INVENTORY MANAGEMENT

– A THEORETICAL APPROACH TO INCREASING DELIVERY PRECISION

Examensarbete – Högskoleingenjör
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Foreword

We would like to thank Parker Hannifin and their employees for their outstanding cooperation and openness during our case study, as well as our supervisors Sara Lorén and Håkan Svensson for their assistance. We would also like to extend further thanks to Jens Bäckstrand, Åsa Lindquist, David Kinander, Manne Björnsson and Christos Michailidis for their great support at Parker.
Abstract

A high level of delivery precision from a focal firm to their customers has the potential to provide competitive advantage amongst competing businesses. This report will detail the subject of inventory management and utilize theories on the subject in order to provide recommendations to a multinational company that wishes to increase their delivery precision. The results of the work conducted are presented and recommendations given in the form of firstly analyzing inventory and segregating the product range where applicable. This should be treated as the first priority to gain an insight into where potential problem areas lie and to determine the products that are the biggest contributors to the overall value of goods sold. As a secondary measure, managing supplier relations carefully and the strategic sourcing of materials are strategies that will help to effectively reduce problems through increased visibility of information in communication channels. An accurate demand forecasting model will predict demand ahead of time, ensuring that the correct products are being held as inventory for no longer than is strictly needed, with a safety stock system being used as a safety net for those products that are suitable. A theoretical implementation of exponential
smoothing based forecasting coupled with standard deviation based safety stock calculations, yields results that effectively raises delivery precision. By forecasting demand for individual months and using calculated safety stock levels, the model is able to adjust for the shortfall between forecasted demand and actual demand.
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1 Introduction

In highly competitive global markets an advantage such as reduced product lead times and increased delivery precision to customer is an effective way to gain a competitive edge over competitors. Two of the customer’s most prominent concerns regarding supplier relations are that deliveries are on time and that lead times may be reduced (Christopher, 2011). Achieving a high delivery precision is dependent on not only the company but also suppliers further upstream in the supply chain. For a company dealing with a large variety of suppliers and products, this can become a frequent problem if not managed effectively (Vachon S, 2002).

When dealing with a large variety of suppliers, there will inevitably be variations in order size, lead times, service levels and more from the supplier. What this means for companies is that suppliers cannot always meet demands of delivery precision and quality. If a delivery from a supplier arrives late or is of insufficient quality or quantity, it will impact production and production planning further downstream in the supply chain. This will then result in deliveries to customers being produced late, which in terms of delivery precision means that the order is late and could result in a customer not returning for future business. To make high delivery precision possible it is important to have the correct materials on hand, in the correct amounts at the correct time. Effective inventory control aids in managing demand and it should not be underestimated how unresolved or hidden problems causing stock-outs or system bottlenecks can have negative consequences further downstream in the supply chain (Madhani, 2015).

This report will cover theoretical aspects of inventory control and demand management, and then apply findings to a case study at a multinational business. Based upon the findings of the case study, a series of suggestions will be given in order to improve aspects of delivery precision from the focal company to customers. Advantages and disadvantages of suggested methods will then be discussed and results will be presented using differences in inventory levels, along with the theoretical implications on delivery precision to customer

1.1 Research Question

The overarching aim of our investigation is to increase delivery precision for products shipped to customers based upon efficient inventory control and effective demand
management techniques. By completing a case study at a focal company, problems within the company’s existing system should be identified and alternative methods to the current safety stock calculations and supplier management strategies should be proposed in a standardized method to control inventory. The research question is:

For a company with a large portfolio of specialized product lines, how should the inventory be managed and how should the eventual need for safety stock be handled? How will this aid in raising the delivery precision to customers and at what cost?
2 Method

To work towards a solution, a study of demand analysis and inventory control techniques will be done via a literature study. Materials and mediums used for the literature study will be publications covering the subject of inventory management and demand analysis techniques found in academic publications. The results of the literature study will in turn give a good ground to discover problem areas during a case study at a focal firm using actual on-site observations as well as interviews and materials prepared by the focal firm. One of the discovered problem areas will then be selected for improvement work, which will be done through a quantitative analysis method (Render et al, 2012).

The quantitative analysis approach does this by firstly defining the problem. A clear and concise statement needs to be forged that is all encompassing of the work area of focus. This is important so that the area of study is focused upon the area that is most required and no undue focus is given to other problems that a focal firm will invariably have. The area of study, or the problem area, should contain variables that can be controlled to yield a better return in efficiency, productivity or profitability.

Once the problem has been defined a preliminary mathematical model can be designed based upon the parameters, decision variables and known quantities given in the problem. An example of a decision variable in the developing of a model is: How many of component X should be ordered? Or what quantity of component Y should be held as safety stock. Variables such as demand and lead time are not decision variables as they are not controllable. (Jonsson, 2008, Langley et al, 2008)

Once the model has been developed, the next step is to acquire suitable and correct input data. It is important that the data is correct and suitable because the model is only as reliable as the data that is entered into it. For our models we have acquired the data directly from Parker’s ERP system, which means that accurate data for products in inventory and their lead times can be put into our model. For an inventory optimization model, the required input data can be found through company reports, databases and interviews with employees at the focal firm. (Bäckstrand, 2015)

The solution will then be derived from the analyzed data combined with the findings from the literature study and presented in the form of a suggested course of action and projected implications (Jonsson, 2008, Weele, 2010).
2.1 Validity and reliability

In order to test the reliability of our forecast 100 randomly chosen products will be put through the forecasting model and have their tracking signal error measurement values plotted as a histogram together with its respective normal distribution curve. If a large portion of results are not in line with the parameters set in section 3.7.4 our forecast would be deemed unreliable (Moskal, B.M., & Leydens, J.A., 2000).

The safety stock model is tested for its validity by testing its ability to prevent stock-outs by comparing expected demand (forecast) to actual demand. These results are then shown in a pie chart and compared to the requirements set for this study.
3 Theory and Literature Study

The theory chosen for this report is based on inventory and demand management techniques. In the following sections relevant theories have been collected.

3.1 Customer Service

A product that is sold to a customer consists of two parts; the physical goods, and the service. In some instances the product is worth more than the service and in others the service takes the upper hand. All of this is dependent on the type of product that is offered to customers. Some examples on what the service can contain are: customer order flexibility, on time delivery, delivery flexibility, etc.

In order to offer a competitive delivery position, it is important for a firm to fully understand their customer needs (Effective Inventory Management, 2013). This will dictate the type of service level that needs to be employed and the standard at which it should be maintained. Of course, a customer may also choose a service level that is required for them to be served by the supplying company also.

By calculating a service level, the reliability of the supplier company can be scored. This score reflects the ability to deliver what is promised in the correct quantity in the time frame agreed. In the event that the focal firm is unable to provide products to its customer, the penalty can be high. Losing customers to competitors, a decrease in future sales and bad will are all potential penalties for failure to operate within service level parameters (Jonsson, 2008). It is usually the case that a service level is set to no lower than 95% (Waters, 2003).

3.2 Delivery Service Elements

Delivery Service is comprised of a number of factors as listed below, and can be expressed as a weighted factor in a more inclusive DSI (Delivery Service Index) calculation or individually as a number of different service areas.

- Delivery precision
- Inventory service level
- Delivery reliability
- Delivery time
- Delivery flexibility
All of the above factors can be used individually, or as a separate metric or they may be assigned weights to reflect their importance. They can then be combined into a single metric delivery service index (Jonsson, 2008)

### 3.2.1 Delivery Precision

Delivery precision (DP) is more commonly known as the ability deliver products on time. DP is a measurement of delivery capacity and not the ability to supply from stock. DP measures the degree at which deliveries of product are made on time as agreed with the customer (Jonsson, 2008). A delivery that is made before or after the requested delivery date is classed as a low delivery precision. The effect of this can be large for a customer company that has little or no safety mechanisms in place to deal with vital components not arriving on time which causes delays further downstream in the supply chain (Jonsson, 2008). Delivery precision can be calculated by dividing the number of on time deliveries by the total number of deliveries made to give a percentage score between 0 and 100. Delivery precision may also be measured by a series of different metrics known as Delivery Service Elements. These are detailed in Chapter 3.3.

### 3.2.2 Inventory Service Level

The inventory service level (ISL) can also be called fill rate and describes the amount of products that are being kept in stock. This measures the ability to deliver to customers directly from stock. This is an important factor in make-to-stock or deliver-from-stock situations (Jonsson, 2008).

### 3.2.3 Delivery Reliability

Delivery reliability is an index that describes the quality of the delivery. This means that the customer receives the correct products in the correct quantity. If a high reliability is achieved then it reduces a large portion of unnecessary work for the customer since inspections of the arrived goods are not needed. Usually delivery reliability is measured by dividing the number of orders that are delivered without complaint by the total number of deliveries made to give a percentage score between 1 and 100 (Jonsson, 2008).

### 3.2.4 Line Item Shipped Complete

Line Item Shipped Complete (LISC) refers to a binary system of measuring service level performance whereby a score is given on the basis of deliveries either being completed by the request date or not (Effective Inventory Management, 2013). LISC is different to the
previously mentioned delivery service index parameters in that it does not consider the individual index scores for a combination of delivery elements such as delivery precision and delivery reliability. Instead it delivers a yes or no score based on the delivery being completed within the agreed delivery reliability and precision parameters. For example in order for the LISC to be achieved, the correct quantity of goods must be delivered to the customer by the agreed request date (Kinander, 2015).

As an example, in a scenario where the service level is set at 95% on the customer's terms, for the LISC to be achieved means that 95 out of 100 deliveries must be completely shipped and received at a customer’s location by the customer’s requested time, not as soon as can be delivered (Bäckstrand, 2015). For the purposes of this report and the case study, we will be measuring delivery precision using the LISC metric, because this is the method that the focal firm of our case study uses.

### 3.3 Strategic Sourcing

To ensure that the supplied materials and or services are conforming to the standards set by both the producing company and their customers strategic sourcing is a tool that can be used. This is done by thoroughly measuring suppliers on multiple factors that are relevant to how products are shipped to customers. Factors such as material cost, delivery precision, ordering patterns and lead times are all taken into account when evaluating suppliers.

“The procurement process is no longer a purely operative process only consisting of transactions; it also includes the establishment and development of relations and more or less strategic business agreements” (Jonsson, 2008).

According to previous research done by both Nishiguchi, as well as Payne and Dorn strategic sourcing is done in a step-by-step process containing the following steps:

1. Data collection and analysis of spending
2. Market research
3. Identifying possible suppliers
4. Developing a sourcing strategy
5. Negotiating and contracting
6. Implementation and continuous improvement

The most important factor in this step-by-step method is the continuous improvement step, which is the basis and foundation for strategic sourcing, improvement. There is no reason why a supplier cannot be exchanged for a better performing one because there has been a longstanding relationship in place. Sinking too deep into routines and not constantly evaluating other options can negatively impact the supply chain.

Collecting the data is done using metrics for current suppliers and considering or calculating what the current performance means for the business. Will an improvement in this area yield great reductions in spending or lead times? Etc. (Payne and Dorn 2012).

When the data has been collected and analyzed, companies can then go to the market in order to evaluate other options. There are a multitude of methods to use for this, such as; benchmarking, auditing, etc. Selecting the best performing options from the research results and investigating the implications from introducing the possible suppliers into the supply chain will give an estimation of the new capabilities in the supply chain. Once possible suppliers have been identified and selected, the new sourcing strategy can be developed, based upon the metrics that are considered for improvement. An example of a new sourcing strategy is to implement consignment stock for a selected material or supplier (Nishiguchi, 1994).

Negotiating the terms of the newly developed sourcing strategy with the intended supplier is another key area in the strategic sourcing process. This is where the terms are set regarding the responsibilities both parties have in the relationship. After all has been implemented and is up and running, the process can start over again (Nishiguchi, 1994, Payne and Dorn 2012).

3.4 Demand Management

Demand management is the practice and processes of balancing customer demand with what is available to be supplied to them (Jacobs et al, 2011). Managing demand plays an important role of providing good customer service. Effective demand management recognizes all aspects of customer demand and utilizes operational planning processes to strategically position supply chain resources such as inventory and capacity to satisfy customer demands in a timely and cost effective manner.
According to Madhani, (2015) a well-designed system to manage demand can improve the competitiveness of an organization and give advantage over competition by providing a better service regarding delivery precision and in some cases pricing. Poor demand management can result in dissatisfied customers, increased cost, lost business, lower profits and insufficient utilization of resources (Madhani, 2015). Forecasting demand is part of the sales and operation process and helps to understand what the levels of demand will be so that the correct amount of products can be produced accordingly. This type of forecasting also provides information about what to keep in stock as inventory and the required levels for make to stock (MTS) products or materials to be kept as inventory.

Adopting a production strategy can also help to manage demand. MTO, MTS and ATO are all examples of production strategies that can be used in different situations to handle demand in a quick and cost effective way. Make to order (MTO) means that a pull method is used to signal starting production. This method is the slowest of the three, but can provide customers with highly specialized products without running the risk of keeping obsolete products in stock. Make to stock (MTS) differs from MTO and builds products to be kept as stock and then pushes the assembled products out to the market when a customer order requires said product. This ensures a quick delivery in large quantities to the customer. Using this strategy however, means that customer specialization is lost and only standardized products are suitable for this strategy. Assemble to order (ATO) is a hybrid version of the previously mentioned strategies and combines the best qualities and can promise quick and flexible delivery of somewhat specialized products through the modularization of products (Jacobs et al, 2011).

### 3.5 Inventory Control Methods

Inventory is of often overlooked as being the most expensive and important assets to a company. In an analysis of working capital such as a Du Pont analysis, inventory can make up as much as 50% of the total invested capital (Render et al, 2012). As the levels of inventory increases, so do the costs associated with holding this inventory. Examples of associated costs are: holding costs, ordering costs, cost of potential damage to goods and cost of stockouts. For this reason, effective and efficient control and management of inventory is essential and often this means finding a satisfactory position that between holding sufficient levels of inventory to satisfy customer demand, and not holding so much inventory that a focal firm’s
cost spiral out of control due to the expense concerned with holding it. One example of a consequence of stocking out on a particular component, is that it may cause a system bottleneck somewhere in the production process. If a particular component cannot be obtained at the correct time, it can delay following processes for which the said component is relied upon. Storing inventory at an optimum level in this instance can be useful as it creates a system buffer to protect against stock-outs between different stages of the manufacturing process.

Decision making regarding inventory optimization depends fundamentally on two considerations; the quantity to order and when to order. By optimizing these levels, it is possible to minimize total inventory costs (Waters, 2003).

3.5.1 Just In Time

Just in time scheduling means that the correct item is delivered in the correct quantity and the right time and in the right location. It is driven by customer demand and is known as pull scheduling. Just in time (JIT) is both a philosophy and a set of techniques (Jacobs et al, 2011). The major elements of JIT extend far beyond minimization of waste in manufacturing and extend to the ultimate pursuit of achieving zero inventories, zero disturbances and zero transactions (Jacobs et al, 2011). Shorter manufacturing throughput times, reduction in distances travelled by materials, simplified MPC systems, more satisfied workers and reduced labor costs are important elements to a JIT environment. The ultimate objective according to Jacobs et al is to have zero inventories, zero lead times, zero failures, a flow process, flexible manufacturing and elimination of waste. Jacobs et al also state the importance of leveling production, achieving very short lead times to improve customer service and responsiveness, reducing hidden costs, and implementing the whole person concept to utilize all persons’ performance improving skills. Jacobs et al also state that JIT is not compatible with MRP (Material resource planning) systems but JIT can be implemented incrementally. A key consideration of JIT systems is to take a holistic view of the whole operation and understand how some action will have an effect further downstream in the supply chain. JIT systems seek continual improvement through increased visibility of operations and procedures (Jacobs et al, 2011).
3.5.2 Re-Order Points

The re-order point method is a way to manage inventory by setting a specific level for when a new order for materials need to be placed. This level should be set so that during the lead time before the ordered materials arrive, there will not be a stock out. Figure 3.1 shows how a typical Re-order point system works, where stock is replenished when it depletes to a predetermined level (Jonsson, 2008).

Compared to the EOQ (Economic order quantity) method, which assumes that all materials will be put into inventory as soon as the stock level reaches zero, the Re-order Point (ROP) method realizes that this is not the case in most scenarios and takes the lead time from suppliers into account when doing the calculations (Jacobs et al, 2011).

\[
ROP = SS + D \times LT
\]

\( SS = \text{Safety Stock level} \)

\( D = \text{average Demand during replenishment lead time} \)

\( LT = \text{Lead Time from suppliers} \)

To calculate the re-order point three variables are needed as input data; safety stock level (if any), average demand during replenishment lead time, and the lead time from suppliers. These three variables combine to form the re-order point as illustrated in Figure 3.1.

Figure 3.1: Illustration of a re-order point system (Talibro.com, 2013)
There are two different ways of applying the ROP method, and the methods differ in how the ROP is estimated (Jonsson, 2008). The more traditional way uses a continuous review of the ROP and reduces the stock level every time there is a transaction of materials. The other way to approach the ROP method is to use a periodic review of the ROP set at a constant time interval. This also reduces stock levels, but not every time there is a transaction of materials, but at the time interval set for the review. This means that the two types of ROP methods are good to use in different scenarios. The first method is good to use for low volume, more valuable products. While the second, periodically reviewing method is more suitable for cheaper products kept in large volumes.

### 3.6 ABC Analysis

The ABC analysis is an informative tool used to gain further insight into total inventory and the areas of focus that should be addressed as a priority (Langley et al, 2008). ABC analyses are used in many instances in companies and businesses all over the world. The ABC analysis method stems from the Pareto principle conceived by Vilfredo Pareto which claims that 20% of the contributors cause 80% of the effect (Bergman, Bo, Klefsjö, Bengt, 2015). The ABC analysis has expanded this into three categories based on inventory level and value of the items. The inventory holder then uses these categories or classes in further applications or investigations. According to Jonsson, the steps for completing an ABC analysis are:

1. Calculate the annual demand for each of the items to be included in the ABC classification.
2. Calculate the volume by value of the items by multiplying the annual demand with the sales price for each item.
3. Calculate the sum of all volume by value for all items.
4. Calculate the percentage volume of the total volume for every item. This gives each item’s contributing proportion of the overall volume value.
5. Rank the items according to their percentage of the total volume value from highest to lowest.
6. Analyze the distribution of items and categorize them into a suitable number of different groups by specifying different volume by value parameters. Each group will represent one class such as A, B, C or more if required.
7. Divide each item into its corresponding class based upon its volume by value (Jonsson, 2008). An example of this segregation is shown in Table 3.1.
Table 3.1: Explanation of a traditional ABC distribution

<table>
<thead>
<tr>
<th>Class</th>
<th>Inventory Percentage</th>
<th>Value Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>15-20%</td>
<td>75-80%</td>
</tr>
<tr>
<td>B</td>
<td>30-40%</td>
<td>~15%</td>
</tr>
<tr>
<td>C</td>
<td>40-50%</td>
<td>10-15%</td>
</tr>
</tbody>
</table>

Following the ABC classification, the items can be given different priorities and strategies in areas such as:

- Customer service
- Safety stocks
- Warehouse location

Assigning higher priority to the most value generating items can be done by using higher inventory service levels and safety stocks to handle the demand. An important note is that items that have low tie-up-costs are more suited to be kept as safety stock.

The A classed items are suitable to be assigned safety stock given the prerequisite that this does not tie-up large amounts of capital and inventory space. If this cannot be achieved, alternative methods are advised (inventory kept at supplier, tighter requirements to supplier, etc.). B classed items are a tricky category, since the B class lack the sales frequency of the A classed items. This means that it is often not beneficial to keep a safety stock for these items unless strong customer terms are in place (example low lead time). C classed items hold low value percentage and can be kept in inventory if sufficient space is available at the warehouse. However, a good way to increase the inventory turnover is to reduce the number of mainly C and some B items since these lack the sales frequency of the high running A items (Langley et al, 2008). Examples of strategies that can be employed after segmentation can be found in Table 3.2.

Different customer service levels can be achieved by distributing the inventory over more warehouses. Given that there are a number of warehouses usable in the supply chain. The item classes can then be stored in different ways. By giving the A items the higher customer service priority, storing them closer to the customer will aid the shorter lead time. The lower
classed items with lower service level requirements can then be stored further away in a more central location to keep costs at a lower level (Langley et al, 2008).

Table 3.2: Example of how to employ strategies for inventory control based on ABC classification.

<table>
<thead>
<tr>
<th>Item Classification</th>
<th>Inventory Management Strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Safety stock, forecast demand, and tight supplier control</td>
</tr>
<tr>
<td>B</td>
<td>Buy material to order</td>
</tr>
<tr>
<td>C</td>
<td>Use re-order point method</td>
</tr>
</tbody>
</table>

3.7 Forecasting

In order to have an effective inventory management system and to gain an insight into future sales demand, it is advisable to have an effective and reliable sales forecasting system. Using this forecasting system can help with avoiding stock-outs, over-production, under-production etc. However, an important note to remember is that a forecast will never be 100% reliable. There will always be an element of uncertainty with any prediction on future demand and therefore it will never give completely accurate predictions on future demand (Coyle, Langley, Gibson, Novack and Bardi 2009).

The forecast only uses past data to give an educated guess on what the future demand will be like (Jonnson, 2008). As discussed by Jonsson (2008) and Waters (2003), the forecast will always carry a degree of uncertainty, and the accuracy of the forecast may be impaired by a number of reasons as listed by Jonsson (2008):

- Ineffective forecasting methods
- Incomplete data
- The forecast is too reliant on either manual or automatic calculations
- Unrealistic expectations
- Lack of forecast responsibility and forecast methods
3.7.1 Forecast Data

A forecast relies heavily on past demand as a major factor in its calculation, however most ERP (Enterprise Resource Planning) systems do not accurately display the actual demand. The data showed within is often based on invoicing and/or delivery statistics (Jonsson, 2008). When plotting the forecasted data, patterns in the demand will become visible. Three commonly occurring types of variation are: random variation, trend variation, and seasonal variation (Coyle, Langley, Gibson, Novack and Bardi 2009).

3.7.2 Demand Types

In order to correctly implement a demand forecasting system, it is important to understand the different types of demand that may be present. According to Jonsson (2008), one case is where a trend is encountered, a demand forecasting formula may then be modified in order to adjust for that trend and provide an accurate forecast.

Random/Normal Demand

Normal demand (shown in Figure 3.2) consists of random variations focused around a mean containing slight variations it is improbable that there is a stable demand without variation (Jonsson, 2008). In the case of normal or random demand fluctuations there is no need for a specialized function in order to increase forecast accuracy as is the case with trending or seasonal demand. Two useful forecasting methods are moving average and exponential smoothing which will be explained in greater detail in a later section of the report. These are both useful tools for reacting to random variations in demand.
Trending Demand

When a trend is encountered, Jonsson states that a need for new methods arises as traditional forecasting methods will not produce an accurate forecast due to the more drastic movements in demand (Jonsson, 2008). Instead, when faced with forecasting trending demand, modifying and adjusting the basic forecast by introducing a trend factor to the formula, will improve forecast accuracy. This trend factor is calculated using a tangent line on a scatter plot with demand data and is multiplied into the forecast.

Figure 3.2: One year’s demand with random variation.

Figure 3.3: an example of a forecast with a trend line
As seen in Figure 3.3 the trend line shows an average decline in demand with \( k \) units per forecast period. For the charted product, using the \( k \) co-efficient in the straight line equation \((y = kx + m)\) and applying it to the basic forecast, the trend adjustment \((k(n-1))\) has been made. For example, if the basic forecast predicts a demand of 100 units next month and the trend coefficient \((k)\) is at -0.1 then the forecast for the next month would be as follows.

\[
f(n)_{\text{Trend}} = F(n) * (1 + k(n - 1))
\]

\[
F(n) = \text{Basic forecast}
\]

\[
k(n - 1) = \text{Trend adjustment from previous period}
\]

\[
f(n) = 100 * (1 - 0.1) = 90 \text{ units}.
\]

**Seasonal Demand**

Seasonal demand differs slightly from a trending demand but it still benefits from an altered forecasting method like the trend factor used with trending demand. When forecasting seasonal demand a seasonality index is needed to correctly estimate the demand (Coyle, Langley, Gibson, Novack and Bardi 2009). While similar to the trend factor, the seasonal index is calculated while keeping seasonality in mind. This index is acquired by averaging the total demand per forecast cycle (year) and comparing this to the average of demand per quarter. This will give a seasonal index that is then used to modify the forecasted data in order to give a more exact number. As seen in Table 3.3 is a basic example of how to calculate seasonality indexes on a quarterly basis. This can then be applied to the basic forecast using the formulas shown below.

Table 3.3: Example of seasonal demand fluctuation and seasonal index

<table>
<thead>
<tr>
<th>Quarter</th>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demand per quarter</td>
<td>97</td>
<td>120</td>
<td>108</td>
<td>75</td>
<td>400</td>
</tr>
<tr>
<td>SI</td>
<td>0.97</td>
<td>1.2</td>
<td>1.08</td>
<td>0.75</td>
<td></td>
</tr>
</tbody>
</table>
3.7.3 Forecasting Methods

There are many ways to obtain a forecast, and according to Jonsson and Beasly there are two popular methods to forecasting. These two methods are as follows:

- Qualitative methods
- Quantitative methods

**Qualitative Method Forecasting**

Qualitative forecasting methods are the collective term for the types of forecasting that do not rely on mathematically calculating the forecasted demand. Instead a qualitative based method is reliant on experience and well-educated estimations from trusted human sources. The usage areas for a qualitative forecast can be determined by a common theme - lack of data. Lacking data in an area as reliant on data as forecasting makes it difficult to use the common mathematical methods, which is why this qualitative method is used (Beasly, n.d.)

Examples of when a qualitative forecast is advised:
- Low demand for products
- Long forecast cycles (yearly forecast)
- Introducing or retiring products from the market

**Quantitative Method Forecasting**

Compared to the qualitative methods described by Jonsson above, the quantitative methods for forecasting are based on analyzing the demand (Coyle, Langley, Gibson, Novack and...
Bardi 2009). Usually this is done automatically by the MRP system, but sometimes, manual interaction is required. Some examples of models used are:

- Moving Average
- Exponential Smoothing

**Moving Average**

The simple moving average forecast works by using demand for a set number of forecast periods, as an example a three month moving average can be used to anticipate the demand for the next month. For a three month moving average three months previous demand data is needed as input data to be able to estimate the forecast for the fourth month as shown in Table 3.4. (Coyle, Langley, Gibson, Novack and Bardi 2009).

Table 3.4: Showing an example of a three month moving average forecast (note that there is no forecast for the first three months since there is no previous demand data)

<table>
<thead>
<tr>
<th>Month</th>
<th>Demand</th>
<th>Forecast</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
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<td>6</td>
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<td>7</td>
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<td>5</td>
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<td>8</td>
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<td>9</td>
<td>5</td>
<td>5</td>
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<tr>
<td>10</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>11</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>12</td>
<td>4</td>
<td>3</td>
</tr>
</tbody>
</table>

\[
F(n)_{MA} = \frac{\sum_{i=1}^{n}D(n)}{n}
\]

*MA = Moving average (three month, four month, etc.)*

*\(D(n) = Demand\) during periods*

*\(n = Periods\)*
Exponential Smoothing

Exponential smoothing differs from the moving average method in the way that it assigns weights to the data. This means that depending on the chosen smoothing constant value the data will have different significance. Exponential smoothing does not require a vast store of historical data to be able to forecast demand, but the previous forecasts are stored within the function and are given less weight in the forecast compared to newer data which is given the higher weight (Coyle, Langley, Gibson, Novack and Bardi 2009).

\[ F(t + 1) = \alpha \times D(t) + (1 - \alpha) \times F(t) \]

\[ F(t + 1) = \text{Forecasted demand for future planning period} \]
\[ \alpha = \text{Smoothing constant (0 < \alpha < 1)} \]
\[ D(t) = \text{Real demand for current period} \]
\[ F(t) = \text{Forecast for current period} \]

Changing the alpha levels of the forecast will cause the model to behave differently depending on the value that is selected for the smoothing constant alpha. Using a low alpha means that the forecast will give less weight to the difference between the past period’s forecast and actual demand. Instead the forecast will assign greater importance to the past period’s actual forecast only making small adjustments based on the differences between the actual demand and forecast for the past period as seen in Figure 3.4.

Should a high alpha value be given in the forecast model, the forecasted values will fluctuate greatly (Figure 3.5) and respond to potential errors in the past forecast period. However this response will not be accurate making a high alpha level unusable in most practical applications. Alpha levels commonly range between 0.2 and 0.3 in realistic scenarios (Jonsson, 2008).
3.7.4 Forecast Errors

As stated before, a forecast will never be an exact representation of the actual demand. It is estimation and will always have a degree of error. A forecast needs to be monitored and kept within acceptable error margins. If not, there is a risk that the forecast will be out of control. The main goal of the monitoring is to detect any systematic errors that will impair the accuracy of the forecast. Besides this the random error that is discovered in the forecast are used as a basis to determine the safety stock levels (Jonsson, 2008).
Ways of measuring forecast errors:

- Mean Absolute Deviation (MAD)
- Time Based Deviation
- Running Sum of Forecast Errors (RSFE)
- Tracking Signal (TS)

**Mean Average Deviation**

Mean Average Deviation is used to measure the error in forecasted demand versus actual demand. A low value in MAD is preferable and a functioning forecast’s MAD value will be zero or close to zero (but the variations in the errors should be small). This means that a forecast with a low MAD value but large variations between the forecasted periods is still an inaccurate forecast due to the large and out of control variation (Langley et al, 2008).

\[
MAD = \frac{1}{n} \sum_{i=1}^{n} |D(n) - F(n)|
\]

\(D(n) = \text{Actual demand for period } n\)
\(F(n) = \text{Forecast for period } n\)
\(n = \text{Number of periods}\)

**Time Based Deviation**

The fundamental problem with forecasting future demand and in turn calculating fixed safety stock levels (See Chapter 3.6) is that the fixed level is applicable to all future planning periods regardless of what the future demand situation will be.

In a situation where the forecasted demand is increasing, the safety stock level remains stagnant and does not respond to demand increments (Krupp, 1997). These types of shortfalls can lead to stock-outs and this will negatively affect service levels. Conversely, if the demand is decreasing and the safety stock levels do not decrease to reflect this, excess stock will be held unnecessarily as inventory. This decline may be an indicator of a product reaching the end of its life cycle and so a forecast will not match actual demand and so a new calculation is needed.
Considering the MAD calculation shown above it is possible to divide the deviation by the number of time periods, to give a demand forecast that is adjusted for future demand fluctuations. By calculating the adjusted forecast demand levels, we are also able to adjust the variable safety stock accordingly for each demand period for future forecasts.

\[ TBN_n = \frac{\sum_{i=1}^{n} |\frac{U_i - X_i}{U_i}|}{n} \]

\( n = \text{Total number of time periods being considered} \)
\( U_i = \text{Average demand or forecast for period } i \)
\( X_i = \text{Actual demand in period } i \)
\( [ ] = \text{Absolute value} \)

**Running Sum of Forecast Errors**

Running sum of forecast errors (RSFE) is a variation of the MAD and is used in combination with MAD to calculate the tracking signal (TS). The RSFE is calculated by summarizing all the forecast error, but unlike the MAD, RSFE is not calculated using absolute values in difference between demand and forecasted demand, nor is it divided by the number of forecast periods (Jonsson 2008). The RSFE is the sum of the differences between actual and forecasted demand and is calculated as shown below.

\[ RSFE = \sum_{i=1}^{n} (D(n) - F(n)) \]

\( D(n) = \text{Actual demand} \)
\( F(n) = \text{Forecasted demand} \)

**Tracking Signal**

The Tracking signal is a useful tool to control and monitor the forecast and its bias, and is calculated by dividing the RSFE with the MAD.

\[ TS = \frac{RSFE}{MAD} \]

Using the TS will give a good look at the capability of the chosen method of forecasting.
Further analysis of the value provided by the TS will give information regarding the bias (over forecasting or under forecasting) or tendencies of the forecast. If the tracking signal values (bigger or equal) 3.75 or (smaller or equal) -3.75 there is a bias, and the forecast is persistently under or over-forecasting (Chockalingam, 2009).

### 3.8 Safety Stock

Safety stock is a type of inventory that is used in conjunction with standard inventory levels to ensure that products can still go out to demanding customers in case of a stock-out for any reason. A stock-out can happen for a multitude of reasons, but some common causes are larger than expected demand, disturbances in suppliers’ ability to supply on time, or if quality of supplied material is not sufficient (Waters, 2003).

While it is expensive to keep additional inventory on hand just in case something goes wrong it is imperative to maintain the safety stock for the right kind of products and in the correct amount. This means that a balance between carrying-costs and shortage-costs must be met. A well designed safety stock mechanism will however not eliminate all stock-outs, just minimize them (King, 2011).

#### 3.8.1 Safety Stock Methods

There are multiple methods available to predict the level of required safety stock levels for future planning periods. It is important to select the appropriate method according to the specific requirements. Factors such as product demand, value of goods, product lead times should be taken into account. Standard deviation of lead time and demand may be incorporated to adjust for uncertainty (Jonsson, 2008). The following is a description of the various ways to calculate optimal safety stock levels for varying situations.

**Manually Estimated**

The most basic, but a labor-intensive method of determining safety stock levels is to decide this manually. This manual estimation considers consequences of material shortage and weighs it against the investment in the tied-up capital. The labor-intensive part in this method is that all this information must also be manually entered into the MRP system (Jonsson, 2008).
Lead Time Based
Another useful method of determining safety stock levels is to base the decisions on the demand during the lead time from suppliers. This uses the deviation of demand during lead time and is a good way to calculate safety stocks that are only in place to protect against long lead times (Jonsson, 2008).

Standard Deviation Based
Using a standard deviation based model to calculate safety stock levels is a commonly used method. Because it uses the standard deviation of the demand to adjust for uncertainty, it is well suited to be used for safety stock calculation. A model described by King (2011) uses two types of standard deviation, both standard deviation in demand and lead time. Using these two types of standard deviation, the model can achieve optimal levels of safety stock for situations where variations are present in both demand and lead-time (these variations are both normally distributed). This makes the model especially useful when dealing with lead time critical products as it takes a supplier’s delivery performance into account when giving a safety stock level (King, 2011).

\[
SS = Z_{\alpha} \sqrt{\frac{(E(LT))}{T} \cdot \sigma_D^2} + (E(D) \cdot \sigma_{LT})^2
\]

\(SS = Safety\ stock\ for\ future\ planning\ period\)

\(E(LT) = PC = Total\ Lead\ time\)

\(T = Forecast\ cycle\ rate\ (how\ often\ you\ forecast)\)

\(Z_{\alpha} = Inverse\ of\ service\ level\ (95\% = 1.65)\)

\(E(LT) = Average\ lead\ time\)

\(E(D) = Average\ demand\)

\(\sigma_D = Standard\ deviation\ of\ demand\)

\(\sigma_{LT} = Standard\ deviation\ of\ lead\ time\)

Service Level Based
According to Jonsson, the most accurate way to calculate the safety stock level is to use a service level based calculation (Jonsson, 2008). This method is achieved by using the desired service level for each item combined and variations in demand. The service level is then
converted into a service factor using the inverse of the normal distribution for the wanted percentage (Krupp, 1997). This type of safety stock will help give a clear indication of the inventory level required to meet customer service level requirements by using the service factor as well as the standard deviation during replenishment lead time.

\[ SS = k \times \sigma_{LT} \]

\[ k = Service \ factor \ (95\% = 1.65) \]
\[ \sigma_{LT} = Standard \ deviation \ of \ demand \ during \ lead \ time \]

**Time Based Deviation**

A safety stock calculation based upon the adjusted time based MAD, will provide safety stock levels that is able to adjust to demand variations (Krupp, 1997).

It is important to note that in order to calculate the required safety stock levels for future planning periods, the formula for this calculation requires the time based MAD forecast information for the future planning period \( t \), and the planning period that immediately follows it, \( (t+1) \). This is to ensure that the level of safety stock that remains at the end of each future planning period \( t \), is sufficient to cover the following month’s forecast (Krupp, 1997).

\[ SS_t = k(TBM_n \times u_{t+1}) \times \sqrt{LT} \]

\( SS_t = Safety \ stock \ for \ future \ planning \ period \)
\( k = Service \ factor \ value \ (95\% = 1.65) \)
\( TBM_n = Time \ based \ MAD \ for \ planning \ period \ n \)
\( u_{t+1} = Forecast \ period \ following \ the \ period \ t \)
\( \sqrt{LT} = Square \ root \ of \ lead \ time \)

Using this method, planned safety stock will flex proportionately with forecasting variations. This approach becomes particularly useful for tracking demand in the lifecycles of individual products. If a product is approaching the end of its lifecycle, then a time series method of safety stock forecasting becomes particularly useful (Stadtler and Kilger, 2004). The time based deviation method is able to adjust safety stock levels for such downturns in demand that can lead to eventual product obsolescence (Krupp, 1997).
3.8.2 Products Suitable for Safety Stock

As stated before safety stocks are kept in order to protect the firm against unstable demand (Waters, 2003) which could lead to a stock-out. Deciding what to keep as safety stock however, falls upon the company in question to finally decide. A simple suggestion to this according to Constantin (2016) is as follows; the safety stock should cover your customer’s needs within the vendor’s lead time, without resulting in lost money due to high carrying costs. But there are further ways to decide what to keep as will be presented below.

Below material will cover three key points mentioned by Waters (2003), Constantin (2016) and Johnsson (2008).

- ABC-classification results
- Important customer
- Unstable customer demand

Waters (2003) mentions that the ABC classification can be used to determine what to keep as safety stock, and is summarized into three points by aforementioned author in Table 3.5. A-classed items are tagged as expensive and needing special care, this means that they should be monitored closely and can be kept as safety stock if integral to business. B-class items tagged as ordinary and needing normal care is suggested to be kept as BTO inventory unless other is required. C-class items on the other hand are considered to be inexpensive and needing little care, which means that they can be kept as safety stock with a high service level unless carrying costs or space occupancy gets out of hand (Waters, 2003).

Table 3.5: Showing the relationship between ABC classification and level of care recommended.

<table>
<thead>
<tr>
<th>Item</th>
<th>Care</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-Class</td>
<td>Expensive and needing special care</td>
</tr>
<tr>
<td>B-Class</td>
<td>Ordinary and needing normal care</td>
</tr>
<tr>
<td>C-Class</td>
<td>Inexpensive and needing little care</td>
</tr>
</tbody>
</table>

As mentioned above, A-class items are suitable for safety stock unless a large portion of either capital or inventory space will be used up for the purpose. B and C-class items however
are not as suitable and the amount of inventory occupied by these types of items should be reduced (Langley et al, 2008). Some C-class items can be kept as safety stock if they are needed; an example of this is generic materials such as packing materials (Davis T, 1993). This type of product can be kept as safety stock with high service levels, and large volumes because it is a cheap, standardized product that does not go obsolete. However, this is only if the product has a high enough inventory turnover ratio to justify the decision, which should ideally be higher than 1 (goods sold should at least be equal in value to cost of keeping inventory) (Gen M., Kim K., Huang X., Hiroshi Y 2015).

Basing safety stock on the premise that a customer is important for the business is one way to decide to keep products as safety stock. This means that there is a lower risk of being shorthanded with materials or products for this customer, which improves the likelihood of the customer returning in the future (Constantin, 2016).

Further suggestions from Waters include a situation where the customer demand is unstable and another where lead times from vendors are long. In this kind of situations a safety stock can be used to serve against being left unable to supply all orders.

Table 3.6: Showing service level and the required service factor from 95% to 99%.

<table>
<thead>
<tr>
<th>Desired Service Level</th>
<th>Service Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>95%</td>
<td>1.65</td>
</tr>
<tr>
<td>96%</td>
<td>1.75</td>
</tr>
<tr>
<td>97%</td>
<td>1.88</td>
</tr>
<tr>
<td>98%</td>
<td>2.05</td>
</tr>
<tr>
<td>99%</td>
<td>2.33</td>
</tr>
</tbody>
</table>

What often goes hand-in-hand with important customers are high service level requirements (Waters, 2003, Constantin, 2016), making service level an important factor for deciding safety stocks. A wish for higher service levels means that larger volumes of materials or products are kept as inventory in order to be able to supply most demand as seen in Figure 3.6 (service level graph) and in Table 3.6 (service level table). Calculating different inventory levels based on service level shows that there is a clear increase in inventory as the service level reaches higher percentages as seen in Figure 3.6 which in turn is based on the data in Table 3.6 which has been applied to a theoretical inventory.
In a situation where demand is unstable it is difficult to decide on what to keep as inventory and this could in turn lead to stock outs and lost business. Waters (2003) mentions safety stock as a possible method to deal with unstable customer demand and make sure that no potential business is lost.

**Alternative Methods**

Besides the traditional safety stock inventory, there are other methods that not necessarily use extra inventory to safeguard against material shortages. If safety stock is deemed unsuitable these other methods will give an improvement in the delivery precision and will not tie up capital in the same way as traditional safety stock methods (Jonsson, 2008).

**Uncertainty Hedging**

Uncertainty hedging means that orders are placed earlier than what they normally would have been. By doing this risks that materials arrive late are minimized by giving the supplier this additional time. What uncertainty hedging essentially is a standard MRP planning sheet that requests materials to be on hand at an earlier time as opposed to the traditional method. Not having to constantly keep materials as inventory makes this a cheaper method to manage low delivery precision from suppliers compared to safety stock (Jonsson, 2008).

![Inventory vs. Service Level](image)

**Figure 3.6:** Showing the relationship between service levels and inventory.
Supplier Kept Inventory
If it is not wished to keep extra materials on hand at the company, terms can be negotiated with suppliers to keep a safety stock of the materials at their location. This means that suppliers can ensure materials on hand at short notice if a rush order comes through. Negotiation of the terms to keep inventory at the supplier’s location must be negotiated in this situation to ensure a good co-operation. Examples of terms to be discussed are; pay for a percentage of the kept inventory, pay a fixed amount every month, etc. (Waller and Johnson, 2001 and Waters, 2003).

Consignment Stock
Consignment stock is an alternative to safety stock that does not require any investment into materials in inventory. The only investment required by the company in a consignment stock situation is to allocate enough warehouse space for the materials to be kept in inventory. To accomplish this, contracts are established with the supplier/suppliers that are willing to cooperate and provide consignment stock. This means that the supplier will keep a set level of materials in the warehouse free of charge. The company is only billed for the materials that are used.

This is a strategy that is susceptible to arguments between the company and supplier regarding inventory. So a good relationship and clear terms in the contract are required for a successful implementation (Battini et al, 2010).
4 Case Study

The case study undertaken in this report has been conducted at Parker Hannifin AB at their location in Borås, Sweden. Parker are currently facing issues with delivery precision and wish to investigate safety stock levels to find a solution to the delivery precision issue. To do this an analysis of customer order processing, material sourcing, production planning, and safety stock practices will be made and compiled into a strategy to improve delivery precision.

4.1 Parker Hannifin AB

Parker Hannifin is an US based company in the motion and control business. Parker has offices all around the world and are currently supporting around 60 000 employees in different sectors of motion and control technologies.

Parker has a culture that promotes premiere customer support in order to gain competitive advantage and win the customer’s business as stated in Parker’s Win Strategy.

“The Win Strategy is built on the established goals of engaged people, premier customer experience, profitable growth and financial performance, and will position Parker to achieve financial performance among its diversified industrial proxy peer companies” (Parker, 2015).

4.2 Background

Based on the previously described culture, Parker are thorough with quality control in all areas, and researching their delivery precision has unearthed a problem. Due to this, Parker Hannifin wish to implement a more effective demand prediction model and a stock keeping policy that allows customers to be serviced at a level of 95% delivery accuracy on their customers’ terms. Parker Hannifin wish to establish which of their clients order the most frequently, so that they can determine for whom they can keep inventory and for whom they cannot. If the order frequency is lower than a set level (once or twice per year), the minimum order requirements/frequency should be calculated to justify holding products as inventory. If the order frequency is less than six months, then Parker cannot justify holding the products as inventory and an alternative production strategy/purchasing strategy should be implemented. If customers have specific requirements regarding lead time, then this should also be incorporated into the new strategy.

The new strategy should include a standardized process for inventory handling to meet customer requirements in their product lines. There are two different types of item that may
be included in the order process. These are LM12 items which are assembled to order, and SD items which are pick and pack items.

4.3 Current Situation

In order to be able to understand problem areas and create a strategy that after implementation will prove effective in increasing LISC (Line Item Shipped Complete, see Chapter 3.2.4), an investigation of current practices and strategies is recommended as to not waste resources on ineffective improvement projects.

4.3.1 Sales Process

The sales process is progressively moving towards being a total EDI (Electronic Data Interchange) based process. Moving towards a totally EDI based operation means that all the orders from customers will be handled electronically with little to no human interaction, hence the abbreviation EDI. Currently the percentage of EDI sales stands at 90%. Over the past five years this has increased from approximately 60% and in future the aim is for sales to be 100% EDI controlled (Gustavsson, 2015). Should the customer be a repeat customer dealt with on a regular basis, their order is handled through EDI.

Lead time is considered within discussions with customers and if the customer’s request date for LM12 orders is considered unrealistic, this will be communicated with them. Where possible, sales will attempt to reduce the lead time on components by contacting the supplier and enquiring about the possibility of expediting the material supply order. If the customer is considered to be an ‘important’ repeat customer then sales and they have asked for a very short delivery date, sales will communicate with LM12 to see what can be done about giving the order priority (Gustavsson, 2015). Also, it is possible for one of the sales team to change the request date in the system, but only if the customer measures Parker’s promise date over the request date (Gustavsson, 2015).

4.3.2 Customer Order Patterns and Habits

The order patterns and tendencies for the customers at Parker are greatly varied. Some customers conduct the order process according to the lead time communicated by Parker, while other customers disregard the information and place orders to have a request date within the lead time, causing issues with the LISC.
As an example: The lead time on a particular component is 90 days and the customer has requested a delivery date of 30 days, which occurs frequently and causes problems. Lead time from suppliers is often not given the consideration that is due when negotiations with customers take place (Kinander, 2015). Not taking these lead times into account means that it is highly probable that customers will unknowingly order products within the lead time from suppliers causing a missed delivery date.

Presently, Parker sources 90% of required components from internal sources while the remaining 10% are outsourced (Kinander, 2015). There are three reasons for the procurement process at Parker.

- Purchasing Process Demand (real). There is a work order in the MRP system and no inventory for that order in stock.
- Demand based. A work order is created when the inventory level drops below safety stock. (Based upon Parker’s own safety stock calculations as described in Chapter 4.3.4)
- Forecast in system. Material is ordered according to a demand forecast that is provided through EDI interaction between Parker and customers (since this comes from forecast data provided by customers the type of forecast used is unknown.

Each night, the MRP system at Parker updates and searches for items that have a negative stock balance, or items that are below safety stock limits. These items will then be included in a purchasing list that is produced by the MRP system. There are two different inventory categories that the MRP system considers when constructing this list; Type 1 for items that are kept as inventory at Parker’s location (most commonly as safety stock) and also Type 7 items, which are not kept as inventory but are purchased when demand arises.

The list created by the MRP system also contains two different categories for the urgency of the purchase. Type B for items that are close or inside the purchasing lead time, and type O for items that are not as urgent. For each work order, a shortage report is created based upon material not in stock. However it does not account for orders already placed (Kinander, 2015).

The two item types covered in this report both have separate purchasers, according to Parker there are no standardized ways of work besides the purchasing frequency.
The current process states that the B item purchases should be done every day, but O items can be done 2-3 times per week. When investigating the purchasing routines more thoroughly, similarities are found in both purchasing departments regarding the purchasing frequency and methods. However, SD item purchasing does not utilize the MRP system’s ability to monitor orders and give warnings if the orders are at risk of running late. LM12 purchasing does however utilize an extracted function of the MRP system’s order monitoring functions and acts upon this information accordingly.

Besides the three reasons for material procurement given by Parker, there is another reason why materials can be purchased. Some customers have integrated into Parker’s MRP system using their own systems giving Parker access to forecasted demand for products using Parker parts. Currently Parker and the EDI integrated customers have an agreement for when the customer’s forecasted demand can be handled as real demand by Parker in order to be able to supply with better delivery precision. These terms vary from customer to customer, but concerns how many forecast periods ahead of time Parker can handle as real demand.

4.3.3 Order Process

Figure 4.1 shows the manufacturing order process for LM12 products at Parker. On average the manufacturing process takes 13 days. This process is preceded by a material purchase that is triggered by a customer order. The customer orders are handled as described in section 4.3.3 by using the B and O type messages. This order needs to be placed so that the materials will arrive at Parker 15 days before the products are planned to be shipped to customers. Before the products are put into inventory Parker has allocated 48 hours as put-away time in order to not put unnecessary pressure on suppliers, resulting in 15 days compared to the average production time of 13 days (Michailidis, 2015). The transit time and production lead time from suppliers vary as suppliers have a wide range of size and capability, and are located all around the world.
4.3.4 Work Order Planning

The planning for LM12 products (Assemble to order) begins when value added services (VAS), looks at new work orders and checks that the request date from customer is viable. If the request date is not viable, it is possible to move it but only if the customer agrees. If the customer does not agree, the existing request date remains in the system.

The actual work for the LM12 however is not planned until all the materials are available in stock. And as explained in Figure 4.1, the average manufacturing time is 13 days with an extra 48 hours and transit time added. This means that materials can be held in inventory for 48 hours until production is planned causing further delays in the production which could affect the LISC.

4.3.5 Inventory Handling and Policies

Parker’s approach to safety stock handling currently does not operate in a way that reflects the methods described in this report. At Parker, the safety stock works as a re-order point and are calculated for every 30 days, currently there is no systematic process for determining what the re-order point for inventory of components should be (Kinander, 2015). The levels are based upon intuition and do not especially account for demand or lead time in the estimations. This means that the levels are not attuned to keep up with the service level requirement of at least 95%, when compared to a more mathematical approach to safety stocks. Besides the way
safety stocks are estimated, Parker are not utilizing any standardized process for determining when to introduce a safety stock for a product. This is also true for materials required by new customers or products.

Parker keeps the materials that are not on hand at the location in Borås at a central warehouse. The European Distribution Center (EDC) is located in Germany. Should there be an urgent need for materials that are stocked at the EDC, Parker can use express freight options to have the materials delivered to the Borås location with a one day lead time. At the EDC, Parker can only keep Parker products, based on management directives (Kinander, 2015), which means that storing a safety buffer of externally supplied materials there is currently not possible.

### 4.3.6 Current Delivery Precision

Parker wishes to have at least 95% LISC (delivery precision) for all products and anything below 95% is deemed unacceptable by Parker. With the current inventory levels at Parker, the LISC is frequently not being met, even for products where there is a safety stock in place. A selection of nine separate products where the LISC is not being met can be seen in Table 4.1. These products were selected by Parker as a basis for investigation since they frequently scored low LISC achievement. The current LISC score for each of the nine products and the level of safety stock that Parker is currently holding is shown in Table 4.1. From these nine products, it can be seen that not one of them comes close to a 95% LISC, with the closest being 80%. This means that customers order patterns are inhibiting Parker from supplying customers at requested dates due to non-correct inventory levels at the time of the order. These low LISC attainment numbers could be masking a hidden problem such as a bottleneck in the system.

<table>
<thead>
<tr>
<th>Product</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>LISC</td>
<td>57%</td>
<td>67%</td>
<td>0%</td>
<td>50%</td>
<td>64%</td>
<td>33%</td>
<td>50%</td>
<td>67%</td>
<td>80%</td>
</tr>
<tr>
<td>Safety Stock</td>
<td>1000</td>
<td>12</td>
<td>10</td>
<td>8</td>
<td>2</td>
<td>20</td>
<td>10</td>
<td>2</td>
<td>50</td>
</tr>
</tbody>
</table>
4.3.7 Supplier Management

The way that Parker manages suppliers stems from the fact that 90% of all the purchased materials stem from internal suppliers (Kinander, 2015). What this means is that there is currently no strategic sourcing done for suppliers. There are metrics that are being measured but no action is being taken based on these metrics.

If a material is supplied by internal Parker suppliers, but there is an external supplier that can offer the material within a lower lead time, Parker cannot choose to use the external supplier over the internal. But currently there are no intentions of changing suppliers (Bäckstrand, 2015).

Currently, a number of suppliers provide materials for Parker with extreme lead times, with some materials having up to 153 days lead time. This kind of lead time will make meeting any kind of demand for products including this material late in most cases. In cases like this there is a strong incentive to press suppliers for better delivery performance or to change the supplier for a better performing one. However, this is currently not an option (Bäckstrand, 2015).

4.3.8 Customer’s Perspective

Parker’s customers expect a service level of no less than 95% on all deliveries. The largest client of Parker is Volvo, who desires a service level of 98%; however they will accept a level of 95% (Lindqvist, 2015). Parker considers the LISC as one of their key core competences. To be able to promise 95% delivery precision on the customer’s terms should not be underestimated as a competitive advantage.

4.4 Problem Areas

Based on investigations, a number of problem areas have been discovered at Parker that are negatively affecting the LISC. The most prominent ones are; customer order habits, work order planning, safety stock levels, and supplier management.

With some customers ordering products within the lead time for purchasing, delivery and production, the result is perhaps not unexpectedly a missed delivery date and negative performance in the LISC. This problem is easily fixed in theory but in reality the problem becomes harder to solve.
Due to the way work orders are planned at Parker, there are some issues that can arise. For example, the work order is not planned until the materials are all on hand. A consequence of this is that because an order that has been placed does not have a work order planned until all of the materials are on hand, any delay in the material’s arrival delays the work order and no time is allocated to this production. As soon as the remaining materials arrive the work will be planned and if this creates a rushed order, it will push aside other production causing further delays (Michailidis, 2015).

The safety stock levels at Parker are not properly calculated, but are based on intuition and feeling instead of mathematical models. Not basing the levels on the mathematical ground can cause the levels to be wrongfully estimated resulting in stock-outs or too high tie-up costs, both scenarios are bad for the business and can cause delayed deliveries to customers.

One of the more prominent issues at Parker is the lack of supplier management, more specifically, strategic sourcing. This is something Parker are aware of but are not working towards due to the way the business is set up, which is more suited to working with Parker suppliers and no external ones. What this means for the business is that the contracts, terms and the supplying capability is not always the best possible for the product and customer nature. As an example, some of the suppliers are currently supplying materials to Parker that have extremely long lead time for a selection of products. Instead of scouting the market for a better performing supplier Parker accepts the lead time and continues to use the supplier.

Reasons for the lack of strategic sourcing can be related to the way Parker’s business is set-up, making the assumption that all suppliers are Parker suppliers. This means that for the parts that are supplied by Parker, no other supplier can be chosen, even if that would mean a much shorter lead time. If no other supplier can be chosen if a Parker supplier is available, and the rest of the business is set-up as if only Parker suppliers were used, means that there is no strategic sourcing, and no plans to implement it either (Bäckstrand, 2015).

When it comes to items that have a safety stock balance, levels are not calculated using any quantitative methods, only qualitative methods are used.
This means that the levels are not always at the optimal level to meet the service level requirements set by Parker and customers. However, not all items have safety stocks in place, and currently there are no specific routines for deciding when safety stock should be implemented.

There is also no process for bringing in new customer products into the warehouse, this means that inventory, safety stock and service levels could be poorly estimated, causing either stock-outs or under-stocking. Both of which are problematic for Parker.

A number of example products from SD (Pick and Pack) and LM12 (Assembled to order) families have been selected and will be analyzed and used to create a model to employ over the entire inventory which will be presented in the results.
5 Results

The following results are all derived from the previous fiscal year's data extracted from Parker’s ERP systems. The following includes actual data application to construct mathematical models for inventory segmentation, demand forecasting and safety stock level calculation.

5.1 Inventory Analysis

The inventories that will be analyzed are mainly LM12, but also SD items. Inventory analysis will be done using ABC analysis and Pareto charts. Further analysis and testing will be done using forecast and safety stock methods.

5.1.1 ABC Analysis

Table 5.1: ABC analysis for all LM12 products at Parker

<table>
<thead>
<tr>
<th>Products</th>
<th>Inventory Percentage</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>98</td>
<td>19.3%</td>
<td>A</td>
</tr>
<tr>
<td>160</td>
<td>31.6%</td>
<td>B</td>
</tr>
<tr>
<td>347</td>
<td>48.7%</td>
<td>C</td>
</tr>
</tbody>
</table>

The ABC analysis of Parker’s LM12 inventory shows a typical distribution of value and inventory. This is shown in Table 5.1 where 19.3% of the inventory contributes 70.1% of the overall value (Langley et al, 2008). Basing different strategies on these classifications will however need further segmentation using service level requirements and current performance of Parker and external suppliers.

5.1.2 Problematic Customers and Products

Looking into the customers that have orders arriving late there are four customers that stand out beyond the rest (Figure 5.1). Drawing these in a Pareto chart illustrates that the customer with the highest number of late orders has double the amount of late days as the second largest one – contributing over 50 percent of the total days late for these four customers.
Figure 5.1: Pareto chart of the top four customers with late orders

Figure 5.2: Pareto chart of products delivered to customer after request date.

The products displayed in Figure 5.2 are products for the customers displayed in Figure 5.1. In total there are 26 products from four customers totaling in 908 days overdue means that Parker are having some great issues dealing with these customers. This should be a good place to start improving the delivery precision.

5.2 Applied Models

Based on the selection of suppliers and products from the Pareto charts, a sample of nine products have been chosen to apply new forecast and safety stock methods upon. The reason that these nine products were chosen is because they are products that currently have a safety stock set by Parker that are not meeting the required delivery precision levels (shown in Table
4.1). In order to highlight the results from applied safety stock calculations discussed in this report these nine products were chosen. The time period for which we have collected the data for the analysis is one fiscal year (12 months). The graphs showing actual demand for the nine products are included in Appendix A of this report. All data has been derived from Parker’s ERP system or from database files provided by Parker. The applied models are as described in the theory section (Chapter 3) of the report.

5.2.1 Forecast

At Parker many of the LM12 and SD products do not have any forecasts in the system. They are instead assembled to order as mentioned in Chapter 4.3.5. This means that if a safety stock model that requires forecast error measurements were to be used, there is a need to introduce a forecast for these products in order to calculate the safety stock levels.

In order to choose the right forecasting model so safety stock levels are not set at an incorrect level, the two quantitative methods; exponential smoothing and moving average were considered for implementation due to their more data centered nature. To make the right choice between the two models, the forecasting accuracy was tested using the error measurement metrics as described in Chapter 3.6.4.

Figure 5.3: showing the difference between Moving Average and Exponential smoothing forecasting models for one of the nine products.
As seen in Figure 5.3, there is little difference between the two forecasting models moving average and exponential smoothing. Using the error measurement techniques described in Chapter 3.6.4 the following information can be extracted from the nine products used in the example (Table 4.1). Both exponential smoothing and three month moving average produce tracking signal values that are well within the acceptable limits (Section 3.7.4) but hint towards a slight over-forecasting but not at such a significant level that it would call for an adjustment in the forecasting model.

In terms of over or under forecasted units the exponential smoothing forecast has a clear edge over the moving average due to the results in both MAD and RSFE. Figure 5.4 shows a lower MAD and lower RSFE for the exponential smoothing method and provides a better coherence to the actual demand and less error. Using this information the model chosen for implementation is exponential smoothing.
To further show that the exponential smoothing method is a good fit for the contents of this report 100 random products were put through the model and their tracking signal error measurements were recorded. The results shown in figure 5.5 show that 94% of the measured products qualify as having acceptable tracking signal values and fall within the limits mentioned in section 3.7.4.

**Applied Forecast Model**

As described in our theoretical investigation, the exponential smoothing forecast does not require a vast store of demand data to function, but will deliver a forecast after only one period of data gathering as opposed to a moving average based model which will start predicting demand after a number of forecast periods. As time progresses, the exponential smoothing forecast will have a better fit to the actual demand due to the historical data stored in the function. The forecast used in our analysis uses the average demand for the fiscal year as the starting value due to the lack of sales data from periods before and operates at an alpha level of 0.3 in order to stay responsive but not fluctuate in uncontrollable ways. The reasoning for choosing an alpha level which will result in a higher MAD value compared to a lower alpha level is to make it more responsive to fluctuating demand.

This forecast model will then be applied to 12 months demand for specific products. Since the forecast cannot be estimated for the first month, the average demand is applied in order to simulate a forecast based on the last month of the previous fiscal year. Applying the model to
an example from the nine products from Parker gives the following results which are shown in Table 5.2.

Table 5.2: Example of forecast using exponential smoothing (Month 1 uses the yearly average as its forecast value.)

<table>
<thead>
<tr>
<th>Alpha Level</th>
<th>0.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Month Demand</td>
<td>Forecasts Demand</td>
</tr>
<tr>
<td>1</td>
<td>210</td>
</tr>
<tr>
<td>2</td>
<td>30</td>
</tr>
<tr>
<td>3</td>
<td>148</td>
</tr>
<tr>
<td>4</td>
<td>40</td>
</tr>
<tr>
<td>5</td>
<td>20</td>
</tr>
<tr>
<td>6</td>
<td>110</td>
</tr>
<tr>
<td>7</td>
<td>70</td>
</tr>
<tr>
<td>8</td>
<td>150</td>
</tr>
<tr>
<td>9</td>
<td>20</td>
</tr>
<tr>
<td>10</td>
<td>120</td>
</tr>
<tr>
<td>11</td>
<td>100</td>
</tr>
<tr>
<td>12</td>
<td>60</td>
</tr>
</tbody>
</table>

Average Demand: 90

The tracking signal for the example product falls well within the acceptable limits at 0.41 showing that there is a slight bias towards under–forecasting, but not at a significant level so that the forecast needs adjustment.

\[
TS = \frac{RSFE}{MAD} = \frac{24}{58} = 0.41
\]

5.2.2 Safety Stock

Quantitative Based Method

Based on Parker’s in-house metrics and requirements the safety stock method that is best suited for this study is based on the standard deviation model as described by King (2011). Since many of Parker’s suppliers are supplying with long lead times, a missed delivery date by suppliers would mean a high risk for a missed delivery by Parker as well. Since this model will take possible delivery inaccuracy from suppliers into account the risk to not have enough materials on hand in case of a missed delivery is minimized compared to other formulas mentioned.
Applying this formula to the example product used in Table 5.2 gives the following results for safety stocks with a 95 percent service level. The average lead time provided by Parker’s ERP system is 44 days, with a standard deviation of 1.77 days. Calculations show that the average demand is 90 and standard deviation is 60.

$$SS = 1.65 \times \sqrt{\left(\frac{44}{30} \times 60^2\right) + (90 \times 1.77)^2} = 289 \text{ pcs}$$

Should a higher service level be requested, the inventory level will rise exponentially along with the service factor as shown in Figure 3.6.

This model when applied to Parker’s LM12 inventory and tested versus actual demand shows that 96.3% of all orders were able to be fulfilled from stock as seen in figure 5.6. This result is well within our scope of 95% delivery precision.

![Figure 5.6: Pie chart displaying portion of satisfied orders.](image)

**Time Based Method**

An alternative to the standard deviation method is the time based deviation method. The forecast model for this produces results that in theory should alter the required safety stock accordingly react to both increased and decreased demand, calculating an optimum level for each month’s forecasted demand. The model does this and calculates an average safety
stock calculation of 58 pieces across the twelve months. Unlike the previously described standard deviation based calculation, the time based deviation method reacts to changes in demand by decreasing the required safety stock when actual demand for the previous month decreases and adjusts the forecast for the following month. Because the MAD is so high after Month 1, the model adjusts the safety stock requirement to meet the next month’s demand. Since Month 2 sees a significant drop in demand and another large MAD is produced, the model again adjusts itself to control the fluctuation. After month 3, the MAD begins to decrease with the model responding well to fluctuations in the demand. Between months 7 and 8, there is a large increase in demand which the model responds to by adjusting the safety stock level from 8 to 76 pieces. The results for twelve months of Time Based Deviation Safety Stock calculation based upon the forecasted demand data shown in Table 5.2 are shown below in Table 5.3.

Example of calculating Time Based Safety Stock for Month 1:

\[
SS_t = 1.65(11.15 \times 132) \times \sqrt{44} = 161
\]

Table 5.3: Safety stock calculations using time based method for twelve months of forecasted demand (Data from Table 5.2)

<table>
<thead>
<tr>
<th>Month</th>
<th>Demand</th>
<th>Safety Stock</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>210</td>
<td>161</td>
</tr>
<tr>
<td>2</td>
<td>30</td>
<td>100</td>
</tr>
<tr>
<td>3</td>
<td>148</td>
<td>60</td>
</tr>
<tr>
<td>4</td>
<td>40</td>
<td>67</td>
</tr>
<tr>
<td>5</td>
<td>20</td>
<td>45</td>
</tr>
<tr>
<td>6</td>
<td>110</td>
<td>37</td>
</tr>
<tr>
<td>7</td>
<td>70</td>
<td>8</td>
</tr>
<tr>
<td>8</td>
<td>150</td>
<td>76</td>
</tr>
<tr>
<td>9</td>
<td>20</td>
<td>62</td>
</tr>
<tr>
<td>10</td>
<td>120</td>
<td>42</td>
</tr>
<tr>
<td>11</td>
<td>100</td>
<td>10</td>
</tr>
<tr>
<td>12</td>
<td>60</td>
<td>31</td>
</tr>
</tbody>
</table>
As mentioned in Chapter 3.6.4, when a product reaches the end of its lifecycle the forecast will differ greatly from the actual demand. This can cause safety stock levels to get out of control and a new model is needed.

The time based deviation method will instead of increasing safety stock levels, decrease them as the actual demand declines and vice versa. This is one instance where the time based deviation method is advantageous.

### 5.3 Results of Theoretical Implementation

The previously estimated safety stock levels are too low to maintain a 95 percent service level for Parker’s customer. Applying revised forecasting and safety stock methods tuned for a 95 percent service level along with stronger supplier cooperation is advised. Maintaining a high service level with the lead times Parker currently has from suppliers yields large volumes for safety stock and in turn ties-up capital into inventory. The requirements from Parker and customers combined with the lead times Parker currently has from suppliers result in an inventory increase of 82 percent in order to meet the SLR (Service Level Requirements).

Table 5.4: Table illustrating old and new LISC and safety stock levels using data from Table 4.1 using the standard deviation safety stock method for nine sample products.

<table>
<thead>
<tr>
<th>Product</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original LISC</td>
<td>57%</td>
<td>67%</td>
<td>0%</td>
<td>50%</td>
<td>64%</td>
<td>33%</td>
<td>50%</td>
<td>67%</td>
<td>80%</td>
</tr>
<tr>
<td>Original SS</td>
<td>1000</td>
<td>12</td>
<td>10</td>
<td>8</td>
<td>2</td>
<td>20</td>
<td>10</td>
<td>2</td>
<td>50</td>
</tr>
<tr>
<td>New SS</td>
<td>1595</td>
<td>22</td>
<td>17</td>
<td>12</td>
<td>7</td>
<td>25</td>
<td>22</td>
<td>4</td>
<td>235</td>
</tr>
<tr>
<td>New LISC</td>
<td>95%</td>
<td>95%</td>
<td>95%</td>
<td>95%</td>
<td>95%</td>
<td>95%</td>
<td>95%</td>
<td>95%</td>
<td>95%</td>
</tr>
</tbody>
</table>

Applying above-mentioned methods to actual inventory with safety stock in place yields the following results. If a forecast is not available for safety stock methods requiring forecast error measurements then it is advised to investigate the different types of forecasting methods discussed in Chapter 3.6.3 and then proceed with calculating the safety stock levels for the desired products. The new safety stock levels based upon the standard deviation method calculated to result in a 95% LISC are shown below in Table 5.4.
For Product 2, to raise the LISC from 67% to 95%, applying the above model yields the following result:

\[
SS = 1.65 \times \sqrt{\frac{5}{30} \times 5^2 + (4 \times 4.3)^2} = 22 \text{ pcs}
\]

### 5.3.1 Cost of Implementation

As seen below in figures 5.7, 5.8, and 5.9 the costs of introducing safety stocks are large and only increases as service levels get higher. Further information derived from below figures show distinct differences between the three ABC categories with, the C-items clearly being the cheapest of the three (being only 16.7% the cost of the A-items and 30.2% of the B-items).

![Figure 5.7](image.png)

Figure 5.7: Showing inventory cost associated with rising service level from A-classed items among the 9 chosen products.
Figure 5.8: Showing inventory cost associated with rising service level from B-classed items among the 9 chosen products.

Figure 5.9: Showing inventory cost associated with rising service level from C-classed items among the 9 chosen products.
6 Discussion

The methods discussed in this report are well suited to deal with a low delivery precision scenario. This is achieved by employing a thorough analysis of inventory and implementing various strategies to best suit the specific inventory segment and nature of the business. This is a practice all businesses should employ in order to understand inventory and how to manage lead times. Not in all cases are all the theories and methods discussed in the report applicable. An example of this is a very small business dealing with long lead times to customers. A small business, in most cases does not have the capital or the supply chain scale required to utilize these methods, which exposes the greatest drawback for the kind of inventory management discussed in this report - the large costs.

Being a very costly area in any business, it is imperative to use a good selection of products and methods in order to reduce the lead times and increase the delivery precision. That is why we recommend analyzing and segmenting the inventory based on the ABC-analysis method. This gives a good overview of the inventory and strategies can be developed based on the results from the analysis.

Segmenting the inventory that has been classed using ABC-methods is a more intricate subject. The differences between the products are so profound that a single catch-them-all strategy cannot be implemented. That is why we have chosen to segment the inventory based on the ABC-classifications and past delivery performance.

The different strategies we have deemed suitable and relevant to increasing LISC and delivery precision are; strategic sourcing, safety stock calculation, demand forecasting, supplier kept inventory, and consignment stock. We understand that there are other ways to increase a low delivery precision but have decided on recommending the above-mentioned strategies in order to achieve the most suited improvement results.

Besides using the inventory segments to apply strategies, a forecast is advisable in order to estimate future demand and make the appropriate decisions regarding material procurement, inventory levels and service levels. The forecast model depends on the kind of product, inventory type, product life cycle, etc. Out of the two forecasting families; qualitative and
quantitative, a quantitative approach yields the most precise results and we have chosen the exponential smoothing forecasting method in this particular case. The reason why the exponential smoothing method was chosen is because it results in lower MAD and RSFE values than the moving average method. In order to keep the forecast more responsive, we decided to set the alpha level to 0.3 making the forecast react quicker to changes in demand. If the scenario faced was different in terms of products, demand, etc. another forecasting method from the ones described in Chapter 3.6.3 would have to be applied for better results based on the needs of the company and products.

The safety stock method used for the case study is based on standard deviation of demand and lead time. Because the demand for the product ranges investigated varies greatly, as well as long lead times from suppliers allowing small margins for error and delays, the model described by King (2011) utilizes averages of both demand and lead time, as well as the standard deviations of demand and lead time. This is the model deemed best suited to deal with the scenario. There are however more suitable methods for other scenarios that in theory provide a more exact level of safety stock. An alternative method that can be used to maintain a constantly changing level of safety stock is time based safety stock methods. This type of forecasting uses the principle of a giving the advantage of a specified demand projection for individual months or for a given period. One immediate drawback is the time and staffing hours required to maintain the upkeep of fluctuating stock levels. The method is effective but comes with the expense of investing heavily into inventory costs. For this reason it is important to not over invest capital into products not suited to be kept as safety stock, particularly when the volume of different product lines is so high and a great majority of the products have low contributing value. This is the reason why we feel that the time based safety stock method is not the most suitable to use in this scenario. Completing an ABC analysis of the inventory is a useful tool to determine which products contribute the highest value and once the inventory has been segregated, suitable inventory keeping policies may be employed for each category. A good product range to start implementing safety stock on are the items classed into the C category (see chapter 3.7 ABC analysis), this is due to this item-class being low in cost which in turn will not mean there is an overly large amount of capital tied up in safety stock. B-class items however, are not recommended to keep as safety stock due to them being higher value than C-class items and higher in frequency compared to A-class items as seen in figures 5.7, 5.8, and 5.9. But ultimately choice lies with the focal firm to
decide if the cost of a missed delivery and possible lost customer outweighs the cost of safety stock (which is a considerable amount for A and B items).

The EDI integration used by Parker and customers is an efficient tool to be able to handle demand without investing heavily into large inventory volumes. Difficulties could arise regarding the terms of the cooperation, which can hurt the cooperation and business between the two parties. However, if handled correctly, EDI integration similar to that which Parker and their customers use is a great asset for any business.
7 Recommendations

Based upon the information and analysis conducted in this report, the most cost-effective and thorough method in order to increase delivery precision is described below.

It is recommended to first analyze inventory to classify and segment products. Implementing different inventory strategies based on the results of the classification. Depending on the size and scale of the available supply chain product inventory distribution will vary. In the case of a large-scale supply chain, the use of a central distribution center accompanied by smaller regional branches is advised, to raise the service level.

Employing strategic sourcing strategies to improve lead times, cost, and quality from suppliers on a continuous basis will further improve delivery precision to customers. Due to the lack of safety stock requirements and the possibilities to greatly improve the supply chain, strategic sourcing is a strongly recommended method to increase delivery precision without investing heavily in inventory and should be accompanied with clear and well-defined contracts with customers. Including customer forecasts and expectations in MRP planning through EDI integration will also further improve delivery precision and make planning significantly easier (Jonsson, 2008).

Using safety stocks is an expensive method for improving delivery precision so it should be done very carefully and only after analysis of inventory and other options have been completed. If the decision is made to implement safety stocks for products, this should be based upon the reason that safety stocks are required (service level based, lead time based, etc.) in order to guarantee that the implementation will give the desired results. In the specific case described in the case study section (Chapter 4), the reason to implement a safety stock was to improve delivery precision. The standard deviation method is well suited to this because it takes into account possible delivery inaccuracy from suppliers (standard deviation of lead time) and standard deviation of demand.

It is recommended to firstly apply these recommendations to a select number of customers or products and closely monitor how the changes affect the delivery precision in a real environment. Should a reasonable increase in delivery precision occur without large amounts
of tied-up capital, rolling out further implementation is strongly recommended with results monitored.
8 Conclusion

Our initial research question was as follows:

*For a company with a large portfolio of specialized product lines, how should the inventory be managed and how should the eventual need for safety stock be handled? How will this aid in raising the delivery precision to customers and at what cost?*

In response to this, our concluding findings are that, the main concern with safety stocks is that large costs are almost certain to follow if an implementation should take place. In order to minimize the risk or the percentage of affected products, it is very important to understand the need for implementing safety stock and also the problems that might arise.

Due to these large costs, we do not advise to use safety stock as a first measure against low delivery precision. Instead we advocate for a thorough investigation of supply chain elements such as supplier performance and customer ordering habits. The importance of analyzing and segmenting inventory and continuously investigating cases where delivery precision requirements are not met cannot be overstated and is an integral part of increasing delivery precision.

If service levels still cannot be met or other hindering factors are present, the need for safety stock is justified, and this should be set based on the need of the safety stock (service level, supplier lead time, etc.)

Using safety stocks is an expensive way of dealing with uncertainty in demand, particularly when used as a measure to maintain a high service level. It is costly to maintain a high service level for all products which is why it is critical to use it for the right products which can be determined by using inventory analysis and segmentation methods and at a service level above 97% the cost of implementing a safety stock becomes economically infeasible and is thus not recommended at such a high service level.
Keeping less of the wrong type of inventory on hand (E.g. low value, low order frequency) and instead using ways to improve the supply chain will result in improved delivery performance and higher quality at a lower cost.

As shown in our case study it is costly to maintain a high service level for all products which is why it is critical to use it for the right products which is decided using inventory analysis and segmentation methods.

Using effective demand prediction techniques such as exponential smoothing based forecasting and standard deviation based safety stock is what we strongly recommend for predicting future demand. Using accurate forecasting methods will establish a reliable demand projection calculation as well as provide a basis for safety stock calculations using the forecast error measurements. Forecasting of demand will also further aid in keeping the delivery precision high by accurately predicting demand and giving a chance to stock inventory and plan production accordingly.
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Appendix

Appendix A

Graphs showing actual demand over twelve months for nine sample products of focal firm. The monthly demand variations are also shown.