# Revolutionary Modeling In Inventory Management Systems

Hamit Topuz, Arda Albayrak, Gamze Karslı

**Abstract**: Lubricant markets are becoming even more competitive and therefore companies are relentlessly striving to reduce the inventory running costs to lessen the company expenses at a reasonable level in order to remain competitive in this highly volatile environment. It helps the companies becoming profitable and thus business grow. In this study our main goal was to focus on imported commodities from other branches of the company. The goods imported, due to the Company Policy, are not manufactured in the country. We try to improve existing model and to adopt above mentioned goods for calculating the safety stock levels that the company, especially during high seasons, experiencing stock outs resulting inevitable business losses. We presented a cost model approximation. It is shown that the proposed model not only reduce substantial cost of inventory, but also help to meet the customer expectations without employing highly expensive sophisticated software tools and therefore, it substantially aims to increase customer service level too.

**Index Terms**: Lubricants, inventory, safety stock, imported commodities, modeling, competitive edge.

## 1 Scope and Content

The main purpose of this work is to reduce the stock holding cost at a minimum level. Because, total cost is simply defined as the sum of stock holding cost and ordering expenses. In order to manage stock inventory successfully, it is needed to find a balance between the costs and benefits of keeping stock. The costs of keeping stock include the expenses that have been spent for purchasing stocks as well as storage and insurance. The benefits include having enough stock in hand to meet the demand of customers at any time that is required.

## 2 Introduction

Inventory management is an important aspect in any successful business. It is the process of overseeing and controlling the flow of inventory units a business uses in the production or manufacture of goods for sale or distribution. Inventories are usually made up of a combination of goods, raw materials and finished products, and effective management of these items is essential to ensure optimum stock levels and to maximize the earning potential of the company. It also allows a business to prevent or mitigate any inventory-associated losses. Effective inventory management is important as not only is inventory one of the most valuable assets to a business; there is a direct link between inventory levels and company profits. Inventory represents an investment that is tied up until either the item is sold, or it is used in the production of another item that is sold. Businesses are reliant on having items in stock; otherwise customers will simply go to a competitor who can provide what they want. However, holding inventory in stock is not without costs – storage, insurance and maintenance all must be considered. When it comes to replenishing stock levels, most management plans seek to strike a balance between having enough units when required, and ensuring supplies are not overstocked.


- *Hamit Topuz, is currently in Department of Industrial Engineering, Maltepe University, Istanbul, Turkey. Tel: +90 216 626 10 50 E-mail: hamittopuz@maltepe.edu.tr*
- *Arda Albayrak is graduate student at Maştepe University in Industrial Engineering Department, İstanbuli Turkey.*
- *Gamze Karslı*


This is why having an inventory management system can be advantageous. There exist several Inventory Management software systems in the market. In this study, we decided to focus on the imported goods inventory optimization of a private company.

## 3 Literature Survey

Some Work in connection with Inventory Management for the last ten years has been found interesting follows. One of the leading works in Inventory Management has been done by Heck V. Guido [1] in performance measurement thereof. It made a first attempt to see what influence the use of ERP software has on inventory activities. This is follow by Kim Young [2] in Health Care System which investigated how to optimize the inventory in a service sector environment. Recently, Optimizing the Safety Inventory Cost under Target Service Level Constraints was done by Shivshoron, T. Cheton [3]. In 2013, a very interesting study in Optimization of Safety Stock Level in a Manufacturing Company which is a good work similar to our work by Çelik Özge [4]. More recently, a study was done by G. Land [5] conducted a research at Body & Fit in the field of forecasting and inventory management within a warehouse. A similar study made by L.F. Tratar [6] on minimizing inventory cost using safety stock concept. Also, H.A. Akkermans, Bogerd,P., Yucesan., van Wassenhove, L.N., [7] ,and Gupta and Kohli [8] , T. Wild [9] , R. Herrin [10] did studies on inventory management.

## 4 The Definition of the Study

As explained earlier a private company blending products are lubricants consisting of engine oil lubricants, industrial lubricants, marine lubricants, and some special highly technological lubricants. Some of lubricants that are not blended in company owned blending plant that they have a big market share in the Lubricant sector. It is therefore, to meet the customer demands those unblended products are imported from the other plants in Abroad. It is for this particular reason that the goods imported need to be kept in stock in order to answer the customer requirement on timely manner. The stock holding cost as in any other business branches is an creating a huge additional burden for the company which is a fact. Currently employed material management module, SAP is not well-fit in order to handle company operations. Often company lived problems in keeping reliable and dependable stock inventories especially during seasonal peak times.

Because of severely competition the company could not tolerate such stock outs. Therefore, our main task was to develop a new method that brings to company some improvements and not to live existing operational problems and to attain its highest performance level. Thus, sales data carefully analyzed and better and appropriate demand forecasting means should be made finally to determine sustainable the safety stock levels throughout.

## 5. Sales Data Analysis

Analyzing sales results is used to understand and improve of sales performance. Two statistical test namely "parametric test" and "non -parametric test " used . A normality test should be performed on a given data set to determine which of these tests is best fit. In this work search made for the data which produced a normal distribution. Fort this purpose, two test were made "Kolmogorov-Smirnov" and "Shapiro-Wilk". "Shapiro-Wilk" test is used when data is too large .Otherwise Kolmogorov-Smirnow case is used. Always a 95% confidence limit is used as required for normal distribution.

### 5.1 Kolmogorov Smirnov Test significant

The Kolmogorov-Smirnov (K-S) Test is used to test whether a random sample of data matches a given distribution (uniform, normal or Poisson). In principle, the (K-S) test samples are based on the comparison of the cumulative distribution function to the cumulative distribution function of the preset version. With this test it is possible to examine whether the data collected from a sample exhibits a normal distribution.

### 5.2 Shapiro-Wilk Test significant

The Shapiro-Wilk test uses continuous variable for normality distribution. The null hypothesis for this test is that the data are normally distributed. The Probability < w value listed in the output is the p-value. If alpha level is 0.05 and the p-value is less than 0.05, the data are normally distributed is rejected. If otherwise, the p-value is greater than 0.05, then it is not rejected.

### 5.3 Statistical Package for The Social Science (SPSS)

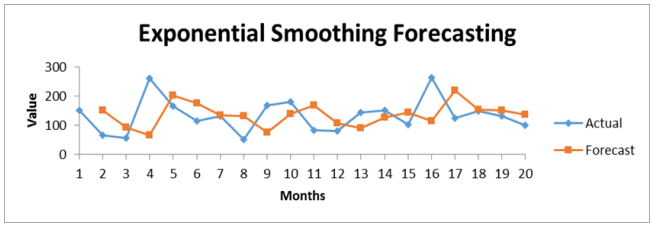
IBM-SPSS Software package 2015 version is used for logical batched and non-batched statistical analysis. Companion products in the same family are used for survey authoring and deployment (IBM SPSS Data Collection), data mining, text analytics, collaboration and deployment (batch and automated scoring services).

## 6 Forecasting Approach

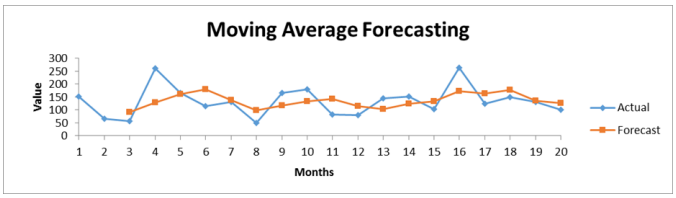
Qualitative Method used when situation is vague and little data exist. It generally uses new products and new technology. This method involves intuition and experience. Whereas, quantitative method used when situation is 'stable' and historical data exist. This generally uses existing products and current technology. Time Series Forecasting was also applied based only on past values. We assumed that factors influencing past and present will also continue influence in the future. Therefore, in order to see the distribution behaviors naive approach forecasting, moving averages forecasting, weighted moving average forecasting, and exponential smoothing forecasting. Forecasting accuracy was checked.

**Typical outcomes shown below:**

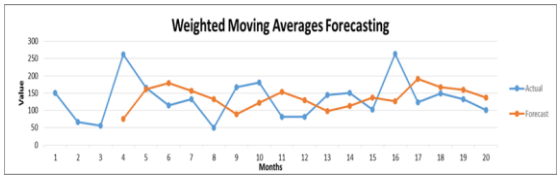
| Material => | 146374 | Forecast | Error | Absolute Error | Squared Error | Absolute % Error |
|---|---|---|---|---|---|---|
| Month 1 | 151 | #YOK | | | | |
| Month 2 | 66 | 151,00 | -85,00 | 85,00 | 7225,00 | 129% |
| Month 3 | 56 | 91,50 | -35,50 | 35,50 | 1260,25 | 63% |
| Month 4 | 262 | 66,65 | 195,35 | 195,35 | 38161,62 | 75% |
| Month 5 | 165 | 203,40 | -38,40 | 38,40 | 1474,18 | 23% |
| Month 6 | 115 | 176,52 | -61,52 | 61,52 | 3784,53 | 53% |
| Month 7 | 132 | 133,46 | -1,46 | 1,46 | 2,12 | 1% |
| Month 8 | 50 | 132,44 | -82,44 | 82,44 | 6795,80 | 165% |
| Month 9 | 167 | 74,73 | 92,27 | 92,27 | 8513,57 | 55% |
| Month 10 | 180 | 139,32 | 40,68 | 40,68 | 1654,92 | 23% |
| Month 11 | 82 | 167,80 | -85,80 | 85,80 | 7360,92 | 105% |
| Month 12 | 81 | 107,74 | -26,74 | 26,74 | 714,96 | 33% |
| Month 13 | 144 | 89,02 | 54,98 | 54,98 | 3022,62 | 38% |
| Month 14 | 151 | 127,51 | 23,49 | 23,49 | 551,95 | 16% |
| Month 15 | 103 | 143,95 | -40,95 | 40,95 | 1677,06 | 40% |
| Month 16 | 263 | 115,29 | 147,71 | 147,71 | 21819,55 | 56% |
| Month 17 | 124 | 218,69 | -94,69 | 94,69 | 8965,38 | 76% |
| Month 18 | 149 | 152,41 | -3,41 | 3,41 | 11,60 | 2% |
| Month 19 | 132 | 150,02 | -18,02 | 18,02 | 324,78 | 14% |
| Month 20 | 101 | 137,41 | -36,41 | 36,41 | 1325,43 | 36% |
| | | 112,00 | | 61,31 | 6034,01 | 53% |



| Material => | 146374 | Forecast | Error | Absolute Error | Squared Error | Absolute % Error |
|---|---|---|---|---|---|---|
| Month 1 | 151 | #YOK | | | | |
| Month 2 | 66 | #YOK | | | | |
| Month 3 | 56 | 91,00 | -35,00 | 35,00 | 1225,00 | 63% |
| Month 4 | 262 | 128,00 | 134,00 | 134,00 | 17956,00 | 51% |
| Month 5 | 165 | 161,00 | 4,00 | 4,00 | 16,00 | 2% |
| Month 6 | 115 | 180,67 | -65,67 | 65,67 | 4312,11 | 57% |
| Month 7 | 132 | 137,33 | -5,33 | 5,33 | 28,44 | 4% |
| Month 8 | 50 | 99,00 | -49,00 | 49,00 | 2401,00 | 98% |
| Month 9 | 167 | 116,33 | 50,67 | 50,67 | 2567,11 | 30% |
| Month 10 | 180 | 132,33 | 47,67 | 47,67 | 2272,11 | 26% |
| Month 11 | 82 | 143,00 | -61,00 | 61,00 | 3721,00 | 74% |
| Month 12 | 81 | 114,33 | -33,33 | 33,33 | 1111,11 | 41% |
| Month 13 | 144 | 102,33 | 41,67 | 41,67 | 1736,11 | 29% |
| Month 14 | 151 | 125,33 | 25,67 | 25,67 | 658,78 | 17% |
| Month 15 | 103 | 132,67 | -29,67 | 29,67 | 880,11 | 29% |
| Month 16 | 263 | 172,33 | 90,67 | 90,67 | 8220,44 | 34% |
| Month 17 | 124 | 163,33 | -39,33 | 39,33 | 1547,11 | 32% |
| Month 18 | 149 | 178,67 | -29,67 | 29,67 | 880,11 | 20% |
| Month 19 | 132 | 135,00 | -3,00 | 3,00 | 9,00 | 2% |
| Month 20 | 101 | 127,33 | -26,33 | 26,33 | 693,44 | 26% |
| | | 117,00 | | 42,87 | 2790,83 | 35% |




| Material => | 146374 | Forecast | Error | Absolute | Squared Er | Absolute % Error |
|---|---|---|---|---|---|---|
| Month 1 | 151 | #YOK | | | | |
| Month 2 | 66 | #YOK | | | | |
| Month 3 | 56 | #YOK | | | | |
| Month 4 | 262 | 75,17 | 186,83 | 186,83 | 34906,69 | 71% |
| Month 5 | 165 | 160,67 | 4,33 | 4,33 | 18,78 | 3% |
| Month 6 | 115 | 179,17 | -64,17 | 64,17 | 4117,36 | 56% |
| Month 7 | 132 | 156,17 | -24,17 | 24,17 | 584,03 | 18% |
| Month 8 | 50 | 131,83 | -81,83 | 81,83 | 6696,69 | 164% |
| Month 9 | 167 | 88,17 | 78,83 | 78,83 | 6214,69 | 47% |
| Month 10 | 180 | 122,17 | 57,83 | 57,83 | 3344,69 | 32% |
| Month 11 | 82 | 154,00 | -72,00 | 72,00 | 5184,00 | 88% |
| Month 12 | 81 | 128,83 | -47,83 | 47,83 | 2288,03 | 59% |
| Month 13 | 144 | 97,83 | 46,17 | 46,17 | 2131,36 | 32% |
| Month 14 | 151 | 112,67 | 38,33 | 38,33 | 1469,44 | 25% |
| Month 15 | 103 | 137,00 | -34,00 | 34,00 | 1156,00 | 33% |
| Month 16 | 263 | 125,83 | 137,17 | 137,17 | 18814,69 | 52% |
| Month 17 | 124 | 191,00 | -67,00 | 67,00 | 4489,00 | 54% |
| Month 18 | 149 | 166,83 | -17,83 | 17,83 | 318,03 | 12% |
| Month 19 | 132 | 159,67 | -27,67 | 27,67 | 765,44 | 21% |
| Month 20 | 101 | 136,33 | -35,33 | 35,33 | 1248,44 | 35% |
| | | 120,00 | | 60,08 | 5514,55 | 47,20% |




Among these forecasting methods, the method with the least percentage of errors was selected for each different product. For example for product 146374, we were selected Moving Average Forecasting method.

| Forecast | 112,00 | 117,00 | 120,00 | Forecast with min error |
|---|---|---|---|---|
| Error | 52,79% | 35,38% | 47,20% | 117,00 |

### 7 Calculation of Safety Stock Level

There is variable demand or lead time, safety stocks are required against stock-outs. Safety Stock level was calculated for each product. Standardize value of standard deviation was also calculated as the 95% confidence interval, while the safety stock was determined.

The Safety Stock Level formula given below was used.
Safety stock = z · dLT
For example for product 146374,

| Material => | Mon1 | Mon2 | Mon3 | Mon4 | Mon5 | Mon6 | Mon7 | Mon8 | Mon9 | Mon10 | Mon11 | Mon12 | Mon13 | Mon14 | Mon15 | Mon16 | Mon17 | Mon18 | Mon19 | Mon20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 146374 | 151 | 66 | 56 | 262 | 165 | 115 | 132 | 50 | 167 | 180 | 82 | 81 | 144 | 151 | 103 | 263 | 124 | 149 | 132 | 101 |

The safety stock is calculated as follows on MS excel sheet. In addition, the re-order point formula is given.

| | std monthly | std daily*(L^1/2) | z=1.96=~2(%95 service level) | |
|---|---|---|---|---|
| Safety Stock => | 56,51911181 | 12,6380576 | safety stock=(z*std daily*(L^1/2)) | 26,00 |

### 8 Calculation of Re-Order Point

The minimum stock level we hold. Re-order Point was calculated for all products. The Re -Order formula given.

Below was used.
R = α.*L* + Safety stock

For illustration for product 146374, re-order point is calculated on MS excel sheet. Also the re- order point formula is given.

| Reorder Point => | (d )* L + Safety stock | 232,00 |
|---|---|---|

### 9 Calculation of Economic Order Quantity – Current Method

Using below formula, the order amount is determined as it level with the re-order point, the EOQ requirement.

EOQ = $\sqrt{\frac{2 \cdot D \cdot S}{h}}$

For illustration for product coded 146374,

| | |
|---|---|
| Setup Cost | 21,96 $ |
| Holding Cost | 0,22 $ |

We calculated the EOQ requirement on Microsoft Exel Sheet as indicated in below.

| | |
|---|---|
| EOQ => | 168,00 |

## 10 Mathematical Modeling – A New Design

A mathematical model is an abstract model that uses mathematical language to describe the behavior of a system. A mathematical model was created for a product. The model is given below.

Decision Variables;
$x_i$: amount of order at month ith
$y_i$: 1 if ordered at month ith
0 otherwise
It: amount of stock at time t

**Parameters;**
ht: holding cost
si: setup cost
Dt: Demand at period t
L: Lead time of the product
Objective Function;
$Z = \sum x_i \cdot s_i + \sum h_t \cdot I_t$ (Minimizing total cost)

**Constraints:**

**1.Constraint of associating order quantity with order variable.**

$y_i <= M_1 \cdot x_i$
$x_i <= M_2 \cdot y_i$

**2.Constraint of determine the amount of inventory on hand.**

I0 – D0 = I1
I1 + x0 – D1 = I2
I2 + x1 – D2 = I3

**3.Constraint of minimum inventory amount.**

I1 <= Safety Stock
I2 <= Safety Stock
I3 <= Reorder Point

**4.Constraint of minimum order size.**

$x_i <= L \cdot y_i$

**Excel Solver of the Model:**

| On hand inventory (grand total) |
|---|
| 583 |

| | |
|---|---|
| Reorder Point => | 232 |
| Safety Stock => | 26 |
| Min Lot Size => | 24 |
| Max Lot Size | 648 |
| Lead Time => | 46 |
| setup cost | 21,44 $ |
| holding cost | 0,21 $ |

| x0 | x1 | x2 | | | | |
|---|---|---|---|---|---|---|
| 0 | 76 | 0 | | | | |
| y0 | y1 | y2 | | | | |
| 0 | 1 | 0 | | | | |
| I0 | I1 | I2 | I3 | | | |
| 583 | 365 | 223 | 232 | | | |
| D0 | D1 | D2 | | | | |
| 218 | 142 | 67 | | | | |
| M01 | M11 | M21 | | | | |
| 1 | 1 | 1 | | | | |
| M02 | M12 | M22 | | | | |
| 648 | 648 | 648 | | | | |
| I0+I1/2 | I1+I2+x0/2 | I2+I3+x1/2 | | | | |
| 474 | 294 | 265,5 | | | | |
| | | | Z(min cost) | | | |
| | | | 1.851,21 $ | | | |

| left hand side | right hand side | Constraints |
|---|---|---|
| 583 | 583 | I0=583 |
| 218 | 218 | I0-I1=D0 |
| 142 | 142 | I1+x0-I2=D1 |
| 67 | 67 | I2+x1-I3=D2 |
| 365 | 26 | I1>=safety |
| 223 | 26 | I2>=safety |
| 232 | 232 | I3>=last inventory |
| 0 | 0 | y0<=M01*x0 |
| -75 | 0 | y1<=M11*x1 |
| 0 | 0 | y2<=M21*x2 |
| 0 | 0 | M02*y0>=x0 |
| 572 | 0 | M12*y1>=x1 |
| 0 | 0 | M22*y2>=x2 |
| 0 | 0 | x0>=L*y0 |
| 30 | 0 | x1>=L*y1 |
| 0 | 0 | x2>=L*y2 |

## 11 Comparisons of EOQ and New Mathematical Modeling

Two methods were compared for the selected product. The cost saving of the first method was approximately 45 % and the cost saving of the second method was approximately 60 %. And therefore the second method was even more economical by 15 %. EOQ Method: We assumed that the demands are linearly decreasing in this method. Easier and more practical to implement by companies. However it needs to be checked month by month. Mathematical Model: This method can be used in situations where the demand is both linearly and non-linearly decreasing. Longer periods of forecasting are preferable. This model should be adapted for each product. It is somewhat difficult for the companies to implement. If so, this method is more profitable and more preferable. Because parameters can be changed in connection with the conditions.

## 12 Conclusion

As a result, our new inventory approach can be used by all concerns. Having the right stock in the right time leads to many advantages for companies. These advantages are annual increased sales, meeting the customer demands, creating new customers, increased and boost customer confidence, improved cash flow, and new investments. There are also different software programs for inventory calculation. But, these software's add additional cost to the companies. As the purposed new design uses Microsoft Office tools, it does not add additional cost as much as other software programs to the user. Therefore, this new design can be preferred by the companies. In addition, this new approach can reduce a substantial cost saving in inventories which is around 45% to 60% respectively.

## 13 Nomenclature

$F_t$: Forecast at time t
$D_t$: Demand at time t
C: Total annual cycle-inventory cost
Q: Lot size
H: Holding cost per unit per year
D: Annual demand
S: Ordering or costs per unit
z: Standardize value of standard deviation to achieve the cycle-service level
dLT : Stand deviation of demand during lead time Average weekly (or daily or monthly) demand

σLT : Standard deviation of the lead time
σd : Standard deviation of weekly (or daily or monthly) demand
L : Average lead time
df : Data frequency

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