INVENTORY MANAGEMENT

DATA WARRIORS

Contents

1. INTRODUCTION

The problem statement is related to the supervision of non-capitalized assets (**inventory**) and stock items. We are given the case of Thomson and Cook Hospital in which the hospital is facing challenges in Inventory Management of its medicines. It has three categories of medicines namely Type A (life saving or emergency medicines), Type B (ordinary medicines) and Type C (special and expensive medicines). The problem statement consists of two parts.

We are given some information about the three types of medicines summarizing the average annual demand, average unit price, average lead time, standard deviation of lead time, constant safety stock and purchasing cost per unit. There are three tasks at hand:

- Data driven approach which will justify whether a constant safety stock should be used or not.
- Forecasting the demand of Type A medicine for next 4 months.
- Calculating EOQ, The number of orders per year, Reorder level, The total annual ordering and carrying costs, Maximum Inventory level for "Type A" medicine. This helps to manage the uncertainty of demand of medicines and lead time to receive medicines from suppliers.

This study helps to:

- Reduce material maintenance cost and helps to improve supply chain management.
- Avoid excess safety stock.

The idea of constant safety stock is eliminated and a module is designed for Type A medicines which focuses to maintain a minimal amount of safety stock to reduce inventory carrying cost and manage the out-of-stock situation by ordering medicines from vendors at higher cost in emergency. To simulate this, we are given a table for the alternatives for the three types of medicines summarizing information about Lead time and Average purchasing cost per unit for the vendors who are given order in emergency. We then try to simulate various possible scenarios and predict a tradeoff between Risk vs Money.

We have been also provided with the data of monthly consumption of Type A medicine for the three consecutive years (2015-2017).

2. SAFETY STOCK

2.1. What is safety stock?

Safety Stock is an additional quantity of an item held in inventory in order to reduce the risk that the item will be out of stock. Safety stock acts as a buffer in case the sales of an item are greater than planned and/or the supplier is unable to deliver additional units at the expected time.

2.2. Constant or Variable?

We have been supplied with data of Thomson and Cook Hospital regarding the 3 years Average Annual Demand of three different kinds of medicines. We can clearly observe that the demand of medicines is not constant for each month in this three year period. Hence, it is quite logical not to maintain a constant safety stock. Also, there is no scope of keeping infinite safety stock, due to both excessive cost and lack of space.

In fact, the amount of safety stock has a direct impact on the total cost (it is a linear dependency). Therefore, the approach should be to find an optimum solution, keeping in mind the need of satisfactory customer service as well as minimizing the holding cost of safety stock.

For this, maintaining a variable safety stock based on predicted demand for each month is an efficient way of making both ends meet.

NO, maintaining a constant safety stock is not justifiable.

2.3. Data Analytics Driven Approach

A data analytics driven approach would be to calculate the holding cost required for safety stock in the two cases – maintaining a constant safety stock and maintaining a variable safety stock – and then comparing them to decide the more efficient method.

2.3.1. Constant Safety Stock Case

The given amount of Constant Safety Stock is 854.8 units and the additional holding cost / inventory carrying cost for all the types of medicines is 10 percent of unit price per year (considering expiry, storage, refrigeration, security, damage, etc.)

For type A medicine, that will be 20 INR since given unit price is 200 INR.

So, Total Cost = (854.8 * 20) INR = **17,096 INR**

2.3.2. Variable Safety Stock Case

For this case, we will use the following formula to calculate the Safety stock needed each month based on the data of previous years:

$$SS = Z * D_m * \sigma_{L.T.} \qquad (*)$$

where we have the following notations :

SS = Safety stock to be calculated

Z = Customer service level

$\sigma_{L.T.}$ = Variance of Lead Time

D_m = Monthly Demand

Z (Customer Service Level) is a factor we have used, which takes into the account the level of satisfactory service that is being provided to the customers.

In the reference the D is mentioned as annual average demand, and the approach to calculate a constant safety stock for the whole year, we modified the formula and calculated the monthly safety stock value.

If we back calculate the values of service level using the given values of constant safety stock the values are as follows:

TYPE OF MEDICINE	A	B	C
SERVICE LEVEL	99%	100%	83%

An "x%" value of **Z** indicates that (100-x) times out of 100, the customers receive their orders on time. Thus, a Z-value of 100% indicates perfect service.

Ideally, Type A medicines should have had a Z-value of **100%** since they are for emergency use. However, the higher holding cost leads to this value slightly decreasing to **99%**. For Type B medicines, the high demand paired with lower holding cost ensures a Z-value of **100%**. Type C medicines are rare and expensive. So, a lower demand and no need of emergency service means that a Z-value of 83% is good enough.

Thus, we can calculate the required amount of Safety Stock to be maintained in each month using the aforementioned formula. For obvious reasons, for some months, the value of SS will come out as less than that in the constant case. This will help in attaining the optimal solution of minimizing the cost as well as providing sufficient level of customer service.

On calculation, the resultant average yearly value is **15,386.30 INR**

2.3.3. Conclusion

The Yearly Average in case of Constant Safety Stock is 17,096 INR while in the case of Variable Safety Stock is 15,386.30 INR. The Constant Safety Stock has a higher value.
This justifies our decision not to keep a constant safety stock.

3. FORECASTING

3.1. Holt-Winters Multiplicative Method

The Holt-Winters seasonal method comprises the forecast equation and three smoothing equations — one for the level l_t, one for the trend b_t,and one for the seasonal component s_t ,with corresponding smoothing parameters **α, β, and γ**. Here m is used to denote the frequency of the seasonality, i.e., the number of seasons in a year. For monthly data m=12.

3.1.1. Overview

In this model, we assume that the time series is represented by the equation

$$y_t = b_1 + b_t + S_t + \epsilon_t$$

Where
b_1 is the base signal also called the *permanent component*
b_t is the linear trend component
S_t is the multiplicative seasonal factor
ϵ_t is the random error component

3.1.2. Multiplicative Seasonal Model

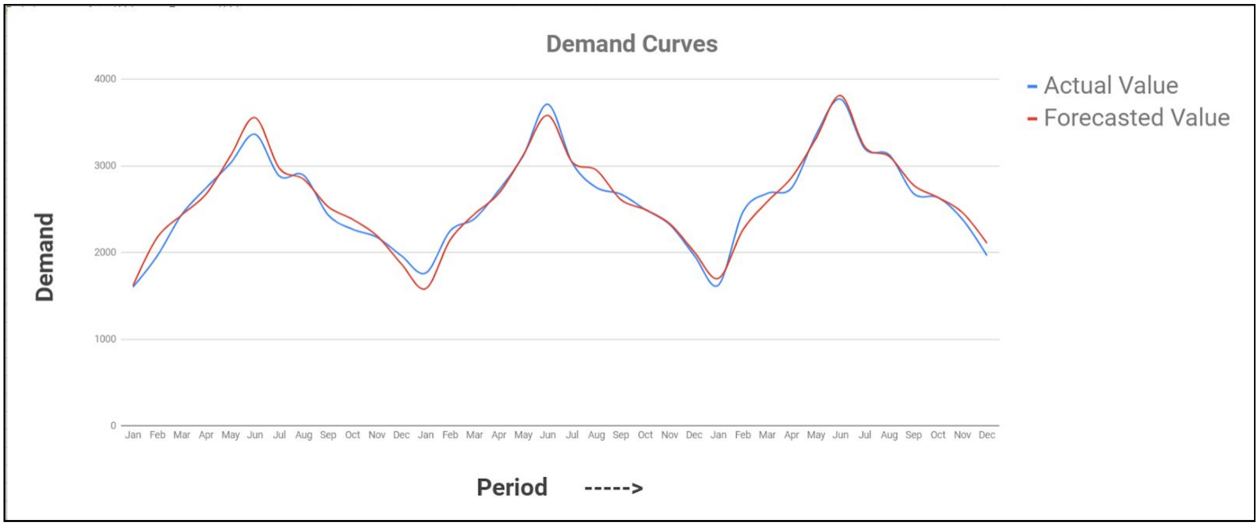
This model is used when the data exhibits Multiplicative seasonality.
In multiplicative method, the seasonal component is expressed in relative terms (percentages), and the series is seasonally adjusted by dividing through by the seasonal component.

The component form for the multiplicative method is:

$$y_{t+h|t} = (l_t + hb_t)\, S_{t+h-m(k+1)}$$
$$l_t = \alpha * (y_t / S_{t-m}) + (1-\alpha) * (l_{t-1} + b_{t-1})$$

$$b_t = \beta * (l_t - l_{t-1}) + (1-\beta) * b_{t-1}$$
$$S_t = \gamma * [\, y_t / (l_{t-1} + b_{t-1})] + (1-\gamma) * S_{t-m}$$

After fitting the model on type A medicine dataset and plotting the forecasted values with original :



The graph above shows that the fitted values differ very less compared to original values which shows the robustness of the model.
The error came out to be 2.88 % on type A training dataset. Here , the error used for measure of accuracy is Mean Absolute Error.

3.2. Forecasted values of 4 months

The predicted values for next 4 months for the type A medicines for the year 2018 are as follows :

Month	Forecasted Value
January	1765
February	2349
March	2639

April	2882

4. INVENTORY MANAGEMENT PARAMETERS

Using the data of monthly consumption of Type A medicine for the last three consecutive years (2015-2017), we have predicted the Inventory management Parameters for the **next year** (2018).

4.1. Economic Order Quantity [EOQ]

It is the ideal order quantity a company should purchase for its inventory given a set cost of production, demand rate and other variables.

$$\textbf{EOQ} = \sqrt{(2 * S * D)/(H)}$$

D - Yearly Demand
S - Average Cost per Order
H - Holding Cost per Unit

Since, the average cost per order is not given, we calculated it using daily average demand and cost per unit.

EOQ = 1104.10 $\approx$ 1105 Units per Order

4.2. Number of orders per year

The orders per year would be the number of times EOQ (Quantity for minimal inventory cost) is ordered to fulfill the annual demand.

Number of orders per year = Annual Demand / EOQ = 29.47 $\approx$ 30 Orders per year

4.3. Reorder level

Reorder level (or reorder point) is the inventory level at which a company would place a new order or start a new manufacturing run.

Reorder Level = Lead Time in Days × Daily Average Usage + Average Safety Stock

Where ,

Lead Time in Days = 10 Days

Daily Average Usage = Average Annual Demand / Total number of days = 85.47 Units

Average Safety Stock = 768.98 Units

Reorder Level = 1623.77 ≈ 1623 Units

Since, we want to be on the safe side of Reorder Level we round down the calculated value.

4.4. Total Annual Ordering and Carrying Costs

Total ordering costs: Cost involved in placing an order or setting up the equipment to make the product.

Annual ordering cost = Yearly Demand x Ordering Cost per Unit = 1,36,703.74 INR

Carrying costs: It is the cost which includes storage, expiry, refrigeration, security, damage.

Annual Carrying Cost = Yearly Demand x Holding cost per unit per year = 6,50,970 INR

4.5. Maximum Inventory Level

The maximum stock level is a not-to-exceed amount used for inventory planning. This stock level is based on a calculation of the cost of storage, standard order quantities, and the risk of inventory becoming obsolete or spoiling with the passage of time.

Maximum Inventory Level = Maximum Safety Stock + EOQ

$= \ 2236.6 \approx 2237$ Units

5. Risk Management

5. 1. Notations used

Let the additional demand in out-of-stock situation be denoted by D_i,
S be the safety stock,
p_i be the Probability of D_i given that out-of-stock situation has occurred,
p_o be the Probability that out-of-stock situation occurs,
p_{no} be the Probability that out-of-stock situation does not occur,
C_h be the holding cost per unit,
C_t be the total cost of buying one unit of "Type A" medicine,
C_b be the total loss in business,
ETAC be the expected total additional cost,
EAVC be the expected additional vendor cost.

5.2. Assumptions Taken

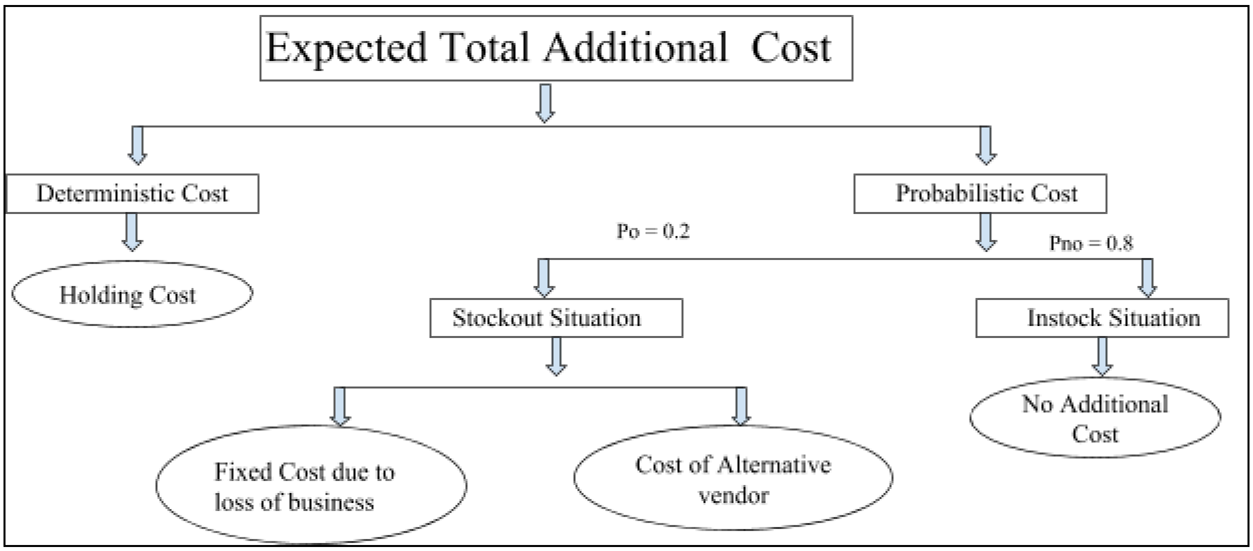
- In order to relate the value of total expected additional cost (it incorporates the cost of additional demand over the forecasted value) with the risk, there are multiple scenarios, but in order to reduce the complexity of the model, we have taken n discrete scenarios having additional demand Di with a probability p_i .
- $\mathbf{p_i > p_{i+1}}$ $\forall$ i ε {1,2,3......,n-1} which signifies that when the additional demand in out-of-stock situation (D_i) is less , probability of its occurrence is more.
- $\Sigma\ \mathbf{p_i = 1}$ $\forall$ i ε {1,2,3……..,n}
- The Probability that the out-of-stock situation occurs is considered to be p_0.

5.3. Simulation

We are simulating the conditions of finite no. of out of stock situations considering a probabilistic model and studying how the total expected cost varies as we vary the amount of safety stock which we keep or in other words how much risk we are willing to take. Formula for Expected Total Additional Cost (ETAC) is given below:

$$\boxed{\textbf{ETAC = Deterministic Cost + Probabilistic Cost}}$$

So, We can further break up the Deterministic Cost and Probabilistic Cost as shown below:



1. **Deterministic Cost:**

   The cost of holding the safety stock is permanent whether or not an out of stock situation occurs, hence it is always deterministic given a value of S. The Formula for the holding cost for the safety stock is given below:

$$\boxed{\textbf{Deterministic Cost = Total holding cost} = \mathbf{S * C_h}}$$

2. **Probabilistic Cost:**

   The costs under this category is defined as probabilistic because its occurrence depends on a probabilistic event i.e whether or not out of stock condition appears.

2.1 In stock situation:

It is clear that when the out-of-stock situation does not occur, there is no additional cost, as we have sufficient inventory level to handle the demand. It's probability is assumed to be 0.8.

2.2 Out of stock situation:

- **Loss of Business Cost:**
  The fixed cost which will be incurred due to the loss of business with the occurrence of an stockout condition. It is denoted by C_b.

- **Expected Alternative vendor Cost:**
  This cost depends on the amount of additional demands in case of an out of stock situation. As explained earlier, we have simulated a finite set of situations where the additional demands are D_i with a probability of p_i **.** The formula for the expected alternative vendor Cost(EAVC) is given below:

$$\mathbf{EAVC = \Sigma\, p_i * \max\{0,(D_i - S)\} * C_t \quad where\ \Sigma\ is\ \forall\ i\ \varepsilon\ \{1,2..n\}}$$

And hence the total probabilistic cost is given by the equation:

$$\mathbf{Probabilistic\ Cost = P_0 * (C_b + EAVC) + P_{no} * (0)}$$

5.4. Investigation

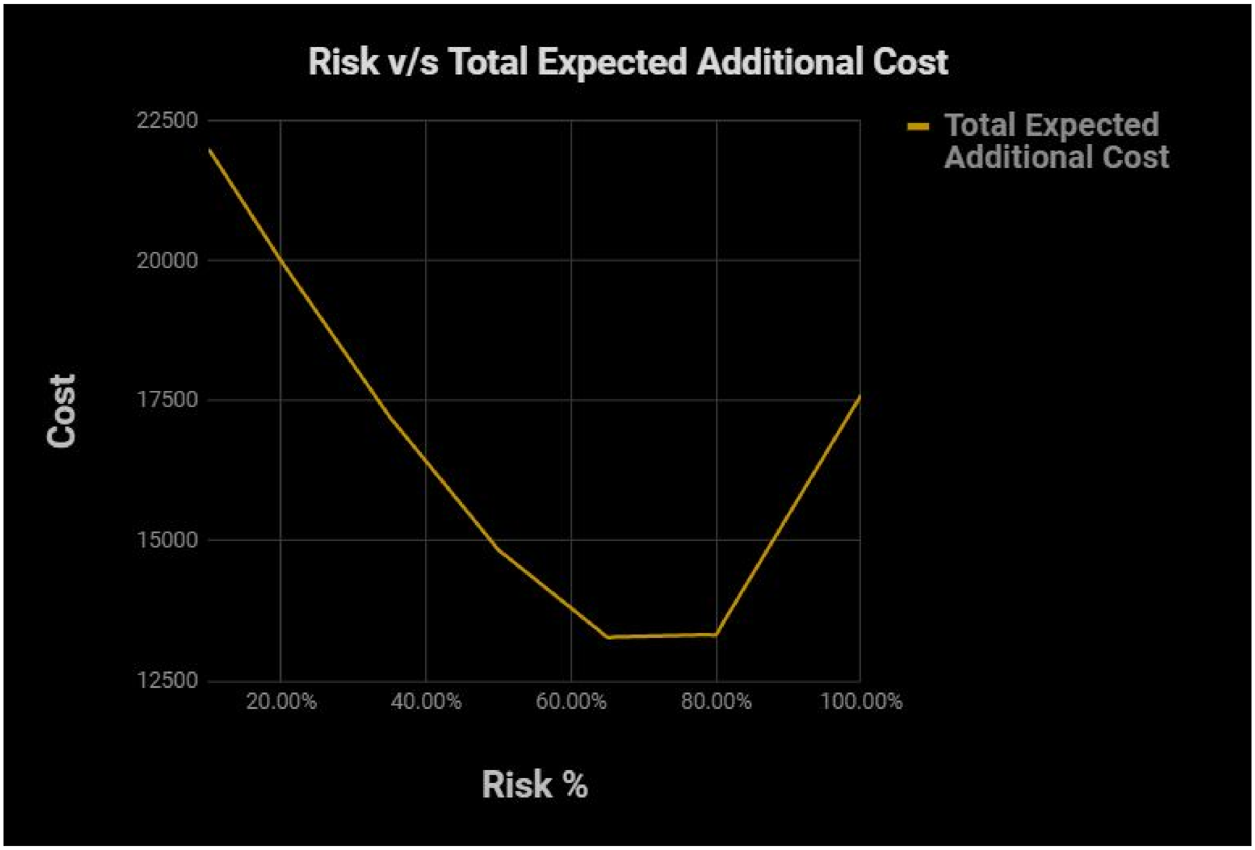
From the simulation done above , we observe that Risk is **negatively correlated** related to the Safety Stock . When the value of Safety Stock is maximum , we have to take a minimum risk whose value is assumed to be β and when the value of Safety Stock is nearly zero , then we have an additional risk of $\alpha(assumed)$ as compared to its value when the Safety Stock is maximum. Thereby Risk can be formulated as (where $\alpha , \beta > 0$)

$$\boxed{\textbf{Risk} = \frac{Smax - S}{Smax} * \alpha + \beta}$$

As we can see from the graph that the Deterministic Cost is increasing with increasing value of safety stock while the Probabilistic Cost is decreasing with increasing value of safety stock. As the Total Expected Additional Cost (ETAC) is the sum of Deterministic Cost and Probabilistic Cost , the value of the Total Expected Additional Cost (ETAC) first decreases and then increases.So, we get a minimum value of Total Expected Additional Cost (ETAC) in the mid-range value of Safety Stock. Using this model , the optimal value of Safety Stock when the Total Expected Additional Cost (ETAC) is minimum is **350**.

5.4. Conclusion

From the graph of Total Expected Additional Cost (ETAC) vs Risk % , we see that the optimal risk % is **65%.**



From the perspective of a Hospital Manager who is a high risk taker , it is advisable that taking lower risk or a higher risk increases the Total Expected Additional Cost (ETAC) , thus an optimal value of Risk should be taken which reduces the ETAC to a minimum. Thus we get a trade-off between Risk and Money i.e. a balance is obtained between the Risk and Money as we take different levels of Risk.

6. References

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