International Journal of Applied Engineering Research
ISSN 0973-4562 Volume 10, Number 11 (2015) pp. 30071-30082

http://www.ripublication.com

Criticality Analysis and Inventory Cost Reduction For High-Value, High Volume Spares

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Abstract

For the smooth functioning of any company, implementation of proper inventory analysis is very critical. Out of different inventories, spare part inventory is one among the major that has to be properly monitored. By the implementation of proper criticality analysis, inventory for spares can be managed to an extent. A case study was carried out in a fertilizer manufacturing company and different analysis like FSN, VED and ABC were carried out for each spare part. Total inventory cost was obtained with two different models, current company model and a revised EOQ based proposed model. Proper safety stock, ROL and lead time demand were obtained for each item which avoids overstocking and stock outs. Finally a reduction in the total inventory cost is obtained with the EOQ based proposed model.

Key words: Inventory of spares, FSN analysis, VED analysis, ABC analysis, Safety stock, Annual consumption, EOQ

Introduction

Inventory can be defined as the current stock,work-in-process goods, raw materials, spares etc.that are considered to be the asset of a company property that are ready or will be ready to use. For the proper functioning of the company it is critical to implement a proper inventory policy. Inventory in a manufacturing company can be mainly classifiedinto 4 types, which are General Stores (Indigenous and Imports), Spares (Indigenous and Imports), Packing Materials and Raw Materials. Minimum stock and staggered delivery policy is followed for packing materials compare to other inventories. However, specific inventory control policies shall be followed for raw materials because of the constraints by way of shipping schedules, storage space,

handling and complexities of transportation. Each type of inventory has its own peculiarity and hence has to be treated differently.

Selective control of inventory shall be done by various types of analysis. As each classification emphasize on a particular aspect, e.g. ABC analysis emphasize annual usage value, VED analysis consider criticality and FSN classification consider consumption pattern, it may also be advantageous to use more than one criterion in conjunction, e.g. ABC and VED analysis may be used for spares, XYZ and FSN analysis may be used to reduce the stock of surplus/obsolete items. Since the ultimate aim of all the inventory policies is to reduce the total inventory cost, it is essential to consider different constrains like lead time, safety stock, and lot size to be ordered, ROL etc. By keeping proper safety stock we can avoid stock outs and over stocking. Implementation of EOQ model is considered to be the best option to reduce the total inventory cost. However many companies are now implementing JIT purchasing for controlling inventory, but JIT is only applicable to those companies which has less fluctuating demands, and the constrains for JIT compared to EOQ is higher.

Literature Review

S.G. Li and X. Kuo[1]has conducted a study on inventory management for spare parts in automotive industry which has centralised stores department. The production rate can be increased and the total cost for production can be minimised through Proper management of spare parts inventory. Matteo Kalchschmidt et al[2] explains that the major issue for maintaining the inventory occurs due to the fluctuation in demand and the un certainty. Eric Porras and Rommert Dekker[3] conducted a case study for spare parts inventory system in a refinery. They say that proper inventory analysis is so important in all companies so as to keep a necessary safety stock to avoid over stocking and unnecessary holding costs. Spare parts inventory are maintained as a backup for maintenance process or a sudden failure of machinery. Whereas work in process inventory or finished goods inventory are maintained to full fill the customer need. The major challenge in maintaining the inventory is keeping non-moving or slow moving components which are very critical in need items. H. Wong et al[4] has conducted a study on multi-echelon spare part system. He had attempted for reducing the total inventory cost through an optimization method. Also explains about the need of keeping proper safety stock and minimization of holing cost for each item.

T.P.Khanhet al[5] Suggests about the effect of maintaining the equipments in spare parts inventory. Proper maintenance is so critical for the maximum utilization of the equipment and smooth production process. Equipment breakdown has to be avoided in order to maintain a steady production rate. It also reduces the energy losses and the total revenue. The paper also discusses about the spare parts that can be repaired and those that have to be replaced based on their age. Hartanto Wong et al[6] has conducted a study on inventory pooling. Pooling is the inter exchange of inventory between different companies or different divisionswithin a company which are separated by geographical distance. Using this method the inventory level can be decreased in large scales and in present scenario pooling can be done with less effort

because of high technological and transportation developments. W.J. Kennedy et al[7] has done a literature survey on spare parts inventory and they have discussed about different papers regarding this. Finished goods inventory are maintained as a safety to full fill the lead time demand, labour issues, quality, cost etc.whereas spare parts inventory is stored so as to avoid interruptions at the production sector.

An Molenaers et al[8] has conducted a case study in a petrochemical company based on the criticality of spare parts. AHP is the tool that they have used for the analysis. Risk factors, failures, maintained, suppliers, replenishment time, technology etc are considered as different factors to determine the criticality criteria of equipment. A similar analysis based on AHP was done by Prem Prakash Gajpalet al[9] in a manufacturing company. Vaisakh P. S et al[10] has done an analysis for spare parts based on combined FSN,VED analysis. FSN analysis is done based on the consumption figure in order to obtain the movement of the spare parts from the store. In VED analysis, Vital Spares are those whose non-availability results in very high production downtime losses. Essential spares are those whose non-availability is expected to cause moderate production downtime losses and desirable items are those whose non-availability does not result in any significant production downtime loss. Criticality analysis of the equipment/spares shall be undertaken in order to classify them as V, E or D, by evaluating their criticality according to the following factors and weight-ages such as utilization of the equipment, its availability, age, ease of repair, maintenance etc. Maj Sushil Kumar and Brig A. Chakravarty[11] has conducted a case study based on ABC an VED analysis. The study was conducted in a hospital. In ABC the classification is done base on the annual usage or based on the demand value for each items. ABC analysis refers that 80 percentage of the demand value can be full filled by major 20 percentage of the inventory that the company possess.

In 1913 a production engineer named Ford W. Harris[12] is the first person who developed a detailed EOQ model and in 1931 raymond[13] published the first text book on inventory management. Harris had mentioned that the major crisis that a manufacturer facing is at the time of placing an order. The quantity to be ordered has to be found out accurately. He has clearly represented the concept of EOQ mathematically and graphically. Kun-Jen Chung et al[14]has developed a proper solution methodology for EOQ model with a constant stock out cost. He explains that obtaining the optimal stock out level and lot size is also critical. He has clearly represented the EOQ model mathematically. L.A.San Jose et al[15] , [16] has written a similar paper based on EOQ. They have mentioned that the total inventory cost is the summation of holing cost and carrying cost. He has considered different assumptions in his modelthat are, the system demand should be steady and known, should possess a fixed ordering cost, stock outs are allowed in the model where the cost is not constant etc. Hoon Jung and Cerry M. Klein[17] has developed EOQ models for increasing the profit based on various cost function. The cost functions are, replenishment should be direct,stock out are not possible and lot to be ordered should be done in batch. Wu Min and Low Sui Pheng[18], [19] has discussed about the effect of implementation of JIT instead of EOQ in many companies. It also refers

the limitations, constraints and the advantages of JIT. JIT can be considered as the best option where the demand deviations are predictable.

Case study

A case study was carried out in a multi-division chemical fertilizer manufacturing company. A systematic inventory control is done for the reduction in inventory cost for spares. Company has three manufacturing divisions separated by geographical distance and each division has their own department for stores. The stores department of operating division is responsible for the collection and receiving of materials purchased. Coordinating of materials and codification are also performed for the easiness in selecting the materials. Timely inspection is being done by vigilance department. Present inventory management strategies are found to be ineffective in control of spares. The major difficulty faced during the inventory management is the redundancy of spare parts. By conducting a survey it was found that the inventory cost for spare parts is highly increasing for the last 10 years as shown in Figure 1. The required data for the analysis were taken from the stores department. 790 spare partswere selected for the case study, which includes different set of bearings, various classes of gaskets, numerous grades of welding electrodes, variety of fasteners etc. The selected components are then tabulated based on the identification parameters of items such as material code, material description, current stock level, price and yearlyconsumption. Criticality analysis is performed for understanding the necessity of each item. Total inventory cost is obtained using two different models, the current company model and a new proposed model. Cost reduction for spares were done using an EOQ based proposed model.

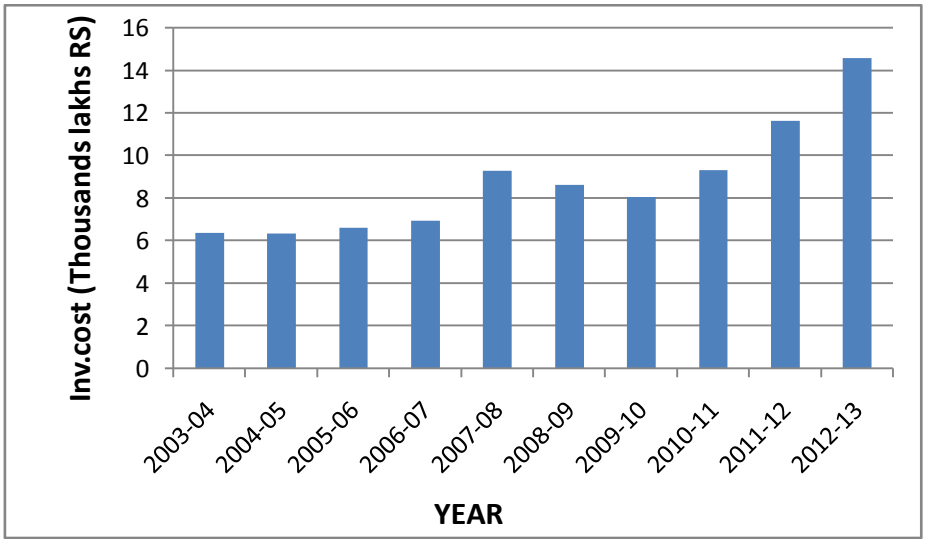

Figure 1: Total inventory cost for last ten years

Solution methodology

Initially the criticality analysis was done for the data collected. As shown in Figure 2FSN analysis was conducted first and those non-moving items were removed from

the data set. With the revised data set VED analysis was carried out. Finally the non-moving items and those items having empty stock were removed from the data set and ABC analysis was conducted. Safety stock value for each spares were obtained based on VED and ABC combined analysis. Then the inventory cost for spares were calculated based on the current company inventory model. Finally reduced inventory cost is obtained using an EOQ based proposed model. Safety stock, ROL, annual consumption and the lead time demand for each item were also obtained.

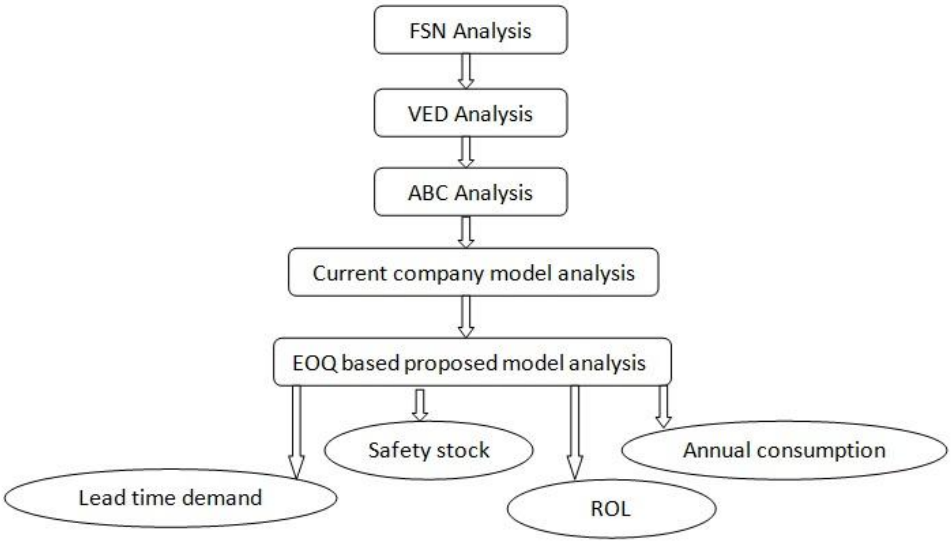

Figure 2: flow chart representing the solution methodology

Criticality analysis

FSN analysis

A data set of 790 spare parts items, which includes different set of bearings, various classes of gaskets, numerous grades of welding electrodes, variety of fasteners etc. were selected. The selected components are then tabulated based on the identification parameters of items such as material code, material description, current stock level, price and yearly consumption. F-S-N analysis was done based on consumption figures of the items. If more than 24 items are moved within the last two years can be classified as Fast moving (F), and those less than 24 in last two years can be classified as Slow-moving (S) and those not moved within last 2 years as Non-moving (N).

VED analysis

Spares shall be classified by a Committee consisting of representative from user department, Technical Services and Materials as Vital (V), Essential (E) and Desirable (D). Vital Spares are those whose non-availability results in very high production downtime loss and entails very high cost due to urgent situation purchase. Necessary spares are those whose non-availability is expected to cause moderate production downtime loss. Desirable spares are those whose non-availability does not

result in any significant production downtime loss. The list shall be reviewed once in 2 years. Basic goal is to ensure the reliability and availability of the spare part to the production section. Analysis will be done for the items in the revised data set where all the non-moving items are removed from the initial sample set.

ABC analysis

'A' Item: 'A' items require relatively senior level attention in user departments, Stores department and Purchase department. Every attempt must be made to reduce lead-time (internal and external) and average inventory by giving priority at all stages. Order quantity and ROL should be determined carefully and accurately. Staggered deliveries are desirable for these items. Detailed records of goods ordered, received, issued and past data must be maintained. Safety stock should be less and stock-out possibility should be avoided by closer and frequent review and follow-up. Location should be easily accessible to the extent possible and stock taking should be conducted once in a year.

'B' Items: Normal control is sufficient for these items. Control by exception may be exercised for critical items. Ordering quantity can be more liberal and deliveries can be staggered. Only moderate safety stock need to be held. These items can be located slightly away from issue point. Stocktaking must be conducted once in a year.

'C' Items: Less control is required and replenishment/ordering can be delegated to lower level. Relatively large inventory can be maintained and frequent issues and postings of material should be avoided. Generally bulk quantity based on single annual order should be bought. Relativelylarge safety stock to be maintained. Materials are to be generally stored in less accessible areas except a few critical items. Stocktaking need to be conducted only once in 2 years.

All the non-moving items and those items with empty stock are removed from the data set and the analysis are carried out for rest of the items. If the percentage cumulative demand value is less than 75%, they are categorised as A items. If Percentage cumulative demand is greater than 75% and less than 90%, they are categorised as B items. And those more than 90% are categorised as C items. Average demand can be obtained based on the consumption value.

Inventory Cost Reduction

The inventory cost for spares was calculated using two different models. Current company inventory model and a reduced inventory cost is obtained using an EOQ based proposed model.

Present system

Inventory management system in the company mainly focusing on the SRR (Stock Replenishment on Request) items. Each spare part is treated individually and all items have same priority. There's no classification used separate items. In current system when a request for an item arrived they look into stock value of the item and if there is enough item they release the required quantity. If the stock value of an item is low a purchase order is released. The order quantity and when to place this order is decided by the inventory controlling personals. They only consider the current stock value of

the item. The main problem in this system is that there is no specific method to find reorder point and how much need to be ordered. And there is no classification among items and treated every item equally. And another problem is that it completely depend on the personal who controls it and the experience and knowledge of the personal. If a new personal came in to this system it becomes very difficult for the new person to understand the system and to work properly. And in this system chance for stock out are very high. Here we don't consider the lead time. And items are ordered based on the stock value. Order cost is same 50 and holding cost is 20% of the unit price of each item. In present system there is no criticality classifications performed. Total inventory cost is obtained by the summation of holing cost and ordering cost for each item. Each and every item has same importance and based on that the analysis is carried out.

EOQ Based Proposed Model

In the current model there is no classification among items, all the items are given the same importance. So a new model is proposed which consider each and every item individually. System also considers the criticality for each item, safety stock to be kept and ROL are also obtained. ROL is considered to be the sum of lead time demand and the safety stock. For obtaining the total cost the system includes the EOQ level and the annual consumption value. No: of orders obtained as the ratio of annual consumption value and the EOQ level. The total cost is considered to be as the summation of holding cost and the ordering cost were EOQ is also considered [15].

Economic Order Quantity

At perfect conditions there should not be any stock at all. Each and every item with right quantity should be available just before it requires. It's not practical because the supplies & needs are not so definite and also the costs of placing orders and proceedings will be high while ordering in small batches. For a particular annual consumption as we increase the quantity of order, the carrying cost increases due to an increase in stock. The ordering quantity where the total cost will be the lowest is called Economic Ordering Quantity (E.O.Q) which can be expressed mathematically as

$$E.O.Q = \sqrt{(2AS/IC)}$$

Where

A = Annual consumption of items in Units.
S = Cost per order in Rupees
I = Carrying charges per year expressed as fraction
C = Unit price
E.O.Q = Economic Order Quantity in Units.

Establishing Safety Stock

The earlier model assumed that demand was steady and known. In common cases demand is not constant and varies from day to day. Safety stock must so maintained to offer some level of safety against stock outs. If the product demand is predictable it's more preferable to keep the safety stock less. This is more important for companies

with a smaller economic cushion or those trying to run on lean manufacturing, which tries to eliminate waste during the manufacture process.High safety stock can end in high holding costs of inventory. Less safety stock can end in lost sales and higher rate of customer turnover. So it is essential to find the optimal safety stock. Safety stock is the amount of inventory accepted in count to the likely demand.

Safety Stock = K x $\sqrt{D}$

K-values are recommended for items on the basis of ABC &VED classification as shown in Table 1.

Table 1: K-Value Based on ABC and VED Classification

K Value			
	V	**E**	**D**
A	2	1	0.5
B	2.5	1.5	1
C	3	2	2

Annual Consumption

To find EOQ for each item we need to find the average yearly demand of the items.

The demand of the item calculated based on weighted average of past 3 years consumption

Average Annual consumption $= ((2xL1) + L2 + L3)/4$

Where L_1 = current year's consumption

L_2 = last year's consumption

L_3 = 2rd last year's consumption

Lead time is considered as 2 months and the lead time demand level has been obtained[16]. ordering cost is taken as Rs 50 per order and holding cost is 20% of the unit price of each item[20]. The total cost is considered to be as the summation of holding cost and the orderingcost,which also consider the EOQ level for each item [15].

Results and Inferences

FSN analysis

The FSN analysis was done for a sample set of 790 spares and the results obtained are shown in Table 2.

Table 2: Result For FSN Analysis

Fast-Moving Items	182
Slow-Moving Items	448
Non-Moving Items	160
Total	790

The result shows that 23% of items in the sample set are fast moving items, 56.7% are slow moving items and 20.20% are non-moving items. That is for last two year these 20.20% of items are not been used. Holding these items will lead to increase the total inventory cost. Through proper study we can decide whether these items have to be stored or they can be considered as scrap and can be removed from the store. For rest of the analysis these non-moving items will be removed from the sample set.

VED Analysis

Out of 790 spares the 160 non-moving items were removed from the data set and analysis wasdone for a sample set of 630 items and the results are shown in Table 3.

Table 3: Result for VED Analysis

Vital	303
Essential	327
Desirable	0
Total	630

The result shows that there are no desirable items in the sample set 0%. 48.09% of items are vital items and 51.9% of items are essential items. That is if any one item in the sample set is not available; it leads to a production loss. There for stock out must be avoided and a proper safety stock has to be maintained.

ABC analysis

From the VED analysis, those items with zero current stock were removed and further analysis were done for 565 items. The result obtained are shown in Table 4.

Table 4: Result for ABC Analysis

A Items	86
B Items	93
C Items	386
Total	565

The result shows that 15.22% of items in the sample set are A items, 16.46% of items are B items and 68.31% of items are C items. I.e. A items accounts for 75% of the total demand. A items need more attention in all the departments. Less safety stock should be there and stock out should be avoided. B category items need only moderate attention.ROP can be more liberal and can maintain moderate safety stock. C category items need only less attention. Bulk ordering can be done for these items, less number of orders andC category items are low cost items.

Inventory cost reduction

Table 5: Result For Inventory Cost Reduction

Model	Total Inventory Cost(Rs)
Present model	11,89,248.00
Proposed EOQ based model	7,51,106.00
Difference in total cost	4,38,142.00

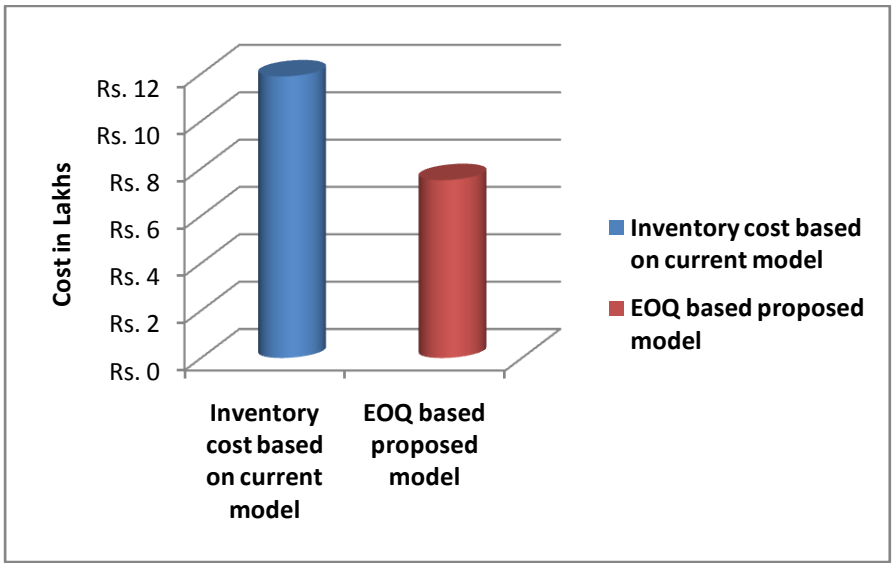

Figure3: Result For Inventory Cost Reduction

Total inventory cost for spares were found with two different models. By current company model and an EOQ based proposed model which also accounts EOQ, safety stock and lead time demand. The total inventory costs obtained with the two models are shown in Table 5. Initially the analysis was carried for the current system which gives equal weightage for all items without considering their importance. Lead time and safety stock are not considered in this system, so more stock have to be maintained in order to avoid stock outs, which increase the holding cost. EOQ is not considered in this system instead ordering is done based on the stock value. Based on the current model total inventory cost is obtained as Rs.11.89 lakhs.

A secondary analysis was done for the sample set based on an EOQ based proposed model. The safety stock, ROL, annual consumption and lead time demand were found for each and every item which is not done presently. Where to keep the order and quantity to be ordered is also found. The model also incorporates the criticality of each item. Model minimizes the safety stock and hence over stocking can be avoided. Using the proposed model the total inventory cost is calculated as Rs.7.51 lakhs. i.e. the EOQ based proposed model is more economical compared to the current model at the company. A difference of Rs. 4.38lakhs in total inventory cost is obtained using the proposed model which is clearly represented in Figure 3.

Conclusions

Criticality analysis and total inventory cost reduction is successfully carried out for all the items in the sample set. Through FSN analysis it was found that out of 790 items in the sample set 160 items are found to be Non-moving. These items were not consumed for last 2 years. So these items can be considered as scrap and can be sold out by conducting a proper study. By doing this we can reduce the space required for storage. VED analysis is then carried out and it was found that no items were desired, the un availability of any one item will results in down time losses. And finally ABC analysis was carried out and it was found that almost 75% of the demand can be full filled by the major 15 to 20% of inventory that the company possess. So a major attention in keeping safety stock and ordering should be given for these items. Total inventory cost value was obtained with the current company model and a revised EOQ based proposed model. It was found that the new model is more effective and economical. A difference of Rs. 4.38 lakhs in total inventory cost was obtained using the proposed model for just 565 items in the sample set. In the present system all items were given equal weightage and the ordering was done based on the current stock. But in the new proposed model an EOQ based analysis is done and safety stock value, ROL and lead time demand were also found for each items based on their importance. A combined ABC- VED method is used for obtaining the safety stock, which incorporates the criticality of each item.

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