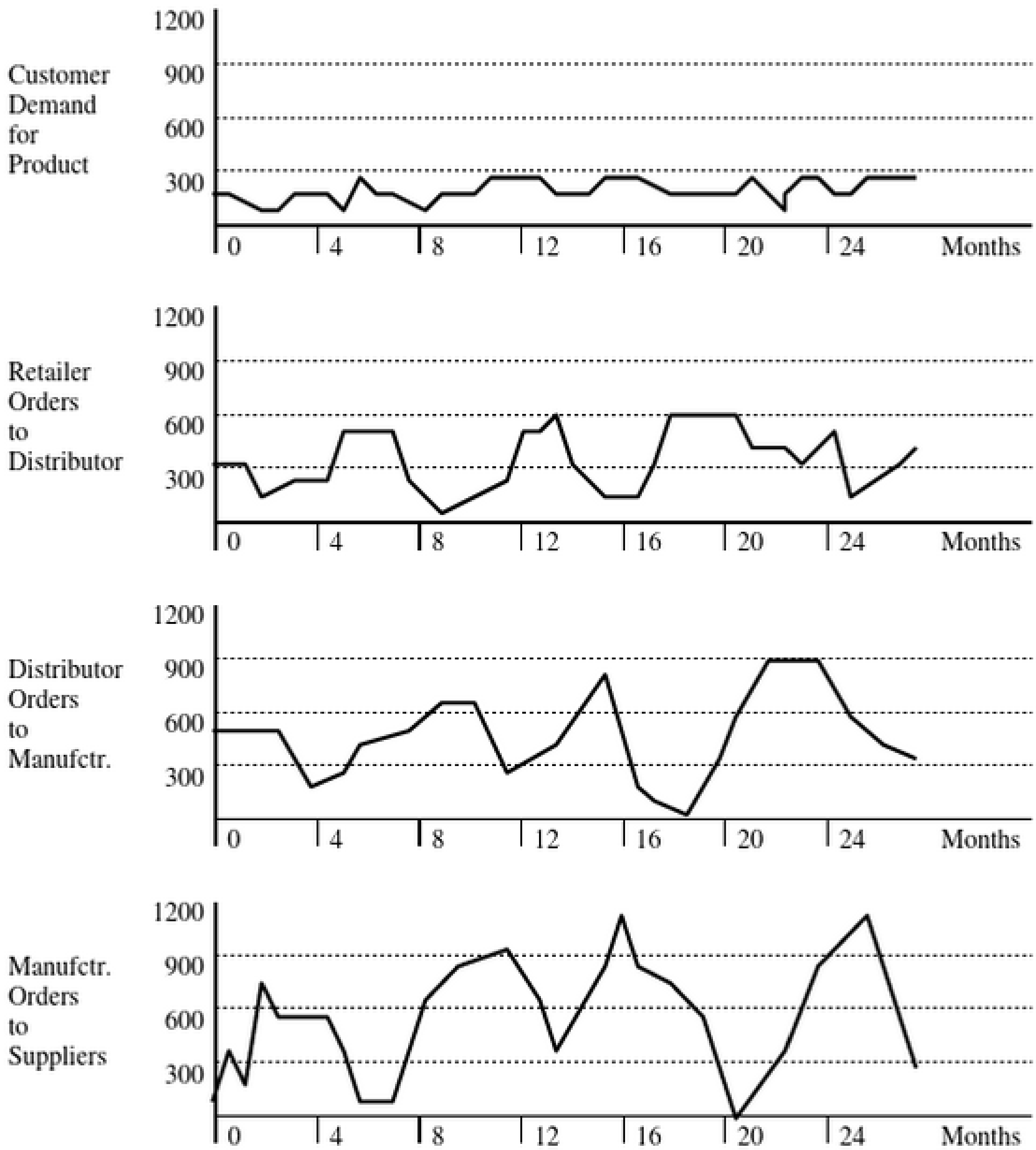

Figure 1. The impact of the bullwhip effect in the supply chain. (Hugos, 2018)

It has been possible to identify five reasons that cause the bullwhip effect. These affect each other in different ways in different supply chains, but the common feature is that they create large swings in demand, making effective supply chain management impossible. These five reasons are, demand forecasting, order batches, production organization, product pricing and performance incentives. (Hugos, 2018)

When forecasts are based on received orders and not on real demand, this causes variation in the supply chain. If a company in the supply chain does not know how the end customer works, they lose an understanding of the real market demand. Each company begins to see demand as a phenomenon created by the bullwhip effect, and they pass this knowledge forward by responding to the demand distortion created by the supply chain. By sharing information about actual demand with the entire supply chain, the impact of the whiplash effect can be reduced. (Hugos, 2003)

What the company knows about its customer's past demand usually already creates preliminary information about future demand. Demand rarely arises completely out of the blue. It is usually the result of various factors and thus is predictable. Companies must try to find out what these drivers affecting the future are and find out their effect on future forecasts. Historical data alone is not always enough to make predictions. It is usually good to be aware of the market situation in order to make forecasts more accurate. Not all things can be predicted based on historical data either, so human understanding of situations can make forecasts more accurate and create significant benefits for the supply chain. A company should be able to take many things into account when making forecasts. These include e.g. past demand, replenishment delivery times, economic environment and competitors' activities. (Chopra & Meindl, 2013)

Forecasting methods can be divided into four groups, qualitative, time series, causal and simulation. The qualitative method is based on human judgment, intuition. Time series are based on past demand. They assume that the past will repeat itself. The causal method assumes that demand depends on certain factors. The causal method aims to find correlations between demand and environmental factors. The simulation combines time series and the causal method. It aims to create models that can predict the consequences of certain activities. (Chopra & Meindl, 2013)

Often, using a single method is not sufficient, so it is worth using several methods to make predictions. All methods of forecasting usually have an element of chance that can be explained by historical data. Observed demand can be divided into two parts, systematic demand and random demand. Random demand should not be forecasted too precisely. In many cases estimating demand range and possible variation is enough. This sets the stage for determining the forecast error. Forecasts should be treated with skepticism if they do not provide any information about the possible margin of error based on historical data. Usually, random demand is not separated from systematic demand, which can be the reason why forecasts probably work poorly. (Chopra & Meindl, 2013)

Uncertainties related to the supply chain come from three sources, suppliers, production and customers. Over time, all processes produce data, on which it is possible to evaluate the performance and probabilities of success in the various parts of the supply chain. The problem with data is the supply chain itself. To be able to make accurate decisions based on data, it must be collected from several different sources. Errors related to data entry also create problems in obtaining accurate data and create the possibility that an incorrect picture of the operation is created. It is not necessary to include all products in the creation of the supply network model. For example, ordinary nuts and bolts can be left out completely. In addition, part of some products can be omitted if their behavior can be described with the help of another product. (Davis, 1993)

4 Inventory Management

4.1 Inventory Management

When talking about inventory management, it means ordering, storing, using and selling the company's raw materials, components and finished products. Inventories are vital for the company's operations. Having the right amount of products, components and raw materials in stock enables serving the customers at an excellent level. Inventories can also be a hindrance to the company's operations. An excessive amount of parts in the warehouse ties up the company's capital, which could be used for other activities, and potentially obsolete products may have to be thrown away without providing any financial benefit to the company. (Hayes, 2022)

When you know when and how much more products need to be ordered, you can keep the company's inventory turnover high and therefore generate more profit. The appropriate inventory management system depends on the company's operations. For example, in an industrial production environment, some parts can be bought in large quantities at once, because their shelf life is good and their replacement with other parts is unlikely. (Hayes, 2022)

4.2 Reasons for Inventories

There are many uncertainty factors associated with the operations of companies. Uncertainties can be related to the amount or timing of demand, delivery times may not be accurate, and the equipment does not always work as expected. When the demand is greater than anticipated, the company needs safety stock in order to be able to meet the demand. If the uncertainty is related to delivery times, the company should use the safety time with its orders. (Chapman, Arnold, Gatewood & Clive, 2017; Hopp & Spearman, 2011)

Companies' inventories include, for example, their raw materials, work-in-progress, components, supplies and finished products. Müller (2011) defines the main reasons for keeping stocks as demand fluctuations, supply uncertainties and product prices. The first two affect the company's ability to serve the customer, and the third affects mainly the company's profitability, but also helps to keep the price level of the products as low as possible so that they are attractive to customers.

No matter how well you prepare, no one can say for sure how much demand there will be in the future. Still, the company should be able to meet the demand. The better the future can be predicted, the less inventories are needed (Müller, 2011)

Delivery times may also vary. Inventories are needed especially when the supplier is known to have difficulties in meeting delivery times. The more reliably the supplier operates, the less need there is for stock. (Müller, 2011)

The last reason is the price. The prices of the products may change depending on the market situation and it may make sense to purchase products to stock when they are at their cheapest. Larger order quantities may also bring large discounts, in which case buying in larger batches to stock is profitable. When ordering larger quantities, the ordering costs are relatively lower compared to smaller order batches and more deliveries. (Müller, 2011)

4.3 Inventory Types

Inventories can be divided into three categories, cycle stock, seasonal stock and safety stock. Cycle and seasonal stocks are affected by economies of scale. Batch size is usually determined based on production and storage costs. The safety stock is determined based on the predictability of demand. The more uncertain the future is to predict, the larger the safety stock should be. (Hugos, 2018)

The purpose of the cycle stock is to cover demand in the period between purchase orders. Its existence is based on the use of batch sizes to achieve lower prices. The end customer may order small batches throughout the year, but the company may find that it makes more sense to order larger batches in terms of cost efficiency. (Hugos, 2018)

Seasonal stock is when the company anticipates future demand by increasing production or order quantities. Decisions to increase production are driven by the desire to act cost-effectively in terms of the entire supply chain. (Hugos, 2018)

A safety stock is necessary in order to be able to react to the uncertainty of demand and supply. The greater the uncertainty, the greater the safety stock should be. The size of the inventory can be reduced in four ways; by reducing the uncertainty of supply and demand, shortening delivery times, and reducing the variability of delivery times. (Hugos, 2018)

4.4 Material Management

Traditional material management thinking assumes that the total demand for a product is built up from the demand of several individual customers. Demand is thought to be independent. For example, in retail, the total demand for a single television is made up of the needs of several customers. (Waters, 2003)

However, this way of thinking does not apply everywhere. In the manufacturing industry, the demand for individual components is usually dependent on the demand for their associated final as-assemblies. This kind of demand can be managed with the help of MRP, which "explodes" the list of components related to the final assembly into individual needs. (Waters, 2003)

Figure 2 shows the differences in the effects of independent and dependent demand on inventory management. Independent demand is based on forecasts that are based on past demand, and the amount of inventory must be the right size to be able to cover potential demand. Dependent demand is based on production planning, where the required number of parts arrives slightly before they are needed. Order quantities vary according to visible demand. When operating according to MRP, stocks can be significantly smaller than when operating based on independent demand. (Waters, 2003)

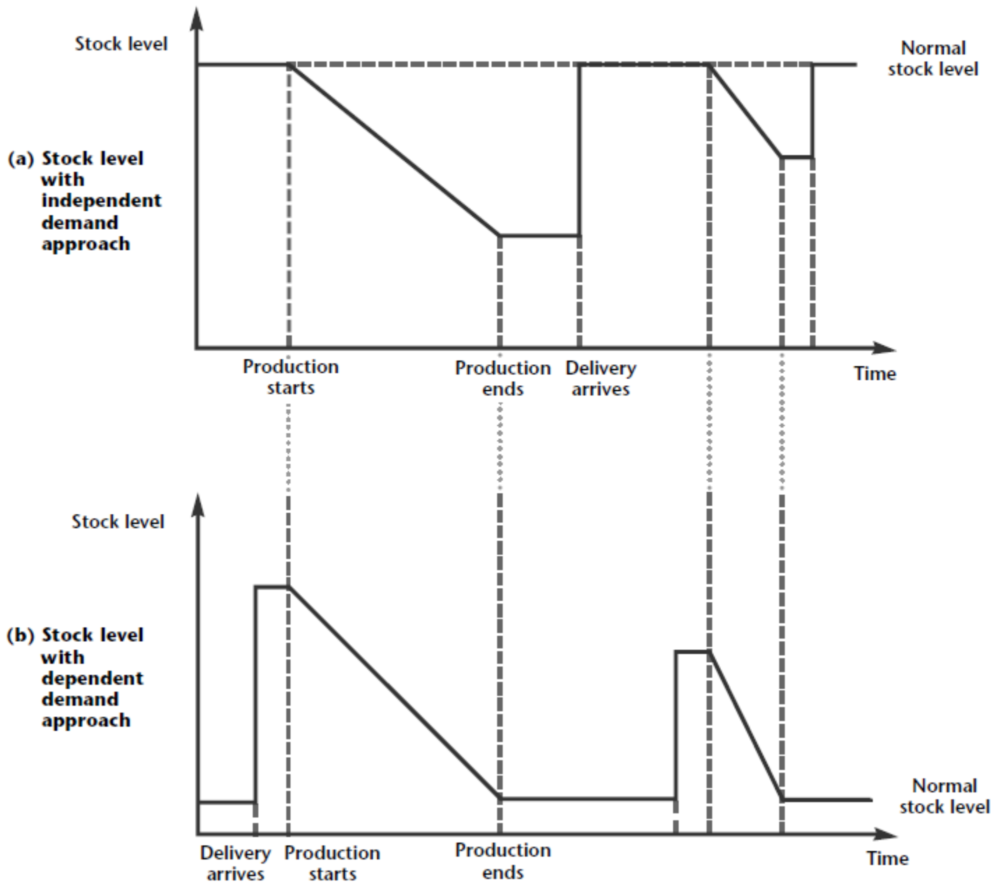

Figure 2. Effect of nature of demand on inventory levels (Waters, 2003)

Just-in-Time (JIT) type production brings one more way to material management planning. In this way, just the right amount of materials is procured so that they arrive in production exactly when they are needed. When working perfectly, JIT can completely eliminate the inventories. (Waters, 2003)

Figure 3 illustrates the effect of different planning methods on the stock levels. In simplified terms, the amount of stock depends on how well the supply of materials can be matched to demand. The bigger the differences are and the less information there is about future demand, the more inventory is needed to meet customer needs.

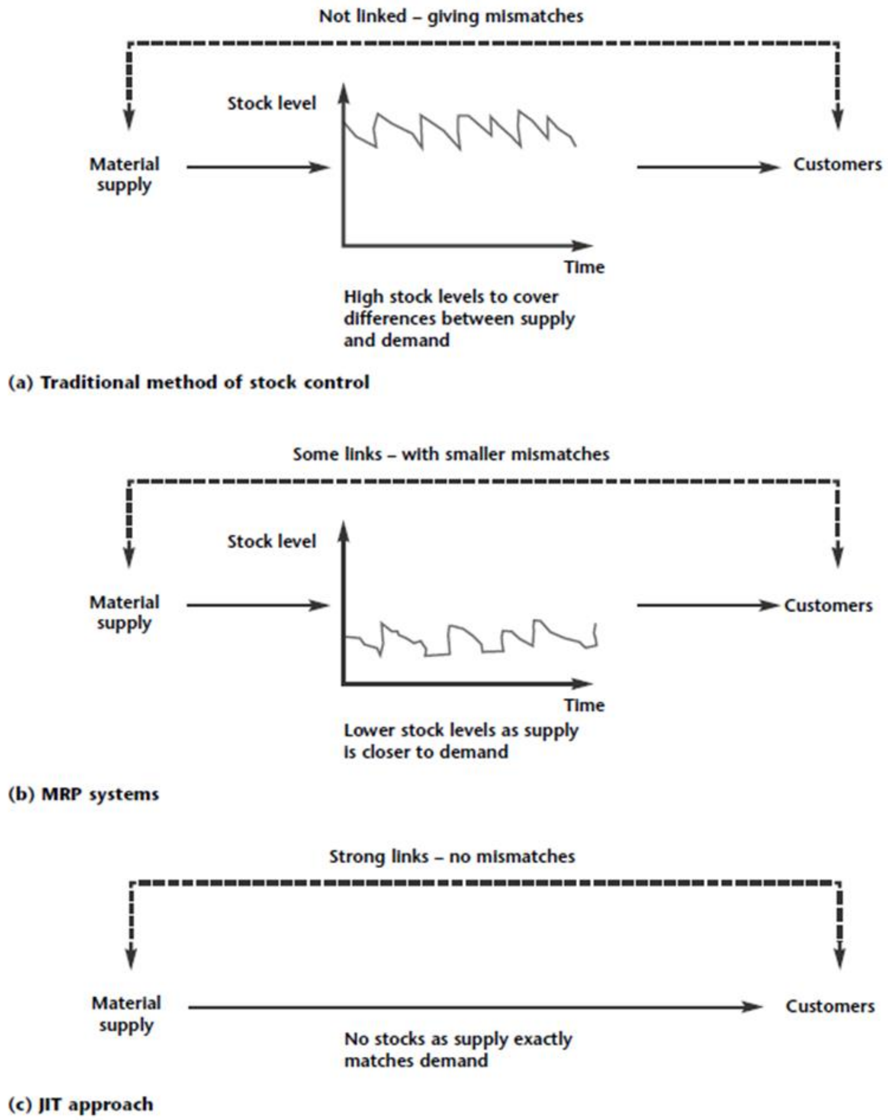

Figure 3. The impact of planning methods on inventory levels. (Waters, 2003)

4.5 Determination of Safety Stock

The purpose of safety stocks is to respond to unpredictable fluctuations in supply and demand. There is no single calculation formula for determining the size of the safety stock. The calculation of the amount depends on how much information is available about the demand and availability of materials.

At its simplest, Chapman et al. (2017) determine safety stock using Z-score and standard deviation of demand.

$$Safety\ stock = Z * \sigma_D$$

Nevil (2023) defines the Z-score as “statistical measurement that describes a value's relationship to the mean of a group of values”. The Z-score is measured in terms of standard deviations and is used to determine how high a service level is aimed for. Figure 4 describes the relationship between the Z-score and the targeted service level.

Desired cycle service level	Z-score
84	1
85	1.04
90	1.28
95	1.65
97	1.88
98	2.05
99	2.33
99.9	3.09

Figure 4. Relationship between desired service level and Z-score. (King, 2011)

King (2011) offers multiple ways to calculate safety stock. Safety stock can be determined using uncertainties related to both demand and supply. Listed below are explanations for the notations used in King's formulas.

- Z = Z-score
- PC = Performance cycle (Total lead time)
- T = Time increment used for calculating standard deviation of demand
- σ_D = Standard deviation of demand
- σ_{LT} = Standard deviation of lead time
- D_{Avg} = Average demand

King (2011) uses total delivery time in addition to the standard deviation of the demand to calculate the safety stock.

$$Safety\ stock = Z * \sqrt{(\frac{PC}{T})} * \sigma_D$$

As an example, we can think of a situation where the company's weekly demand is 100 units, the standard deviation of the weekly demand is 15 units, and the delivery time including transportation is 8 days. If the delivery time is easily predictable, the safety stock can be calculated using the above formula. The service level is defined as 95%, in which case the Z-score is 1.65 according to the table.

The uncertainty of operations can also be caused by supply. Then King (2011) determines the safety stock using the standard deviation of the delivery time and the average of the demand.

$$Safety\ stock = Z * \sigma_{LT} * D_{Avg}$$

When the uncertainty is caused by both demand and delivery time, then the formulas used can be combined in order to calculate the safety stock. When demand and delivery time are independent of each other, and follow a normal distribution, the safety stock is calculated using the formula:

$$Safety\ stock\ =\ Z * \sqrt{\left(\left(\frac{PC}{T} * \sigma_D\right)^2 + \left(\sigma_{LT} * D_{Avg}\right)^2\right)}$$

(King, 2011)

If demand and delivery time are not independent, the formula is the sum of the previously presented formulas:

$$Safety\ stock\ = \left(Z * \sqrt{\left(\frac{PC}{T}\right) * \ \sigma_D} \right) + \left(Z * \sigma_{LT} * D_{Avg} \right)$$

(King, 2011)

The use of safety stock is a good operating method in an uncertain operating environment. However, the formulas used to calculate the size of the safety stock can give unnecessarily large values, which results in too large quantities being kept in stock. The size of the inventory can be reduced with a working expedite process. The process is especially suitable for more expensive products with high storage costs. (King, 2011) When utilizing the expedite process, however, one must understand what kind of products are involved and in what kind of supply chains they are used. If it is a product that the supplier keeps in stock, the expediting process can be a viable method of operation. In long supply chains, where products are ordered through several suppliers, expediting can be difficult or even impossible.

4.6 Inventory Control Systems

Understanding the average and variance of supply and demand, and also delivery times is the key to optimal inventory management. The commonly used ABC analysis, which is based on the product of price and demand, does not provide an efficient way to manage inventory. When using ABC analysis, a 1,000-euro product with a consumption of one unit in the review period gets the same classification as a one-euro product with a consumption of 1,000 units in the review period. However, parts like this should not be treated with the same principle. Keeping cheap, high-demand products in stock is a good practice, while with expensive products, you should strive towards the buy-to-order method. (Pound, et al., 2014)

Many ERP vendors offer an ABC analysis-based approach to inventory management in their programs. Although this is the way the software recommends, it does not mean it is the most efficient way to manage inventory. (Pound, et al., 2014)

In a business-to-business operating environment, products usually have some kind of lead time defined. Usually, this time allows you to get the products during this time. If the delivery times of replenishments are shorter than the delivery times of sales orders, taking into account the variation, no additional safety stocks are needed. In this case, it is possible to keep smaller stocks. In these situations, the only inventory is the number of parts left over from the optimal order lot size. (Pound, et al., 2014)

In general, MRP systems use one of two corresponding systems, an order point system, which uses an order point and an order quantity, or a time phased order system, which uses a planned delivery time, safety stock, and inventory surplus. Both systems provide the same information on how much to order and when to place the order. (Pound, et al., 2014)

In an order point system, an order is placed when the stock quantity reaches a specified order point. In a time phased system, the order is placed when the forecasted stock quantity in the delivery time of the replenishment reaches the safety stock. Mathematically, this can be described by the formula R = PLT x D + SS, where

- R= Order point
- PLT = Planned delivery time in days
- D = Average demand per day
- SS = Safety stock in pieces

The order quantity is a predefined quantity in the order point system. In the time phased system, the order quantity is defined as how many days' needs to be ordered. Expressed mathematically, the quantity to be ordered is expressed as Q = DOS x D, where

- Q = Order quantity
- DOS = Days of stock ordered
- D = Average demand per day (Pound, et.al., 2014)

In the order point system, an order of quantity Q is placed when the quantity in stock + the quantity on order - the quantity of late customer deliveries reaches the point r. However, this system does not take into account future sales. The order is placed regardless, even if there are no needs in the future. (Pound, et al., 2014)

In a time phased system, MRP checks the available quantity, which means the quantity in stock + future receipts - demand, at the specified delivery time of the part. If the available quantity is less than or equal to the safety stock quantity, the system creates a purchase proposal. (Pound, et al., 2014)

Davis (2013) also offers two other ways to replenish stocks. These methods are the base stock replenishment method and the min-max replenishment method. In both methods, an upper limit is defined for the parts, which serves as the basis for the level at which stock replenishment should be made.

The base stock replenishment method is recommended for products whose ordering costs are lower compared to storage costs. In method for each sold product, an equivalent amount of products is ordered back into the warehouse. (Davis, 2013)

The min-max replenishment method is recommended for products which ordering costs are higher than the storage costs. In the method, minimum and maximum values are defined for the product, which guide the replenishments. In the min-max method, the amount of stock is reviewed at regular intervals, for example weekly. When the quantity falls to the specified minimum value, an order is sent to the supplier with at least the quantity calculated as the difference between the maximum and minimum values. The quantity can also be higher depending on the order coefficients set for the product. (Davis, 2013)

4.7 Analyzing Materials Management

Several different means of analysis can be used to support inventory management. In order to reach an optimal result, several different methods must be used so that the peculiarities related to supply chains can be observed and taken into account when planning inventories.

The ABC classification system answers the question of how important a certain product is and how they should be managed. The system is based on the observation that a small part of the products causes most of the expenses. This observation is called Pareto's Law and is named after the Italian economist Vilfredo Pareto. In the ABC analysis, group A is responsible for about 20% of the products and about 80% of the expenses. Group B has 30% of parts and 15% of costs. The last group C has 50% of products and 5% of expenses. (Chapman et al., 2017)

The classification shows how much attention should be paid to a certain product. Group A products are usually expensive and make up most of the total costs, so it makes sense to invest time and resources in managing them. Group C parts are the cheapest, so the extra stock doesn't cause significant extra costs for them. Because of this, it does not make sense to spend too much time controlling them. Group B needs more control than group C products, but not as much as group A products. Depending on the inventory management system, the ways to manage these inventories may be different. Each of these inventories should be controlled in its own way. (Hopp & Spearman, 2011)

XYZ analysis classifies items according to fluctuations in demand. Figure 5 visually shows the differences between the classes. By understanding the differences between the categories, they can be used to make inventory management more efficient. A better understanding of the titles enables the automation of operations, and with it, it is also possible to calculate the quantities of titles in stock if necessary. (CGMA, n.d.)

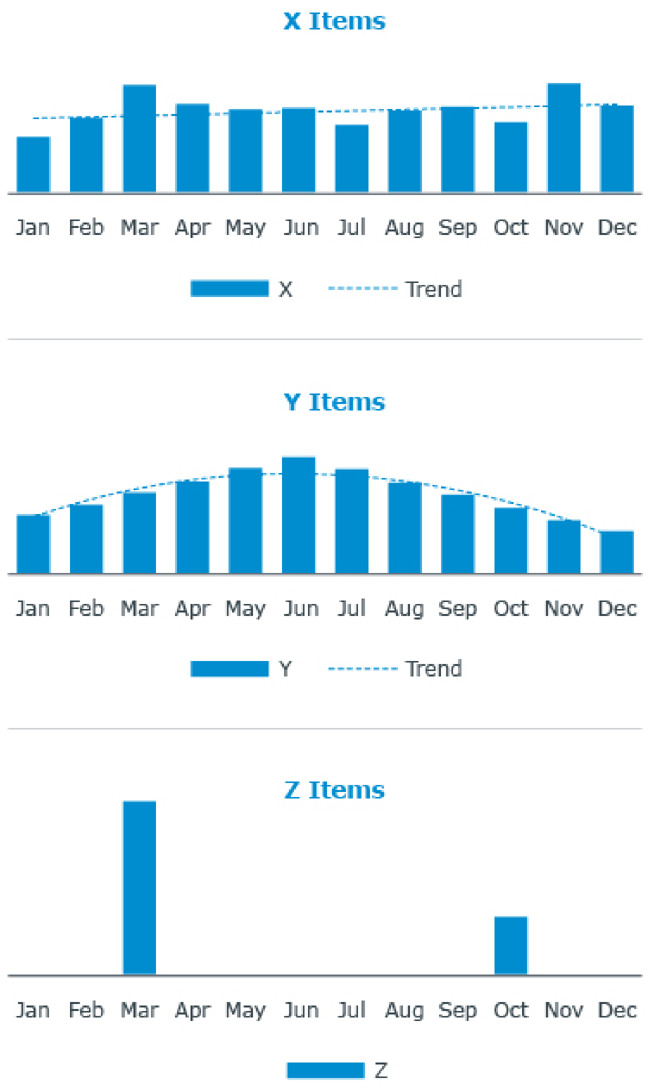

Figure 5. Classification of XYZ-analysis (CGMA, n.d.)

The demand for X items remains constant all the time, and their future demand is easy to predict. Due to the small variation, it is possible to automate the replenishment of these titles, as there are rarely surprises in their demand. The quantities of safety stocks can also be calculated for the same reason. (CGMA, n.d.)

There is some variation in the demand for Y items. However, the variation is predictable, and its causes can be determined. Foreseeable reasons include, for example, the seasonality of demand and the life cycles of items. Larger safety stocks are needed for these titles, and their replenishment must be done more manually. (CGMA, n.d.)

The demand for Z items is the most difficult to predict. The demand may vary greatly, and it is impossible to connect any foreseeable reasons to it, which is why it is impossible to reliably predict the demand for these items. In replenishment of these products, you should prefer replenishment based on orders. (CGMA, n.d.)

The SDE analysis classifies items based on the challenges associated with their acquisition. The abbreviation SDE comes from the words scarce, difficult and easy. S items are not easily available on the market and acquiring them may require a lot of work. D items are difficult to obtain in terms of availability. They can be, for example, products manufactured for the company according to the drawing. Only a couple of suppliers may have been specified for these items and the prod-ucts have to be ordered well in advance to ensure their availability. E items are already available on the market. There are several sources available for titles, usually also locally, and their supply often exceeds demand. (Bose, 2006)

5 Results

The purpose of the thesis is to find ways to reduce SKF's inventory value. The methods are covered with the help of a one example case, with the aim of obtaining as comprehensive view how data could be utilised in inventory management. The sample case is selected using ABC analysis and informed selection. The purpose is not to find a perfect solution that can be implemented immediately, but the purpose is to find a direction towards which to proceed. Although the demand that comes from customers may seem random, there are often regularities to be found. There are a lot of variables involved in a company's inventory management, which you cannot directly influence and which you may not know how to identify. Because of this, giving a perfect solution is practically impossible.

5.1 Data Collection

Data for this thesis is collected from the company's ERP system. There are three sources that are used to gather all required data. First, to understand the demand for the selected product, sales data is needed. To understand the supply, data from purchase orders and transactions from goods receipt are needed.

The selected component is part of several assemblies. From ERP the information about the assemblies where the part is used can be found. From sales order data only order lines for the defined assemblies were taken into account. To understand the demand order date, delivery date and customer is collected. There is a limitation related to delivery date. Using only order date and confirmed delivery date to understand customers buying behavior might give wrong view of the demand. To solve this issue, requested delivery date should also be collected to understand when the customer wants the product to be delivered.

To understand how the supply works purchase order data and transaction data is used. From purchase orders the purchase date, requested delivery date, confirmed delivery date and supplier is collected. This data is combined with transaction data from goods receipts to get the information of actual delivery date.

5.2 Analyzing supply

Analysis starts by going through data gathered about the supply of the item. The goal for the analysis is to find out if there are any specific patterns for how supplier operates. It is also important to understand what kind of product is analyzed.

The chosen product is made according to the drawing company provides to the supplier. It is important to understand how the supply chain operates. This knowledge becomes important if some-thing goes wrong and you have to find backup solutions to receive the items. With this type of product, the supplier's delivery reliability takes on a big role in order to be able to meet the emerging demand. In order to be able to evaluate the supplier's performance, there should be defined performance indicators that show how well the supplier performs. Good indicators are, for example, how well the supplier confirms the order by the requested delivery date and how well the supplier is able to deliver the products on the confirmed delivery date.

The most important measurement for supply is delivery accuracy. When calculating the delivery accuracy of the selected product, deliveries ordered during last 12 months period are taken into account. The LT column in Figure 6 shows how well the supplier can meet the requested delivery time. The supplier confirmed 11% of the orders for a day later than requested, with an average change of 5,25 days. The DEL column shows how well the supplier keeps to the confirmed delivery time. The TOT column measures the supplier's delivery reliability in relation to the requested delivery date. In total, 22% of orders are late, with an average delay of 4,875 days.

	LT	DEL	TOT
On time %	89 %	86 %	78 %
Late %	11 %	14 %	22 %
Avg days late	5,25	3	4,875

Figure 6. Supplier's delivery accuracy of the product

The days used in the measurement are calendar days, so a delivery that goes over the weekend, it is always delayed by two more days in terms of measurement. With deliveries being late on average by about five days, it can be stated that the supplier has no significant problems with delivery reliability. For this reason, when determining the safety stock, you only need to take into account only the uncertainty due to demand.

If challenges were found in the reliability of supply, it would be necessary to analyze the product's supply chain in more detail. The analysis would be used to find out what causes the difficulties and what causes the bottleneck in deliveries. Problems should be solved in cooperation with the supplier to get the best result.

One of the reasons for inventories is the uncertainty related to the supplier. Based on the analysis, it can be stated that this problem does not exist in the example case. Possible challenges caused by a small delay can be avoided with effective monitoring and communication. If you want to play it safe, you can think about using the safety time when ordering. In this case, the requested delivery date of the products would be a specified amount of time before the actual need. In practice, in this case, the only supply-related need for inventories is the standardized batch size. However, this does not have a significant long-term impact on the value of the company's inventory due to the high turnover.

5.3 Analyzing Demand

Analyzing the demand starts by going through how much the product is used during the year. The product is part of several different assemblies, so the consumption of all assemblies must be taken into account. The information is obtained by collecting the transactions related to the products in question. Based on the analysis the annual consumption is approximately 1500 pieces. Annual consumption alone may not be sufficient information to determine inventory levels. The annual consumption in our example case can be obtained by selling, for example, fifty times a lot of thirty pieces or once a lot of 1500 pieces. Figure 7 shows how demand is distributed on a weekly basis, which already gives a little more information on how consumption behaves.

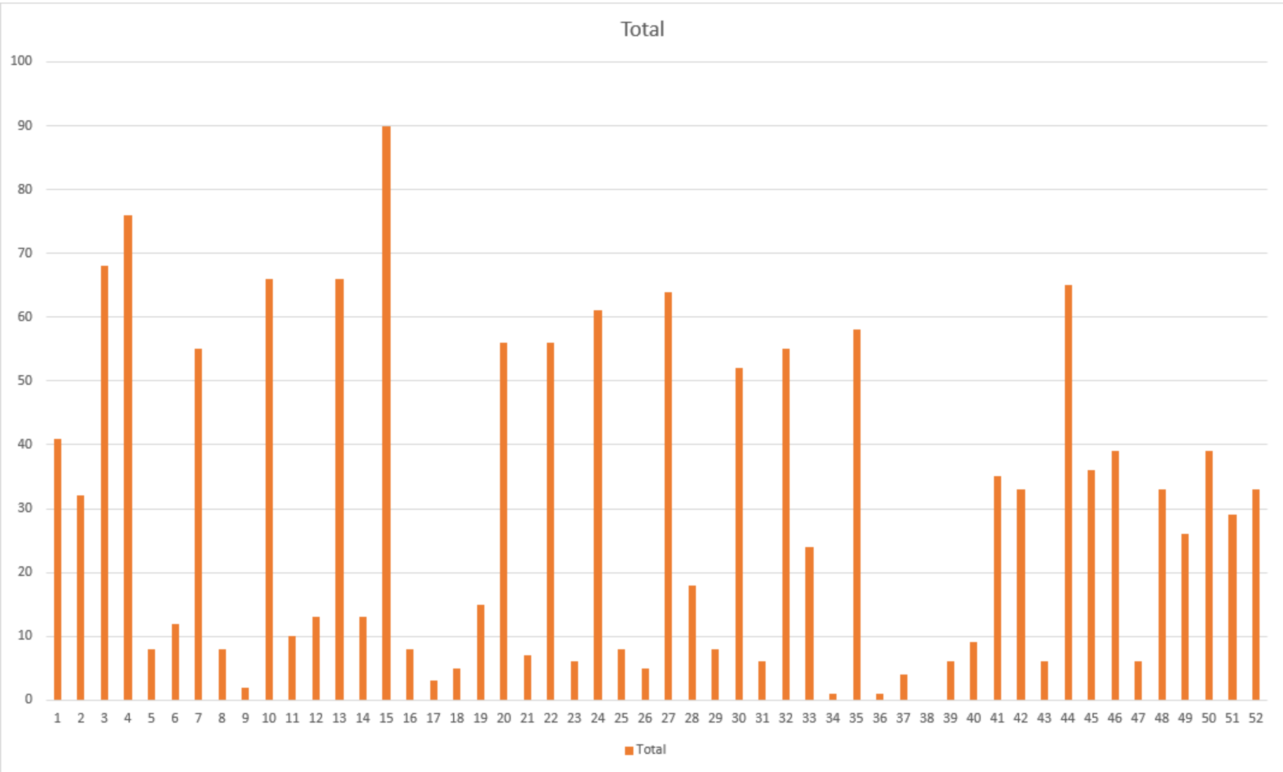

Figure 7. Graph of the whole demand

Based on the picture above, the demand is very variable. As a result, large inventories would be needed to meet the demand. With the help of data, it may be possible to smooth out fluctuations in demand. The product's delivery time is three weeks, so if sales come with longer delivery times, we have the opportunity to react to them. There is no need to store products separately for those needs, but arrivals at the warehouse will be scheduled based on the needs. However, it is good to use the safety time, which ensures that the purchase orders can be processed and the products are in stock before they are needed. In the example case, a two-week safety time is used, making the total delivery time five weeks. Looking at demand with a delivery time of less than five weeks (figure 8) we get a completely different picture of needs. The demand is clearly lower, only about 400 pieces, and at the same time the fluctuations in demand are significantly smaller.

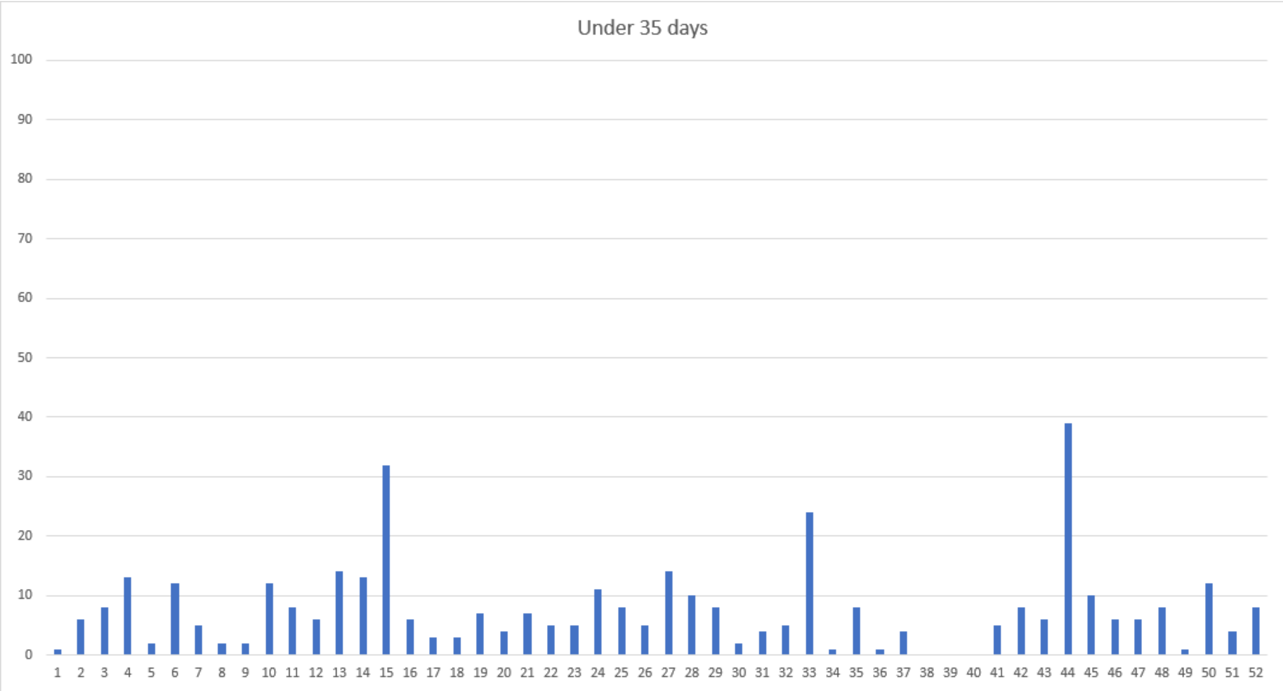

Figure 8. Graph of demand with less than 35 days lead time

When the previously presented results are shown together in the same graph (figure 9), the difference can be seen more clearly. A smaller variation in demand enables smaller safety stocks to be kept, and the knowledge of how demand behaves enables the delivery performance to be kept high at the same time.

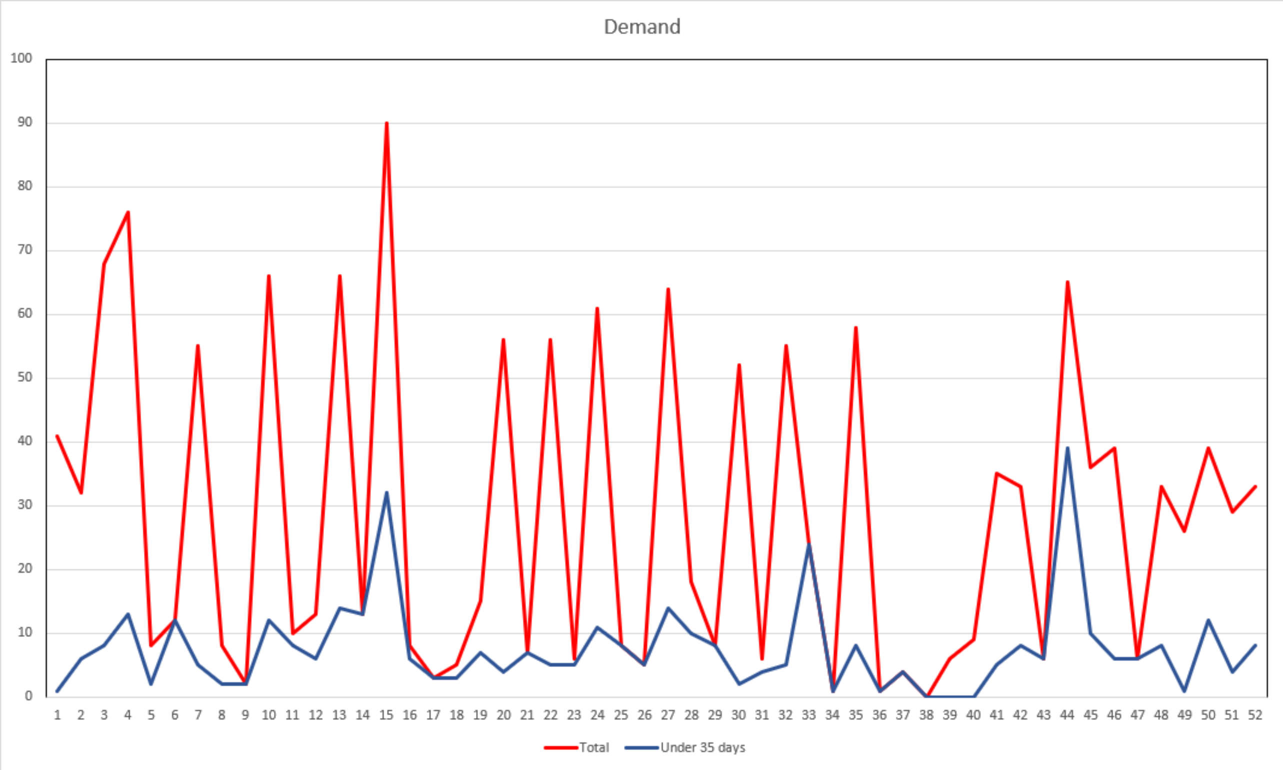

Figure 9. Combined graph with total demand and demand with under 35 days lead time

5.4 Defining Safety Stock

The purpose of the safety stock is to respond to fluctuations in demand. In figure 9, we could see how big the difference in demand variation can be when we look at it a little more closely. A large difference in demand fluctuations also means a large difference in the size of the safety stock. Since there was no significant problem with supply, then King's (2011) formula below can be used.

$$Safety\ stock = Z * \sqrt{(\frac{PC}{T}) * \sigma_D}$$

When comparing the size of the safety stock needed in different cases, the basic information can be identical, only the standard deviation is different in each case. The basic information is a delivery time of three weeks and a service rate of 95%, which means a Z-score of 1.65. When calculating safety stock for the total demand, the standard deviation is 24.5, and when calculating the demand for delivery time less than 35 days, the standard deviation is 7.2. Based on these figures, when using the total demand, the safety stock should be 70 pieces, while only in preparation for future demand with a delivery time of less than 35 days, the safety stock is only 20 pieces. Such a large difference already has a significant impact on the capital tied up in the company's inventory.

5.5 Ordering Process

A common way to order products is to use the order point method. With the order point method, the order is sent to the supplier when the quantity in stock reaches the specified reorder point. The reorder point is determined by multiplying the average consumption by the product lead time and adding to this the amount of safety stock. With total demand, the average consumption is 30 pieces per week, the delivery time is 3 weeks, and the previously determined safety stock is 70 pieces. In this case, the reorder point is 160 pieces.

However, the order point method is not necessarily the most efficient method in terms of inventory management, as it does not take future needs into account. A more efficient way would be to utilize MRP combined with forecasts. This would provide an opportunity to keep inventory levels significantly lower, as orders can be better timed to arrive closer to inventory depletion. With a delivery time of more than 35 days, future needs are already known well in advance. In addition, a forecast based on average demand can be used, which is 8 pieces per week for demand with less than 35 days delivery times.

Orders could be sent to the supplier well in advance, when based on the forecast it is known when the ordered goods should roughly be on the shelf. By ordering early, you can better ensure that the supplier has sufficient ability to meet the demand. In addition, providing the supplier with information about forecasted needs can also lead to a reduction in the bullwhip effect.

However, a forecast based on the past is not a guarantee of future demand. That is why it is necessary to monitor the realization of demand every week, in order to be able to notice possible changes in demand and adjust future forecasts if necessary. In addition, with the help of monitoring, it is possible to notice early if one of the orders is arriving too late in the warehouse. With co-operation with the supplier, efforts can be made to advance the delivery of the product or make a partial delivery, which would be able to avoid delays in customer deliveries.

6 Conclusion

The thesis dealt with inventory management from the point of view of only one product. The method can also be applied to other products. The presented method is particularly suitable for A-class items, which make up a significant part of the company's inventory value. According to the Pareto principle, A-class items are about 20% of a company's number of items but make up about 80% of the inventory value.

The presented method shows the basic principles that can be used to find information that facilitates inventory management from the company's transaction data. By understanding where supply and demand are made up, it offers the company the opportunity to reduce inventory value. When you understand how demand and supply are formed, you don't needlessly store goods waiting for future events, but capital tied up in warehouses can be freed up for other uses.

To make data analysis more effective, more information should be gathered. Transactional data shows only what has happened before and focusing too much to it might cause wrong results for future actions. Communication through the whole supply chain will give more information which can be used to improve operations. This information can for example be forecasts from customers or suppliers unusual opening hours during summer.

Analyzing the products one by one is laborious and time-consuming. A-class products alone may contain hundreds of items, so even though what is presented offers an opportunity for savings, there may not be enough time for it. In the future, as technology develops, would artificial intelligence, for example, find opportunities to automate analysis and even find new ways to make inventory management more efficient.

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