SCHOOL OF INDUSTRIAL ENGINEERING AND TELECOMMUNICATION

UNIVERSITY OF CANTABRIA

Final Project

OPTIMIZATION OF SAFETY STOCK LEVEL IN A MANUFACTURING COMPANY

To access the title of

INDUSTRIAL ENGINEERING

Author: Özge Çelik

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LIST OF ABBREVIATIONS

GMRAE : Geometric Mean Relative Absolute Error

MAE : Absolute Error

MAPE : Mean Absolute Percantage Error

MdAE: Median Absolute Error

MdAPE: Median Absolute Percantage Error

MdRAE: Median Relative Absolute Error

MRAE : Mean Relative Absolute Error

MRP : Materials Requirement Planning

MSE: Mean Square Error

RelMAE : Relative Mean Absolute Error

RMdSPE: Root Median Square Percentage Error

RMSE: Root Mean Square Error

RMSPE : Root Mean Square Percentage Error

SC: Supply-chain

SCM : Supply Chain Management

TL: Turkish Lira

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This project would not have been possible unless I received such an amazing support. First of all I would like to thank my family who was there to support me no matter what throughout my life. I would like to thank my supervisor Dr. Carmen Ruiz Puente as well for her guidance with this paper. Also, I would like to thank Murat Bilsel and Özalp Vayvay who are lecturers in Marmara University and my supervisor Başar ÖĞÜN who is manager at Eczacıbaşı for letting me to use this issue for my final project.

ABSTRACT

For final project, I worked with a furniture manufacturing company which name is ECZACIBASI VİTRA. I collaborated with production department and manufacturing manager for this project. In this Project the target was to find optimum safety stock level acording to uncertain demand. Firstly, actual sales data was analyzed and forecast accuracy was controlled.Then, ABC analysis was implemented all materials to find critical products. Materials were categorized according to annual sales value. Then, lead time was analyzed for materials and service level was determined. Service levels were assigned in a way that, the more critical product gets higher service level.Next, inventory model was decided according to unceartinity of the demand.This model was stochastic and covered unceartiny of the demand.The model determined an expected monthly demand for each product, a safety stock amount for each product and reorder point.

My project is about inventory management and completed in June, 2013.

Keywords: safety stock optimization, inventory, production

CHAPTER 1: INTRODUCTION

Supply chain management includes all processes for transforming raw materials into finished goods from suppliers to customers. Supply chain refers to all network that participate in the production, delivery and sale of a product. Recently in dynamic and developing markets, design and analysis of supply chain have been become more important. In supply chain management cycle, material requirements planning (MRP) is a fundamental activity in order to control production planning and inventory management processes.

In the long run, MRP provides controlling of all of these processes that work together to design, produce, deliver and service products.

MRP functions are determined and designed to achive these objectives:

- Controlling availability of materials for manufacturing organizations
- Improvement of stock tracking system and optimization of stock levels
- Efficiency management of planning & purchasing activities and delivery schedules.

There exist several MRP software systems in the market. In this project, we decided to study about process improvement in material requirements planning at Eczacıbaşı Vitra Ceramic Factory. Production area of Eczacıbaşı Vitra is bath series which are constituted of modules as mirror, faucets and bathroom cabinets. MRP module of SAP is already used by Eczacıbaşı Vitra. Functions of this module could not meet the requirements and expectations of the factory. The problems occured related to inventory management and controlling of manufacturing processes. The company needs some improvements and redesigns of current methods so as to create solutions for these problems and achive targeted point. In order to reach this point, sales data and forecasts should be analyzed, appropriate demand forecasting method should be chosen, required amount of materials should be determined and finally Safety Stock Level should be calculated.

Thus, the aim of our project is reaching excellence in material requirements planning with analyzing sales data which obtained from Sales and Operation

Planning and controlling forecast accuracy; in the long term determination of Economic Order Quantity and Safety Stock Level.

Another objective of the project is to determine demand-forecasting method by analyzing historical sales data. We should consider seasonality, trend and promotion effects on sales data to improve demand forecasting method.

One of the most important subjects is making demand forecasting correctly and evaluating factors which affect demand. As a result of this, risk of being stock-out would be prevented.

As metioned above, supply chain involves entire network of processes that transforming raw materials into finished goods from suppliers to customers. Supply chain consists of two fundamental process: the Production Planning and Inventory Control Process and the Distribution and Logistics Process. Scope of our project is related with the first process which is the Inventory Control Process.(Beamon, 1998) Inventory control defines the management of inventory for raw material, semi products and finished goods.

The Steps of the project were determined as it is shown below;

- Analyzing actual sales data on series and channel basis
- Time series analysis
- Controlling forecast accuracy
- Determination of sales forecasts of materials
- Comparing actual sales data with forecasts for each material
- Determination of safety stock levels

1.1 Information About Company- Eczacıbaşı

Founded in 1942, Eczacıbaşı is a prominent Turkish industrial group with 41 companies, 11,730 employees and a combined net turnover of 2.6 billion Euro in 2012.

Eczacıbaşı’s core sectors are building products, healthcare and consumer products. Additionally, the Group is active in finance, information technology, welding technology, mining, and property development and facility management. In Turkey, Eczacıbaşı is the leader in most of its businesses with some of the most effective distribution networks in the country for building products, pharmaceuticals, and fast-moving consumer goods. Globally, Eczacıbaşı has established itself among the world’s top providers of bathroom and tiling solutions for homes and commercial venues with its VitrA, Burgbad, Villeroy and Boch (Tiles), and Engers brands. It is also a major exporter of tissue paper, welding electrodes, electronic smart cards and industrial raw materials such as clay and feldspar.

International partnership is a central component of the Eczacıbaşı Group’s growth strategy. Eczacıbaşı has four international joint ventures and numerous cooperation agreements with leading international companies. All of these are grounded on the principles of long-term mutual benefit and sustainable business practices.

The Eczacıbaşı Group’s mission is to be a pioneer of modern lifestyles that are healthy, high quality and sustainable. Accordingly, the Group encourages each of its companies to surpass established standards and raise consumer benchmarks of product and service quality. Through sponsorship and responsible corporate practices, it also promotes social and economic development that nurtures cultural and scientific activity, protects the environment and preserves scarce natural resources.

The Eczacıbaşı Building Products Division operates globally and owns a total of 15 manufacturing facilities: 9 spread out over Germany, England and France and 6 in Turkey. Combined, these factories produce an average of 5 million ceramics sanitaryware, 36 million square meters of ceramic and wall tiles, 370 thousand modules of bathroom furniture, 3 million faucets, 350 thousand bathtubs, 2,5 million bathroom accessories, 150 thousand concealed cisterns and 550 thousand WC pan seats and covers every year.

With a wide range of products and an extensive distribution network, Eczacıbaşı Building Products Division currently exports its products to more than 75 countries. It has become a globally recognised supplier of bathroom products and tiles through acquiring the Engers Keramik, Villeroy & Boch Fliesen and Burgbad, alongside VitrA.

1.1.1 Eczacıbası VitrA

VitrA is an award-winning global brand offering complete bathroom solutions and ceramic wall and floor coverings for residences and commercial venues.

Innovative design, sustainability principles and superior concepts underpinned by sophisticated technology are the hallmarks of VitrA's bathroom and tile collections, which are increasingly positioning the brand as a design leader.

Inspired by the millennia-old Anatolian tradition of ceramic art, VitrA combines superior aesthetic concepts with sophisticated technology to redefine our relationship with water, and to reinvent the bathroom.

Production Sites:

VitrA

Bozüyük, Bilecik, Turkey

5 million pieces of ceramic sanitaryware, 3 million faucets, 2.5 million bathroom accessories and 20.1 million square meters of tiles are produced here yearly. Established in 1977 but completely overhauled in 1995, this mega complex is one of the world's top sanitaryware production facilities in capacity, technology and quality. Advanced technology includes: high-pressure casting, rapid-drying moulds, fettling robots in casting shops and barcode follow-up. The Bozüyük tile plant produces wall and floor tiles, porcelain floor tiles, swimming pool products and complementary pieces, while an adjoining factory produces bathroom accessories, shower systems and faucets.

VitrA

Tuzla, Istanbul, Turkey

Established in 1991, this tile factory produces the entire mosaic range for VitrA, as well as glass tiles, decorated tiles and complementary pieces, with 3.35 million square meters of tiles produced here annually.

VitrA

Gebze, Kocaeli, Turkey

VitrA is the first brand to offer acrylic bathtubs produced in Turkey, and since it opened in 1991 the Gebze plant has grown considerably. Now 350,000 acrylic bathroom pieces – including acrylic bathtubs, whirlpools, shower trays, shower systems, compact systems and walk-in shower units – are produced here yearly.

VitrA

Serpukhov, Russia

VitrA's most recently opened tile production facility is in the Russian town of Serpukhov. It produces mosaic, porcelain and wall tiles at a total annual production capacity of 3.2 million square meters. Currently under construction nearby is a second Serpukhov facility, which will open to production in 2013 to produce 300,000 pieces of ceramic sanitaryware yearly.

Engers

Rheinland Pfalz, Germany

Engers Keramik joined the Eczacıbaşı Building Products Division in 2006. A well- established player in the German tile market with a history dating back to 1911, Engers produces 2,300,000 m2 of highly fashionable wall tiles.

CHAPTER 2: PROJECT DEFINITION

The project was required as a stage of process improvement in material requirements planning. The project was implemented in Eczacıbaşı Vitra which is premier supplier in the Turkish market of high quality bathroom furniture.

The purpose of the project is reaching excellence in material requirements planning with analyzing sales data and controlling forecast accuracy; in the long term determination of safety stock level.

The Project was required because :

▸Manufacturing managers face increasing pressure to reduce inventories across the supply chain. However, in complex supply chains, it is not always obvious where to hold safety stock to minimize inventory costs and provide a high level of service to the final customer.

▸Another reason for requirement of this project that there is a need for a strong inventory model with a good formulation in order to achieve a more systematic approach.

▸Besides, determination of the order amounts and the reorder points are done manually and stock level is quite high.

Inventory management is a financial trade-off between inventory costs and stock-out costs. The more stock, the more working capital is needed and the more stock depreciation you get. On the other hand if you do not have enough stock, you get inventory stock-outs, missing potential sales, possibility interrupting the whole production process.

Inventory stock depends essentially of two factors:

- Demand; the amount of items that will be consumed or bought.
- Lead time; the delay between reorder decision and renewed availability.

Inventory management is primarily about specifying the size and placement of stocked goods. It is required at different locations within a facility or within multiple locations of a supply network to protect the regular and planned course of production against the random disturbance of running out of materials or goods. The scope of inventory management also concerns the fine lines between replenishment lead time, carrying costs of inventory, asset management, inventory forecasting, inventory valuation, inventory visibility, future inventory price forecasting, physical inventory, available physical space for inventory, quality management, replenishment, returns and defective goods and demand forecasting.There are four basic reasons for keeping an inventory:

Time - The time lags present in the supply chain, from supplier to user at every stage, requires that you maintain certain amounts of inventory to use in this lead time. However, in practice, inventory is to be maintained for consumption during 'variations in lead time'. Lead time itself can be addressed by ordering that many days in advance.

Uncertainty - Inventories are maintained as buffers to meet uncertainties in demand, supply and movements of goods.

Economies of scale - Ideal condition of "one unit at a time at a place where a user needs it, when he needs it" principle tends to incur lots of costs in terms of logistics. So bulk buying, movement and storing brings in economies of scale, thus inventory.

Appreciation in Value - In some situations, some stock gains the required value when it is kept for some time to allow it reach the desired standard for consumption, or for production.

On the other hand, keeping such stocks can prove to be too costly for small businesses, because of the costs involved in purchasing and storing the inventory (especially because safety stock is mostly a non-moving stock). Wholesale businesses, which are already looking to cut costs, might not appreciate the idea of spending their (already limited) capital on safety-stocks.

The level of customer satisfaction largely depends on manufacturer’s ability to respond to customer orders with promptness. The swiftness with which the manufacturers are able to meet customer demand is measured by the service level. Meeting customer demand on time not only improves profit margins, but also develops a better public image. In an increasing competitive market hence it becomes important to meet customer demands on time.Customer satisfaction or the ability to effectively respond to customer demand can be gauged by measuring service level (Nahmias 2007). Service level is defined in many ways; the simplest definition is the fraction of orders that are filled on or before their delivery due date (Nahmias 2007). It simply means having enough safety stock in the inventory so as to satisfy the customer demand. Holding an inventory can however be very expensive (Ghiana, Laporte and Mussamo, 2004). They state the following reasons,

1) A company that holds safety stock incurs an opportunity or capital cost represented by the return on investment the firm would have realized if the money had been better invested.

2) The warehousing costs must be incurred, which is made up of leasing cost and the operating and maintenance cost of the warehouse.

3) The company may also incur costs in form of insurance, shrinkage of the products or damage costs (Nahmias 2007).

CHAPTER 3: LITERATURE SURVEY

In this part of report, literature survey related with the project was conducted in order to examine similar implementations about forecast accuracy, time series analysis, Winters Method, ARIMA, Minitab Software and Safety Stock Calculation and Inventory Modeling. According to examinations, the following information was obtained.

3.1 Time Series Forecasting

There are several useful techniques to choose a model with the potential of producing the best forecasts. In the beginning the best step is constituting plots of time series to analyze data which will be forecasted. It gives us a visual impression of the raw data of the time series in order to have information about behavioral components such as trend and seasonality. For example if data exhibits both trend and seasonality, Holts Winter can be used as a forecasting method.

Seasonality can be defined as the tendency of time series data and its behaviour is same for every L period. L is the season length in periods. Kalekar (2004) mentioned an example in article, in November and December and also during summer (with a smaller peak), annual sales of toys may peak. This will be probably repeat every year although amount of sales in December may slowly change from year to year. Sales in December may increase by 1 million dollars every year. Therefore amount of 1 million dollar can be added to forecast for every December. In this case, the seasonality is additive. (Kalekar, 2004)

3.2 Forecast Accuracy

In genaral, monthly, quarterly or annually forecasts are generated for product groups. Range of forecasting period expand between one and five years. For deciding future demands a daily, weekly and monthly basis in operational planning, some forecasting softwares are utilized.

Operational plan includes :

-demand plan

-inventory plan

-transport and distribution plan,

-replenishment plan,

-production plan,

-maintenance plan,

-collaborative plans.

In order to obtain better results from forecasting methods and enhance forecast accuracy, analysists should concentrate on different forecasting models while producing forecasts for a few series. (Küsters, McCullough, & Bell, 2006)

In order to control forecast accuracy, some methods commonly used are chosen according to properties of data. There are some notations so as to calculate accuracy measures. Yt refer to the observation at time t. F_t is forecast of Y_t. Forecast error is defined as $e_t = Y_t - F_t$.

There are various accuracy measures whose scale depends on the scale of the data and while comparing different methods for same data set, these measures help choosing the most effective method. They are grouped like these:

1-Scale-dependent measures:

In general, the most commonly used measures for this group are shown below;

Mean Square Error (MSE) = mean(e_t^2)

Root Mean Square Error (RMSE) = $\sqrt{MSE}$

Mean Absolute Error (MAE) = mean(|et|)

Median Absolute Error (MdAE) = median(|et|)

2-Measures based on percentage errors:

Percentage errors are used to compare forecast performance of different data sets and they are scale-independent.Percentage error is defined as $p_t = 100e_t / Y_t$.

However, if Y_t equals to zero at any time t, measures become infinite or undefined. Commonly used measures are :

Mean Absolute Percantage Error (MAPE) = mean(|pt|)

Median Absolute Percantage Error (MdAPE) = median(|pt|)

Root Mean Square Percentage Error (RMSPE) = $\sqrt{\text{mean}}(p_t^2)$

Root Median Square Percentage Error (RMdSPE) = $\sqrt{\text{median}}(p_t^2)$

3-Measures based on relative errors:

$r_t = e_t/e_t^*$ is obtained using another standard method of forecasting.

Formulas for this errors are defined below :

Mean Relative Absolute Error (MRAE) = mean ($|r_t|$)

Median Relative Absolute Error (MdRAE) = median ($|r_t|$)

Geometric Mean Relative Absolute Error (GMRAE) = gmean ($|r_t|$)

4-Relative measures:

As an example MAE_b comes from the benchmark method of MAE. Then :

Relative Mean Absolute Error (RelMAE) = MAE / MAE_b

As it was mentioned above, while confirming the model, some error measures such as MSE, MAPE, RAE can be used. This choice has a significant influence to decide which forecasting method is most accurate so it affects decision of model which gives the least error.(Hyndman & Koehler, 2006)

3.3 Winters Method

In the early 1960s, designing forecast methods were performed individually by using either Assembler or FORTRAN. Winters' first published paper on the Holt-Winters Method (1960) explained how to compute forecast with showing detailed flow diagrams.(Küsters, McCullough, & Bell, 2006) Holt-Winters Method is one of the variants of exponential smoothing which is used for producing short-term forecasts for sales or demand time-series data and is also simple and give good results in practise. This method can be applied both automatic and non-automatic way.

Generating reliable forecasts is essential therefore the best way of calculation should be known. However, it is not known to which is the best even though there are various types of forecasting procedure. Because different treatments are required for each kind of forecasting problems and deciding method depends on different considerations such as the number of series, properties of data and so on.

Winters (1960) supported that the seasonal factors should be normalised in the beginning because the trend effect would be observed on series later. On the other hand, some authors recommended that normalization should be done once a year or at every observation in order to be suitable for different definitions of seasonality. When empirical results are considered, it can be said that seasonal indices normalised at least once a year.

Some weights like level, trend and seasonal are used in this method. In order to select these parameters and decide optimal values, two general ways are used. One of them is minimizing some function of the forecast errors of historical data to calculate and other one is 'guestimate' them. (Chatfield & Yar, 1988)

There are two main models of Holt-Winters. These are additive model for time series exhibiting additive seasonality and multiplicative model for time series exhibiting multiplicative seasonality. (Kalekar, 2004)

3.4 ARIMA

X-1 1 ARIMA developed by Dagum provides to decrease the size of the revisions and model for the series. Model simply consists of modelling the original series, forecasting one or two years of raw data by using fitted values and seasonally adjusting the enlarged original series.

There are some requirements for ARIMA method. When past data are considered, the series should be explained simply. While generating short-term forecast, the method is successful to give desired results. One or two years of data should be incorporated strongly and forecasts should not change essentially when there are small variations in parameter values in order to avoid frequent changes of models. Forecasted values should follow movement well within year and improve current seasonal adjustment. In addition to this, model must forecast optimally with minimum mean square error forecast. ARIMA model is useful to calculate the best fits by using past data of a time series so as to generate forecasts. Some transformations such as differencing are used to stationarize the series. Differencing operator is useful if there is a model for non-stationary time series. (Dagum, 1988)

ARIMA models are, in theory, the most general class of models for forecasting a time series which can be stationarized by transformations such as differencing and logging. In fact, the easiest way to think of ARIMA models is as fine-tuned versions of random-walk and random-trend models: the fine-tuning consists of adding lags of the differenced series and/or lags of the forecast errors to the prediction equation, as needed to remove any last traces of autocorrelation from the forecast errors.

The acronym ARIMA stands for "Auto-Regressive Integrated Moving Average." Lags of the differenced series appearing in the forecasting equation are called "auto-regressive" terms, lags of the forecast errors are called "moving average" terms, and a time series which needs to be differenced to be made stationary is said to be an "integrated" version of a stationary series. Random-walk and random-trend models, autoregressive models, and exponential smoothing models (i.e., exponential weighted moving averages) are all special cases of ARIMA models.

A nonseasonal ARIMA model is classified as an "ARIMA(p,d,q)" model, where:

- p is the number of autoregressive terms,
- d is the number of nonseasonal differences, and
- q is the number of lagged forecast errors in the prediction equation.

To identify the appropriate ARIMA model for a time series, begin by identifying the order(s) of differencing needing to stationarize the series and remove the gross features of seasonality, perhaps in conjunction with a variance-stabilizing transformation such as logging or deflating. If you stop at this point and predict that the differenced series is constant, you have merely fitted a random walk or random trend model. (Recall that the random walk model predicts the first difference of the series to be constant, the seasonal random walk model predicts the seasonal difference to be constant, and the seasonal random trend model predicts the first difference of the seasonal difference to be constant--usually zero.) However, the best random walk or random trend model may still have autocorrelated errors, suggesting that additional factors of some kind are needed in the prediction equation.

3.5 SUPPLY CHAIN MANAGEMENT

Suply chain management is defined as an integrative approach for planning and control of materials and information flows with suppliers and customers as well as between different functions within a company (Minner, 2003). The aim of supply chain is to provide right product, at the right time, at the right location to the customer.This is done by managing the balance between the different supply chain member's needs while keeping in mind the best interest of all (Bloodgood, Katz & Pagell, 2003) SCM is encompassed into the strategic, tactical and operational activities of a firm (Badell, Espuna, Guillen and Puigjaner, 2006). Badell et al. (2006) and Gamberini, Gebennini and Manzini (2009) described the following hierarchical integration of SCM Activities in the firm :

1.Strategic Level: This level referred to a long-term planning horizon and adressed the problem of designing and confuguring a generic supply chain. Decisions included the number of facilities, locations, capacity and allocation aspects.

2.Tactical Level: This level referred to both long and short term horizons and deal with the determination of the best operating policies and material flows in a multi-echelon inventory system.

3.Operational Level: This level referred to the day-to-day operations such as scheduling.

The integration of these complexities across different decion levels posed challenging in terms of optimal supply chain integration (Badell et al 2006).

De Toni and Nassimbeni (1999) have characterized supply chain management (SCM) by four elements: a large supply base, short term relationships, low-price bidding, and low flexibility.Council of Logistics Management (2000) defines SCM as a systemic coordination of the traditional business functions and tactics across these business functions within a particular organization and across businesses within the SC for the purposes of improving the long-term performance of the individual organizations and the SC as a whole. Currently, manufacturers have realized the potential benefits of the supplier partnership – a mutual, ongoing relationship that involves a high level of trust, commitment over time, and long-term contracts (Scannell et al., 2000). SCM is a research area attracted the attention of many researchers from the academicians, consultants, and business managers, over the last two decades. It is concerned with cost effective way of managing materials, information and financial flows from the point of origin to the point of consumption to satisfy customer requirements (Narasimha Kamath and Roy, 2007). An important point to be taken into consideration in the designing stage of the SC is the decision made regarding the initial SC capacity.

Supply-chain (SC) excellence is the key to gaining competitive advantages. To arrive at, companies have been trying to reduce costs, increase customer responsiveness, and optimize asset utilization. Such efforts do not always work well. This is because there may be little link between the competitive strategies of these companies and their SC processes, operations and practices. Many managers had argued that SC demonstrates the single most important business process leading to improved customer service, reduced cycle times, and enhance profitability. Most organizations have a good SC vision, yet struggle to find the most cost-effective means to achieve and sustain it.

Recently, the most important work a company can do is to fully understand and advance its SC contribution. Strategic sourcing and logistics are key enablers for achieving lowest total-cost producer status. By defining customer's wants and needs, and trying with accomplishing them, the organization's SC represents a complex array of business processes, decisions, and resource commitments, unsurpassed by any other dimension of the organization.

3.6 ABC Analysis

The objective of inventory management is to make decisions regarding the appropriate level of inventory. In practice, all inventories cannot be controlled with equal attention. Inventory classification is an effective way to manage a large number of items. As a basic methodology, ABC analysis is widely used for classification. ABC Analysis is an inventory control system. The traditional ABC classification is based on only a single criterion.

As a basic methodology for material classification, ABC analysis originated by Dickie based upon the Pareto principle is one of the most widely used tools. Traditionally, this approach classifies the items into three groups based on a single criterion such as annual use value.

The ABC Method can be used for material, subassemblies, component parts, or products depending on company. This method helps define how stock is managed and usually categorizes inventory into three classes with each class having a different management control associated :

A - outstandingly important;

B - of average importance;

C - relatively unimportant as a basis for a control scheme

ABC Analysis is necessary for material management processes. . It can form the basis of various activity including leading plans on alternative stocking arrangements (consignment stock), reorder calculations and can help determine at what intervals inventory checks are carried out (for example A class items may be required to be checked more frequently than C class stores).

ABC Analysis is also known 80:20 Rule.It means aproximately 20 percent of items contribute 80 percent of the cost and the remaining 80 percent of items account for only 20 percent of the cost . ABC Analysis is useful and appropriate technique for classifying inventory items according to the importance of their contribution to the annual cost of the entire inventory system.This process allows business owners and managers an opportunity to better define the areas of manufacturing or sales that generate the most profit for the company. Inventory analyzed under the ABC method is classified in order of profitability to the company. Class A inventory accounts for 80 percent of revenue, class B inventory for 15 percent of revenue and class C inventory for 5 percent of revenue.

All the items of inventory has been divided into three categories and these are as below :

- A-items are goods which annual consumption value is the highest. The top 70-80% of the annual consumption value of the company typically accounts for only 10-20% of total inventory items. These items requires special care and more frequent controls.

- C-items are, on the contrary, items with the lowest consumption value. The lower 5% of the annual consumption value typically accounts for 50% of total inventory items. These items requires little care.

- B-items are the interclass items, with a medium consumption value. Those 15-25% of annual consumption value typically accounts for 30% of total inventory items. These items requires Standard care.

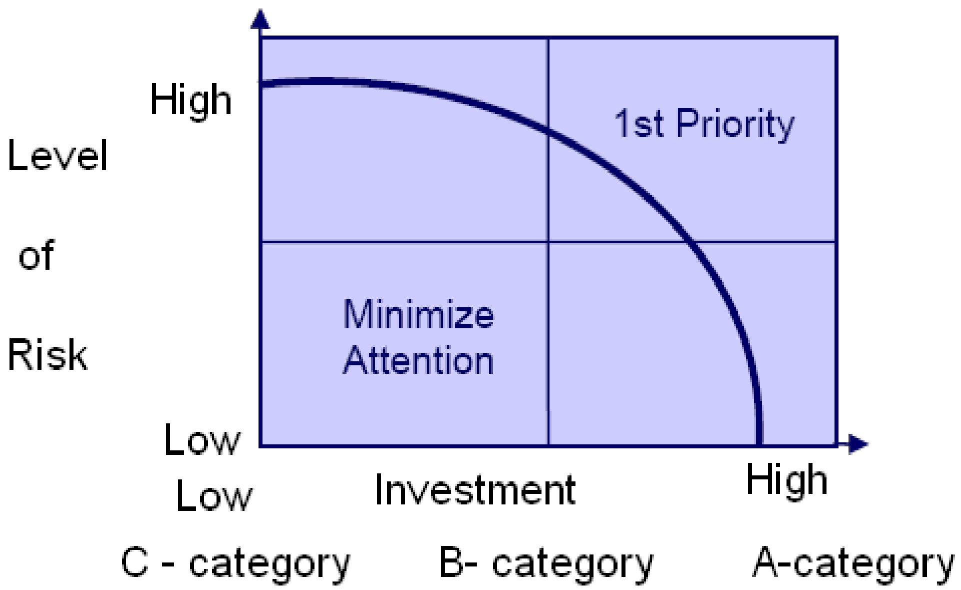

Figure 1 ABC Analysis graph

The annual consumption value is calculated with the formula:

Annual consumption= (Annual demand) x (item cost per unit).

Through this categorization, the supply manager can identify inventory hot spots, and separate them from the rest of the items, especially those that are numerous but not that profitable.

The following steps will explain to you the classification of items into A, B and C categories:

1. Find out the unit cost and the usage of each material over a given period.
2. Multiply the unit cost by the estimated annual usage to obtain the net value.
3. List out all the items and arrange them in the descending value. (Annual Value)
4. Accumulate value and add up number of items and calculate percentage on total inventory in value and in number.
5. Draw a curve of percentage items and percentage value.
6. Mark off from the curve the rational limits of A, B and C categories.

3.6.1 Inventory management policies

Policies based on ABC analysis leverage the sales imbalance outlined by the Pareto principle. This implies that each item should receive a weighed treatment corresponding to its class:

- A-items should have tight inventory control, more secured storage areas and better sales forecasts. Reorders should should be frequent, with weekly or even daily reorder. Avoiding stock-outs on A-items is a priority.

- Reordering C-items is made less frequently. A typically inventory policy for C-items consist of having only 1 unit on hand, and of reordering only when an actual purchase is made. This approach leads to stock-out situation after each purchase which can be an acceptable situation, as the C-items present both low demand and higher risk of excessive inventory costs. For C-items, the question is not so much how many units do we store? but rather do we even keep this item in store?

- B-items benefit from an intermediate status between A and C. An important aspect of class B is the monitoring of potential evolution toward class A or, in the contrary, toward the class C.

Splitting items in A, B and C classes is relatively arbitrary. This grouping only represents a rather straightforward interpretation of the Pareto principle. In practice, sales volume is not the only metric that weighs the importance of an item. Margin but also the impact of a stock-out on the business of the client should also influence the inventory strategy.

3.6.2 Procurement and Warehouse Applications

The results of an ABC Analysis extend into a number of other inventory control and management processes:

- Review of stocking levels – As with investments, past results are no guarantee of future performance. However, “A” items will generally have greater impact on projected investment and purchasing spend, and therefore should be managed more aggressively in terms of minimum and maximum inventory levels .Obsolescence review – By definition, inactive items will fall to the bottom of the prioritized list. Therefore, the bottom of the “C” category is the best place to start when performing a periodic obsolescence review.

- Cycle counting – The higher the usage, the more activity an item is likely to have, hence the greater likelihood that transaction issues will result in inventory errors. Therefore, to ensure accurate record balances, higher priority items are cycle counted more frequently. Generally “A” items are counted once every quarter; “B” items once every 6 months; and “C” items once every 12 months.

- Identifying items for potential consignment or vendor stocking – Since “A” items tend to have a greater impact on investment, these would be the best candidates to investigate the potential for alternative stocking arrangements that would reduce investment liability and associated carrying costs.

- Turnover ratios and associated inventory goals – By definition, “A” items will have greater usage than “B” or “C” items, and as a result should have greater turnover ratios. When establishing investment and turnover metrics, inventory data can be segregated by ABC classification, with different targets for each category.

- Definition of 'Inventory Turnover'

  A ratio showing how many times a company's inventory is sold and replaced over a period the:

  Generally calculated as:

  = Sales / Inventory

  However, it may also be calculated as:

  =Cost of goods Sold / Average Inventory

3.7 Optimizing Safety Stock

Safety stock were introduced into supply chains to hedge against unceartinity and ensured that customer received the promised service levels (Blau et al,2008) When stock level is high, service level will be high but also supply chain operating cost increases. According to Koumanakos (2008) firms with higher levels of inventory are associated with lower rates of return. These levels therefore had to be suitably optimised (Blau et al,2008)

If there is stochastic demand or lead time, safety stocks are required against stock-outs. Safety stock is held in addition to cyle stock and the three most common analytical approaches for determininfg safety stocks are the ‘time supply approach’, the ‘order costing approach’ and the ‘service level approach’.(Aghezzaf et al 2007; Mattsson, 2007)

- Time supply approach : The aim is to set safety stock equal to a certain time of inventory supply. At the conclusion, fixed supply patterns are obtained.

- Order Costing Approach : The goal of this approach to minimize the total of ordering cost an carrying cost.As outcome total cost is minimized.

- Service Level Approach: The aim of using service level approach is to minimize carrying cost subject to satisfying a certain pre-specified percentage of customer demand. As a result, optimal customer sercive is provided versus cost.

The order costing and service level approaches are more popular among researchers.The time supply models were rarely used in literature (Dullaert et al,2008). Service Level models are useful approach for determining safety stock and used in three different ways depending on how service levels are defined. These are:

S1-Satisfying a specified probability of no stockout per replenishment cycle

S2- A specified fraction of demand to be satisfied by inventory on hand

S3-A fraction of time with positive stock on hand

The aim of these models is determining accurate reorder points and safety stocks based on the required service levels that was defined by management. There is inconsistency between the service levels recommended in literature and the service level in practice. According to Aghezzaf et al (2007) it is clear that S2 is beter than S1 and S3 methods. Mean and Standard deviation of demand during lead-time; cost of cycle stock, Transportation, inventory in-transit, safety stock, transportation lead times, transportation lead time variability, shipment quantity are variables to determine S2. As outcome, safety stock level and reorder point are calculated.To reduce complexity of stochastic variable and variable lead time, more accurate safety stock models needs to be developed (Cetin, Gardner & Talluri, 2004).

Safety Stock Formulations by quadrant:

		LEAD-TIME Constant	LEAD-TIME Variable
DEMAND	Constant	No Safety Stock	$R_L = RL$ $\sigma_L = \sqrt{R^2 s_L^2}$ SS= F_s^{-1} (CSL) σ_L
DEMAND	Variable	$R_L = RL$ $\sigma_L = \sqrt{\sigma_R^{\ 2} L^2}$ SS= F_s^{-1} (CSL) σ_L	RL = RL $\sigma_L = \sqrt{R^2 s_L^2 + \sigma_R^{\ 2} L^2}$ SS= Fs-1 (CSL) σ_L

Table 1 Safety Stock Formulations

Where,

R: The average demand per period

L: Average lead time for replenishment

R_L: the demand per lead-time of replenishment

σ_R: standard deviation of demand per period

s_L: standard deviation of lead-time

σ_L: standard deviation of demand during lead-time

CSL: cycle service level

F_s^{-1}: represents the inverse normal(Cetin et al.)

SS: Safety Stock

Cetin et al (2004) claims that the value of the model presented in Figure, was captured in its ability to account for both supply and demand variability in setting safety stock targets. The majority of safety stock models were based on the assumption of normal probability distributions and it was a reasonable assumption especially under the condition of rather long lead times (Mattsson, 2007) .This view was in contrast to Dullaert et al (2008) who found that the assumption of normal probability distribution is often invalid for real life situations and can have significant impacts on the safety stocks and service levels. The model presented was dependent on re-order points that are controlled by the supply chain department (Mattson,2007). Mattsson (2007) concluded that inventory control measures used in industry fail to achieve the desired service levels that the methods are designed to attain.

From the literature review, it is clear that supply chains are becoming more complex and lead times of delivery is increasing. As a result, inventory levels get high and there is more supply variablity. Besides, customers require more attention and at this point service level should be high. It means optimization of safety stock level has an important role to provide customer satisfaction and also to reduce inventory costs.

3.7.1 Terminology and calculations

The following is a list of the variables and the terminology used in this safety stock model:

- Normal distribution: Term used in statistical analysis to describe a distribution of numbers in which the probability of an occurrence, if graphed, would follow the form of a bell shaped curve. This is the most popular distribution model for determining probability and has been found to work well in predicting demand variability based upon historical data.

- Standard deviation: Used to describe the spread of the distribution of numbers. Standard deviation is calculated by the following steps:

1. Determine the mean (average) of a set of numbers.

2. Determine the difference of each number and the mean

3. Square each difference

4. Calculate the average of the squares

5. Calculate the square root of the average.

Also Excel function STDEVPA can be used to calculate standard deviation. In safety stock calculations, the forecast quantity is often used instead of the mean in determining standard deviation.

- Lead time: Highly accurate lead times are essential in the safety stock/reorder point calculation. Lead time is the amount of time from the point at which you determine the need to order to the point at which the inventory is on hand and available for use. It should include supplier or manufacturing lead time, time to initiate the purchase order or work order including approval steps, time to notify the supplier, and the time to process through receiving and any inspection operations.

- Lead-time demand: Forecasted demand during the lead-time period. For example, if your forecasted demand is 3 units per day and your lead time is 12 days your lead time demand would be 36 units.

- Forecast period. The period of time over which a forecast is based. The forecast period used in the safety stock calculation may differ from formal forecast periods. For example, you may have a formal forecast period of four weeks while the forecast period you use for the safety stock calculation may be one week.

- Demand history. A history of demand broken down into forecast periods. The amount of history needed depends on the nature of business. Businesses with a lot of slower moving items will need to use more demand history to get an accurate model of the demand. Generally, the more history the better, as long as sales pattern remains the same.

- Order cycle: Also called replenishment cycle, order cycle refers to the time between orders of a specific item. Most easily calculated by dividing the order quantity by the annual demand and multiplying by the number of days in the year.

- Reorder point: Inventory level which initiates an order.

Reorder Point = Lead Time Demand + Safety Stock.

• Service level: Desired service level expressed as a percentage.

• Service factor: Factor used as a multiplier with the Standard Deviation to calculate a specific quantity to meet the specified service level. Service factor table is below or Excel function NORMSINV is used to convert service level percentage to service factor.

Service Level	Service Factor		Service Level	Service Factor
50.00%	0		90.00%	1.28
55.00%	0.13		91.00%	1.34
60.00%	0.25		92.00%	1.41
65.00%	0.39		93.00%	1.48
70.00%	0.52		94.00%	1.55
75.00%	0.67		95.00%	1.64
80.00%	0.84		96.00%	1.75
81.00%	0.88		97.00%	1.88
82.00%	0.92		98.00%	2.05
83.00%	0.95		99.00%	2.33
84.00%	0.99		99.50%	2.58
85.00%	1.04		99.60%	2.65
86.00%	1.08		99.70%	2.75
87.00%	1.13		99.80%	2.88
88.00%	1.17		99.90%	3.09
89.00%	1.23		99.99%	3.72

Table 2 Service Factor Acording to Service Level

3.8 Inventory modeling

Inventory exists to meet the demand of customers. Customers can be external (purchasers of products) or internal (workers using material). Management needs accurate forecast of demand.

Items that are used internally to produce a final product are referred to as dependent demand items.Items that are final products demanded by an external customer are independent demand items.

If demand and lead time are known (constant), they are called deterministic models. If they are treated as random (unknown), they are stochastic. Each random variable can have a probability distribution.

There are three basic types of systems: continuous model (fixed-order quantity), periodic model (fixed-time), and Single-Period model

• Continuous system: An order is placed for the same constant amount when inventory decreases to a specified level.

• Periodic system: An order is placed for a variable amount after a specified period of time.

• Single-period system: An order is placed just for one period.

3.9 Reorder Point

The reorder point is the inventory level at which a new order is placed. Order must be made while there is enough stock in place to cover demand during lead time.

The reorder point for basic EOQ model with constant demand and a constant lead time to receive an order is equal to the amount demanded during the lead time, Reorder Point Formulation:

- $R = dL$

  where d = demand rate per time period

  L = lead time

3.9.1 Reorder Point with Variable Demand

To compute the reorder point with a safety stock that will meet a specific service level, we will assume the demand during each day of lead time is uncertain, independent, and can be described by a normal distribution. The average demand for the lead time is the sum of the average daily demands for the days of the lead time, which is also the product of the average daily demands multiplied by the lead time. Likewise, the variance of the distribution is the sum of the daily variances for the number of days in the lead time. Using these parameters the reorder point to meet a specific service level can be computed as:

$$R = \bar{d}L + Z\sigma_d\sqrt{L}$$

where:

R = reorder point

$\bar{d}$ = average daily demand

L = lead time

σ_d = the standard deviation of daily demand

Z = number of standard deviations corresponding to service level probability

$Z\sigma_d\sqrt{L}$ = safety stock

The term $\sqrt{\sigma_d^2 L}$ in this formula for the reorder point is the square root of the sum of the daily variances during lead time:

Variance = (daily varience)*(number of days of lead time)

$= \sigma_d^2 L$

Standard deviation = $\sqrt{\sigma_d^2 L}$

Under deterministic conditions, when both demand and lead time are constant, the reorder point is set equal to lead time demand.

Under probabilistic conditions, when demand and/or lead time varies, the reorder point often includes safety stock.

CHAPTER 4: APPLICATION STEPS

First of all, factory was visited with project supervisor Başar Öğün. Manufacturing processes and production layout were observed at factory. After we had visited production facility, a meeting was conducted to give us information about whole process improvement. Problems in material requirements planning were discussed and how to solve them was considered. According to this meeting, tasks that we would deal with were determined. These are controlling forecast accuracy, estimating ratios in order to convert series forecasts into material forecasts, calculating Economic Order Quantity and Safety Stock Level. As a result of these studies, flow-process diagram related with our subject will be constituded.

The first step of our project is controlling forecast accuracy by using historical sales data. Actual sales data on series and channel basis and series forecasts were collected. Before starting other steps in project, we need to control forecast accuracy on series basis.

In competitve market, forecasting is an important activity for success in business life. Effective forecasting helps to balance demand and supply management in order to improve customer satisfaction.We decided to focus on time series forecasting for 6 series which is shown below.

2012 Actual Sales										
MVGT2	03	04	05	06	07	08	09	10	11	12
S50+	1.059	1.633	840	1.026	1.035	953	531	543	1.450	865
S50	654	1.332	664	658	674	555	1.021	451	261	153
Casa&Casa+	857	656	639	626	737	599	816	378	409	64
T4	258	336	312	284	413	236	317	186	197	20
Mira	51	25	73	180	181	121	94	114	96	15
Step	66	594	59	321	179	113	278	87	34	

Table 3 2012 Actual Sales

By analyzing historical sales data as input, we produced forecasts for last nine months through application of various methods including Winters Method and ARIMA. We decide to compare the forecast accuracy of these two simple methods.

We do not say that these are the best methods used for forecasting but these two methods are widely applied. We also consider MSE as best available measure of forecast accuracy so we compared MSE values of methods to decide most proper forecast values. With the purpose of choosing the most effective method, we utilized MINITAB.

As a first step, we applied time series analysis on actual sales on series basis. When we utilized MINITAB and MS Excel in order to observe behaviour of series, we observed that distribution of sales amounts for same periods in a year behaves similarly. For example, when we analyzed actual sales data of T4 series, sesonality can be observed. By sesonality, we mean periodic fluctuations

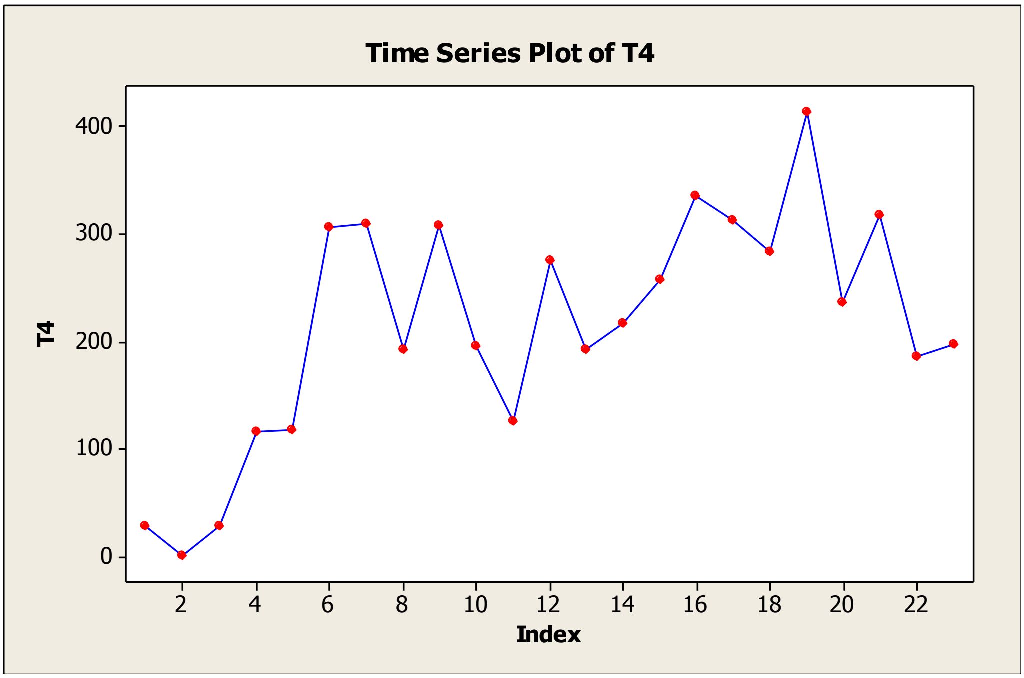

Figure 2 Time Series Analysis by using MINITAB

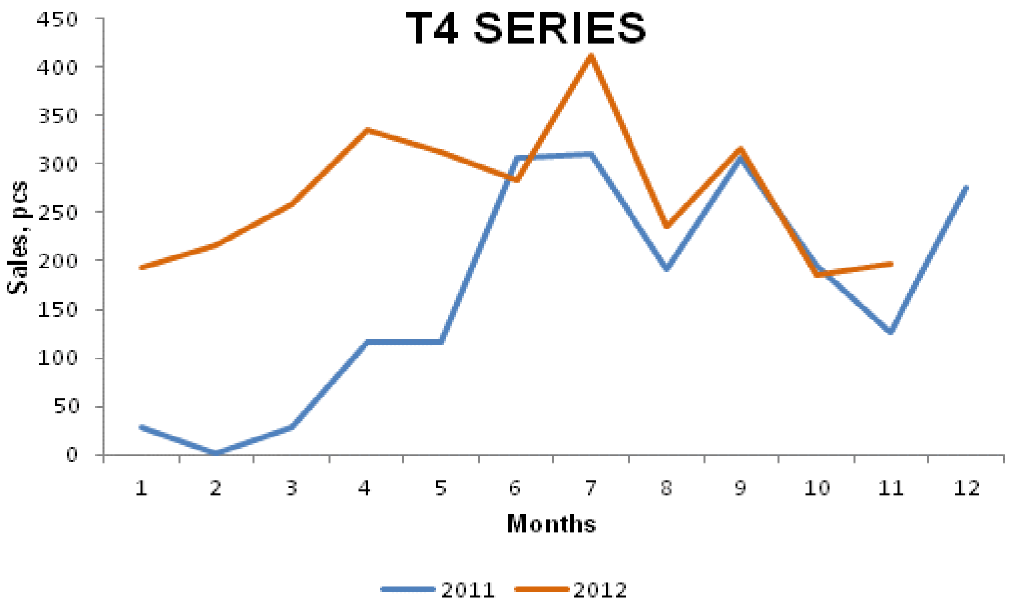

Figure 3 Monthly sales of T4 series in 2011 and 2012

We analyzed data in order to observe and interpret distributions of sales. Data were analyzed on series and materials basis by using Easyfit. We found the most proper distribution of series and materials. We implemented this step to obtain information about materials in series and to determination of sales forecasts of materials and comparing actual sales data with forecasts for each material. When we analyzed Casa Series in January 2011, the corresponding distributions in this series are Poisson, D.Uniform, Geometric and Neg. Binomial. The most proper distribution of Casa Series in January is Poisson Distribution. In January 2011, materials which constitute Casa Series distribute according to poisson distribution. Then we found mean, variance and standard deviation according the parameters in this distribution.

January 2011	POISSON	
mean	1,3846	λ
variance	1,3846	λ
std dev	1,176690274	$\lambda^{1/2}$

Table 4 Mean, variance and standard deviation values according to poisson distribution

Next step in our project is controlling forecast accuracy. Collected data include forecast values on series basis of previous nine months until December 2012, because the material planning specialist in company make forecast since March

2012. We were assumed to control forecast accuracy for this period by using MINITAB. Fit values were generated with ARIMA by considering all data we have for six series and we found predicted values for same period. We chose last nine values to be able to control forecast accuracy and compare Mean Absolute Error (MAE). We implemented this practice on series we focused on. The data of practice on S50+ are below.

S50+	Actual Sales	Arima Forecast	Given Forecast	eA	eF
March	783	457	713	326	70
April	1383	651	761	732	622
May	549	920	768	371	219
June	513	495	785	18	272
July	502	479	811	23	309
August	546	476	553	70	7
September	440	499	659	59	219
October	392	451	585	59	193
November	246	435	522	189	276
			MAE	185	219

Table 5 Comparing forecast accuracy of ARIMA with given forecast

As a result of calculations, we can say that predicted values generated with ARIMA provide less error. Therefore forecasting with ARIMA gives better results instead of current method used by company. Besides, we implemented Winters Method to control forecast accuracy.

When we had entered data to MINITAB, seasonal fluctuations were observed apparently. Furthermore, we have foreseen seasonality effect on sales according to our meetings with project team of company.In order to control whether forecasting with Winters Method is consistent or not, this method was implemented. We utilized MS Excel solver extension so as to calculate optimal α, β, γ values required for solution of winters method. Fits were computed for nine months.

Casa	Actual Sales	Winters Forecast	Given Forecast	eA	eF
March	660	322	661	338	1
April	593	548	672	45	79
May	398	618	643	220	245
June	434	626	662	192	228
July	485	714	714	229	229
August	405	705	483	300	78
September	647	554	537	93	110
October	269	568	542	299	273
November	189	514	456	325	267
			MAE	204	151

Table 6 Comparing forecast accuracy of Winters Method with given forecast

After computation, we compared MAE of Winters Method with MAE of actual forecasts.To sum up, we found out that error value computed for Winters Msethod is relatively high.Therefore, this method is not an effective way to generate forecasts when our data are considered.

Consequently, we have more accurate forecast values on series basis. In addition to series forecasts, material forecasts are required for next steps of the project .At this point, we computed index ratio in order to convert series forecast into material forecasts. We calculated sales amount of materials for each series by creating pivot table in MS Excel. For calculation index ratio we divided sales amount of material to total sales of series.We implemented this.

For example Mira series,

Actual sales data of :

Mira in March 2012 = 51 pcs

MVMRLAV120C2 in March 2012= 9 pcs

index =9/51= 0.18

In conclusion, we have been examining alternative methods in order to forecast on material basis. After specifying material requirements, remained steps will be completed. This research has thrown up many questions in need of further investigation. More broadly, these findings provide the following insights for future research determination of safety stock level and EOQ. Considerably more work will need to be done to determine these steps. The current study was unable to analyse these variables. For this purpose, we will collect data such as reorder levels, lead time, purchasing cost, ordering cost and holding cost from factory. Necessary data will be obtained and these calculations will be made.

4.1 ABC Analysis

Typically

- The top 20% of the items account for the 80% of the annual dollar value of sales
- The next 30% for the next 15% value of sales
- Remaining 50% for 5% value of sales

To use ABC analysis:

- Select criterion for ranking (for example I chose annual usage value)
- Rank items on basis of criterion
- Calculate cumulative percentages
- Set up classes around break points

There is an example of how to ouse ABC Analysis with ten materials at below;

Firstly the annual TL volume was calculated for each item and the items were listed in descending order based on annual dollar volume.

Item	Annual usage in units	Unit TL Value	Annual Usage (TL)	Rank
1	40.000	0,7	28.000	5
2	195.000	1,1	214.500	1
3	4.000	1,0	4.000	9
4	100.000	0,5	50.000	3
5	2.000	1,4	2.800	10
6	240.000	0,7	168.000	2
7	16.000	0,8	12.800	6
8	80.000	0,6	48.000	4
9	10.000	0,7	7.000	7
10	5.000	0,9	4.500	8

Table 7 ABC Analysis Calculation First Step

Then, the cumulative annual TL volume was calculated as a percentage of total TL and finally the items are classified into groups.

Rank	Item	Annual Usage (TL)	Cumulative TL Value	Cum % TL Value	Class
1	2	214.500	214.500	39,8%	**A**
2	6	168.000	382.500	70,9%	**A**
3	4	50.000	432.500	80,2%	**B**
4	8	48.000	480.500	89,0%	**B**
5	1	28.000	508.500	94,2%	**B**
6	7	12.800	521.300	96,6%	**C**
7	9	7.000	528.300	97,9%	**C**
8	10	4.500	532.800	98,7%	**C**
9	3	4.000	536.800	99,5%	**C**
10	5	2.800	539.600	100,0%	**C**

Table 8 ABC Analysis Calculation Second Step

Based on Pareto Law: 80-20 rule, roughly 80% of the effects come from 20% of the causes.When we apply ABC analysis to our material stock; the result is ;

	Annual Usage	USAGE UNITS	UNITS%	VALUE	% VALUE
A	X > 53000TL	327	11%	1.320,10	71%
B	20000TL < X < 53000TL	584	20%	364,123	20%
C	X< 20000TL	2059	69%	164,741	9%
TOTAL		2970	100%	1.848,96	100%

Table 9 ABC Analysis Result

- 71% of the inventory value is formed with just 11% of the whole parts.
- So we label the A category as critical

4.2 Inventory Model

The target is to find reorder levels for each product; that is, at which point we need to make the order.Then the question is; which inventory model could we apply to get the optimum reorder points that wil minimize our inventory level?

The model should cover the the uncertainity of the demand and We do not have a deterministic demand data type but it is stochastic. So; we should find a stochastic inventory model with safety stock.

The model will determine,

- an expected monthly demand for each product,
- a safety stock amount for each product (in order not to be stocked out),

and will add them up to get the targeted reorder point.

We have already know the demand history for the products and the lead time of the product. Also the service level determined by the manager.

4.2.1 Service Level

Service level is defined as the probability of not incurring a stockout during any one lead time.

The higher the probability inventory will be on hand, the more likely customer demand will be met.

- Up to this point, we have constructed our demand data sheet. Now, we need to determine the service levels.
- Service levels are assigned in a way that; the more critical material gets higher service level.

For example when mirror gets 95% (critical part), glass gets 85% (not critical)

4.2.2 Safety Stock and Reorder Point

The amount of safety stock to hold at each stage in a supply chain is an important problem for a manufacturing company that faces uncertain demand and needs to provide a high level of service to its customers. The amount of stock held should be small to minimize holding and storage costs while retaining the ability to serve customers on time and satisfy most, if not all, of the demand.

Safety stock is a term to describe a level of extra stock that is maintained to mitigate risk of stockouts (shortfall in raw material or packaging) due to uncertainties in supply and demand. Adequate safety stock levels permit business operations to proceed according to their plans. They serve as an insurance against stockouts.

Assumptions:

- Lead-time demand is normally distributed with mean μ and standard deviation s.
- Service level is defined in terms of the probability of no stockouts during lead time and is reflected in z.
- Shortages are not backordered.
- Inventory position is reviewed continuously.

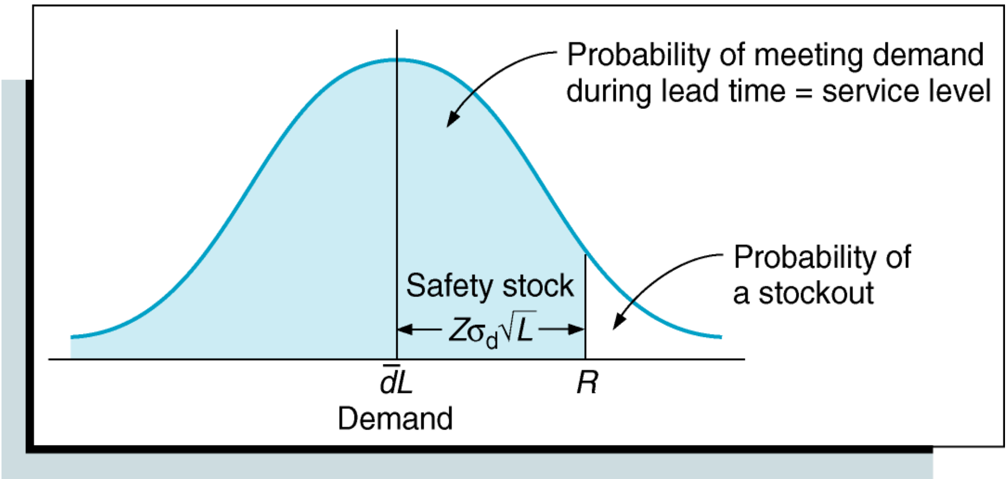

Figure 4 Normal Distribution

For calculating safety stock level and reorder point, the formula is:

$$R = \bar{d}L + Z\sigma_d\sqrt{L}$$

where:

R = reorder point

$\bar{d}$ = average daily demand

L = lead time

σ_d = the standard deviation of daily demand

Z = number of standard deviations corresponding to service level probability

$Z\sigma_d\sqrt{L}$ = safety stock

When calculating safety stock level and reorder point by using with MsExcel; formulas and a example at below;

	A	B	C	D	E	F	G	H	I	J
1	For one material (MVCAB36)									
2	Past							Forecasted		
3	01.11.2012	01.12.2012	01.01.2013	01.02.2013	01.03.2013	01.04.2013	01.05.2013	01.06.2013	01.07.2013	01.08.2013
4	38	48	98	51	50	47	46	35	20	27
5										
6	Lead Time (months)		3							
7	Service Level		0,9							
8										
9	Lead time demand:		82	Summing the forecasts				SUM(H4:L4)		
10	Standard Deviation:		19,857828	Deviation in the past sales				STDEV(A4:G4)		
11	Service factor:		1,2815516	Inverse of the normal distribution				NORMSINV(C7)		
12	Lead time factor:		1,7320508	Square root of lead-time to forecast ratio				SQRT(C6)		
13	Safety stock:		44,078668	Combining factors				C10*C11*C12		
14	**Reorder point:**		126,07867	Lead time demand + safety stock				C9+C13		

Table 10 Calculation of Safety Stock Level and Reorder Point by using MsExcel

Yet, two functions are noticeable:

- NORMSINV; estimates the cumulative normal distribution, noted cdf here above.
- STDEV; estimates standard deviation, noted σ here above. We recall that the standard deviation σ is the square root of the variance σ^2.

In conclusion, firstly forecast accuracy was controlled on serial basis, then series forecast convert into material forecasts.ABC analysis is implemented to the materials to find critical materials. Reorder point and safety stock level are calculated with an appropriate inventory model bu using Ms Excel.

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