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Estimation of Safety Stock for Inventory Control using MADM approach in an Electrical Industry

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***Abstract*— In majority of the organization cost of material forms a substantial part of the selling price of the product. Inventory planning is critical for the successful operations of any firm because shortage of raw material can shutdown the shop or production line or lead to modification of production schedule. In order to efficiently control the inventory and to determine suitable procurement policies a MADM approach is used. In this paper AHP is used to determine the weightage of the criteria selected through expert opinion. The proposed inventory model classifies the materials into twenty seven composite classes. The Safety Stock of the each class of material is determined through CSS formula. To validate the proposed model safety stock of the selected classes of the materials is determined and compared with the actual value.**

Key Words- Analytic Hierarchy Process Combined Safety Stock, Composite Classes, Expert Opinion, Multi Attribute Dimensional Model.

I. INTRODUCTION

Scientific inventory management is an extremely important problem in the material management function. Materials account for more than half of the total cost of any business and organization maintain huge amount of stock, much of this could be reduced by the scientific inventory principles .Inventory management is highly amenable to control. In Indian industries there is substantial potential for cost reduction due to inventory control. Inventory being a poor symptom of procurement policies but reduction in the uncertainty of lead time can be achieved by variety reduction and in many other ways also. Formulation of an inventory policy requires an understanding the role of inventory in production and sales. Inventory serves the following five purposes.

1. It enables the company to achieve economies of scale
2. It ensures produce right product at right time and deliver to customer on time
3. It enables specialization in manufacturing
4. It provides protection from uncertain demand and order cycle
5. It acts as a buffer between critical interfaces within manufacturing stages

Inventory planning is critical for the successful operations of any firm because shortage of raw material can shutdown the shop or production line or lead to modification of production schedule. These events may increase expenses or results in delay in meeting customer orders. While shortage of inventory can disrupt manufacturing or excessive inventory can increase inventory carrying cost and reduce profitability. Finally Inventory can be used as a means of improving customer service level by reducing the likelihood of stock out due to unanticipated variability in lead time of suppliers. If inventory is balanced customer service level is high. A balanced inventory is one that contains items in proportion to the expected demand from the customer.

In simplest terms, inventory management deals with issue of how much to keep on hand and how frequently or when to reorder each class or subclass of materials. Inventories in manufacturing industry under study is classified into Stock-controlled items and Non-Stock controlled items based on ABC classification by giving more focus to A items. There has been no attempt so far for developing sub classification and composite classification for stock items and non stock items separately. There are no scientifically derived strategies for each class of material regarding how much to buy and when to buy. At present company is employing common strategies for all A, B, and C class of materials while purchasing, storing and issuing, which is not appropriate because one Vital Essential C (VEC) class items may be available in local market, its lead time may be one day, on the other hand Vital Scare C class items have to be imported from UK, its lead time is 90 days, the strategies to be followed should be different. Unless the firm won't classify materials, it is difficult to follow different strategies for different composite classes of materials which fetch quantitative and qualitative benefits to company.

The slow moving items (SMI) are those which are not regularly demanded and their movement off the shelf is occasional. Inventory models valid for fast moving items are not applicable to slow moving items due to lack of regular demand pattern. Generally slow moving items are generally expensive and therefore one has to first decide whether to keep them all in stock and if to keep them in stock what quantity. Further difficulty of slow moving parts is that initial over buying decision could take years to remedy the situation due to rarely occurring demands.

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Hence an attempt is made to develop an inventory model for inventory control of materials especially slow moving items.

II. LITERATURE REVIEW

The initial step for multi criteria inventory control is the identification of different criteria for the classification of inventories. Literature gives different criteria used for classification of inventories based on the study done in different industries from automobile, distribution firms, power sector, manufacturing firms to pharmaceutical industries.Following are the criteria identified from the literature Cost, Demand, Criticality, Lead time, Last use date, Durability , Substitutability, Payment terms, Commonality, Obsolescence , Reparability ,Limitation of warehouse space.

The experts were identified on the basis of their individual experiences. In an expert opinion three to five experts can be selected. In the company the major decisions on the relevant subjects as procurement and inventory policies have been made truly by purchase manager and his assistant. Therefore the study group consisted of three experts from the industry who are having sufficient practical experience. To even out the errors while making judgment one expert is selected from Academia who is having thorough knowledge in subject and sufficient experience. Another expert is selected from a consultancy that has much expertise in subject and practical field (A Multiattribute ABC Classification Model Using Fuzzy AHP Ferhan ÇEBİ, Cengiz KAHRAMAN, Bersam BOLAT 2012).

The Analytic Hierarchy Process (AHP) is a multi-criteria decision-making approach and was introduced by Saaty (1980). The AHP is carried out in two phases: the design of the hierarchy and the evaluation of the components in the hierarchy (Saaty, 1980; Vargas, 1990). The implicit weights for this pair wise comparison matrix can be obtained by a variety of software products recently available on the market. One of these is EXPERT CHOICE, AHP with excellent graphics and user assistance. The weightage of the various criteria identified through the expert opinion for the study is done through Analytic Hierarchy Process (B.E. Flores, D. L. Olson and V. K. Dorai 1992, Ishizaka Alessio, Labib Ashraf 2009 , Geoff Coyle: Practical Strategy. Open Access Material AHP 2004).

The weighted rating methods are used to obtain the final service level of each class of material. This formula can now be used to evaluate inventory items, reflecting all criteria considered. Application of AHP to weighting multiple criteria in inventory management can be viewed as a linear estimator of utility. Saaty [1990] presents the method, intending ratio evaluation of each alternative as part of the hierarchy. With the large number of inventory items typically managed, it will be necessary to apply the set of weights obtained from AHP, rather than treat each alternative through pair wise comparison as proposed by Saaty. If ratio measures for each characteristic were available (such as average unit cost, annual dollar usage, and lead time), the ratio character of AHP could still be applied.

The graphical framework of inventory model shows the categorical measurements of the different criticality criteria. Along each axis, the three measurements – vital, desirable and essential defined. The nine segments of this cube on each phase are grouped according to the level of criticality (An Molenaers, HermanBaets, LilianePintelon, GeertWaeyenbergh 2011).

Safety stock can be an effective way to mitigate demand uncertainty and lead time variability while still providing high service levels to customers. There are various safety stock methods available to determine the safety stock depending upon the demand and lead time conditions (By Peter L. King, CSCP APICS Magazine 2011).

III. PROBLEM DEFINITION

Based on the study conducted in a manufacturing industry in Kerala company retains 25000 items in the database of which 15000 plus items are not in use for the last eight years. Percentage of the non moving items as per data base is 60% and the material cost has gone up to 65%.The scrap value as per the records is 5,00,00,000 cr. This data shows that company lacks proper scientific inventory control leading to severe accumulation of scraps which results in high inventory costs and blocking of capital.

IV. RESEARCH METHODOLOGY

The criteria for the classification of the inventory are identified based on the Literature Survey and Expert Opinion. The inputs are explored through systematic brain storming sessions. Groups of Experts, three from industry, three from academia, and one consultant from industry is selected for identifying the criteria for classification of industry. The methodology for the MADM approach is shown in fig I

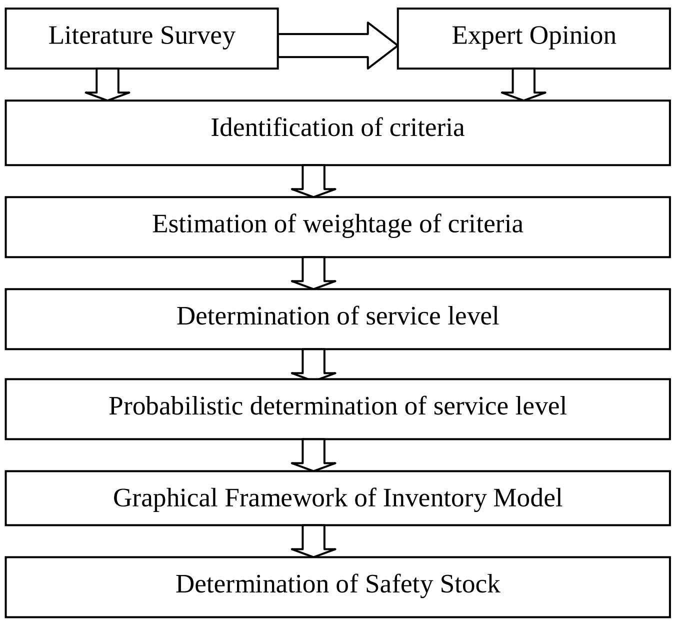

Figure I: A schematic diagram of MADM approach

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I. IDENTIFICATION OF CRITERIA FOR INVENTORY CLASSIFICATION

Twelve criteria for the classification of inventories in various industries are identified from the literature published till date. Then the criteria relevant for the classification of inventories in the electrical manufacturing industry are identified from the opinion of a panel of experts in the field through brainstorming. Thereby three criteria namely cost, criticality and lead time are identified by the experts relevant for the study. Then the Experts are asked to estimate the rating for these three criteria on a 1-9 AHP pair wise comparison scale. The estimated ratings for the criteria given by the experts are shown in the Table I.

TABLE I
ESTIMATION OF RATING FOR THE CRITERIA

	Cost	Criticality	Lead time
Cost	1	4	4
Criticality	1/4	1	3
Lead time	1/4	1/3	1

It is not economic always to be able to service an order from stock on hand. Decision on the right service level for a certain product is essentially balancing inventory cost vs. stock out. Service level is therefore an important variable for calculating the appropriate safety stock. Service level expresses the probability of being able to service incoming orders (or demand) within a reference period without delay from stock on hand. The implicit assumption within this statement is the higher the desired service level, the more safety stock needs to be held. The experts are also asked to estimate the service level for the three criteria in three levels balancing stock out and piling up of excessive inventories.

II. ESTIMATION OF WEIGHTAGE OF CRITERIA

The weightage of the criteria is determined by Analytical Hierarchical process (AHP). The hierarchical models of the AHP have a goal at the top, criteria influencing the goal in the next level down, possibly sub-criteria in levels below that and alternatives of choice at the bottom of the model. Judgments are made on pairs of elements throughout the structure and synthesized to prioritize the alternatives.

The criteria will be pair wise compared with respect to the goal. The pair wise comparison judgments are made using the Fundamental Scale of the AHP and the judgments are arranged in a matrix, the pair wise comparison matrix. The numbers in the cells in an AHP matrix, by convention, indicate the dominance of the row element over the column element; a cell is named by its position (Row, Column) with the row element first then the column element. In the AHP pair wise comparison matrix below the (Cost, Criticality) cell has a judgment of 4 in it, meaning cost is 4 times as important as Criticality. So logically this means Criticality has to be 1/4 as important as Cost so 1/4 is automatically entered in the (Cost, Criticality) cell. The diagonal elements are always 1, because an element equals itself in importance. Matrices with this property are called inverse matrices. Only judgments in the non diagonal area need to be made and entered. Priorities for the criteria are obtained by calculating the principal eigenvector of the above matrix. A short computational way to obtain this vector is to raise the matrix to powers. Fast convergence is obtained by successively squaring the matrix. The row sums are calculated and normalized. The computation is stopped when the difference between these sums in two consecutive calculations of the power is smaller than a prescribed value. The weightage of the criteria calculated from the AHP is shown in Table V

TABLE II WEIGTAHE OF CRITERIA

	Inconsistency- 0.13040
	Normalized Values(Weights)
Cost	0.10479
Criticality	0.60456
Lead time	0.29064

III. DETERMINATION OF SERVICE LEVEL

Service level expresses the probability of being able to service an incoming orders (or demand) within a reference period without delay from stock on hand. The implicit assumption within this statement: It is not economic always to be able to service an order from stock on hand. Decision on the right service level for a certain product is essentially balancing inventory cost vs. stock out. A typical service level in retail is 95%, with very high priority items reaching 98%or even 99%.

Final service level of each category of material is calculated by weighted rating method. It is the sum of the product of the factor rating and service level of the each class of material estimated by the experts. Weighted rating method is the form of multi criteria analysis. Weighting factors are estimated values indicating the relative importance or impact of each item in a group as compared to the other items in the group. Weighted rating method is used to assign weights to each factor in a group to obtain the total weightage.In the proposed methodology material is classified in to twenty seven classes based on three criteria that are cost factor in three levels (ABC), criticality factor in three levels (VED) and lead time factor in three levels (SDE).

IV. PROBABILISTIC DETERMINATION OF SERVICE LEVEL

Probabilistic models are used when there is a variability in demand and lead time i.e., uncertainty in demand and lead time. Probabilistic determination of service level means we are determinining the expected probability of keeping an item so that stock out can be avoided and the level of Slow Moving Inventory (SMI) can

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be reduced to a minimum level. In this model we assume both the demand and lead time are random variable that is normally distributed. Normal distribution is selected for two reasons. First many natural and artificial processes are normally distributed. Second any process can be treated as normally distributed through sampling. The expected probability of keeping an item is expressed in terms of standard normal variate 'z' of that item. A standard normal variate is a normally distributed random variable with mean 0 and variance 1. Standard normal variables play a major role in theoretical statistics in the description of many types of model, particularly in regression analysis, the analysis of variance and time series analysis. The standard normal distribution is a picture of z-scores of any possible normally distributed process. The probabilistic values of all the twenty seven classes of material calculated is shown in the table III,IV, and V

TABLE III STANDARD NORMAL VARIATE 'Z' FOR LEVEL 1(VITAL) OF CRITICALITY FACTOR

VITAL(V)			
	S	D	E
A	VSA-0.9865; Z=2.21	VDA-0.9749;Z=1.96	VEA-0.9604;Z=1.755
B	VSB-9917;Z=2.39	VDB-0.9801;Z=2.055	VEB-0.9656;Z=1.82
C	VSC-0.9959;Z=2.64	VDC-0.9849;Z=2.17	VEC-0.9698;Z=1.88

TABLE IV STANDARD NORMAL VARIATE 'Z' FOR LEVEL 2(ESSENTIAL) OF CRITICALITY FACTOR

ESSENTIAL(E)			
	S	D	E
A	ESA-0.9805;Z=2.06	EDA-0.9689;Z=1.865	EEA-0.9544;Z=1.69
B	ESB-0.9858;Z=2.19	EDB-0.9742;Z=1.95	EEB-0.9597;Z=1.75
C	ESC-0.99;Z=2.33	EDC-0.9784;Z=2.02	EEC-0.9639;Z=1.80

TABLE V STANDARD NORMAL VARIATE 'Z' FOR LEVEL 3(DESIRABLE) OF CRITICALITY FACTOR

DESIRABLE(E)			
	S	D	E
A	DSA0.9563;Z=1.71	DDA0.9447;Z=1.595	DEA-0.930;Z=1.475
B	DSB0.9616;Z=1.77	DDB0.9447;Z=1.645	DEB0.9355;Z=1.515
C	DSC0.9658;Z=1.82	DDC-0.9542;Z=1.69	DEC-0.9397;Z=1.55

V. SAFETY STOCK DETERMINATION

The economic order quantity formula is based on the assumption that the demand is known and certain and the lead time is constant and does not vary. In actual practical situations, there is an uncertainty with respect to demand and lead time. The total forecasted demand is more or less than the actual demand and the lead time may vary from estimated time. In order to minimize the effect of this uncertainty due to demand and lead time, a firm maintains safety stock, reserve stock or buffer stock. The safety stock is defined as the "additional amount of material to be maintained in order to meet the unanticipated increase in demand arising out of uncontrollable factors". Because it is difficult to predict the exact amount of stock to be maintained by using statistical methods and simulation, it is possible to determine the level of safety stock maintained. If the level of safety stock maintained is high, it locks up the capital and there is possibility of obsolescence. On the other hand, if it is low there is a risk of stock out because of which there may be stoppage of production. When the variation in the lead time is predominant, the safety stock can be computed as

Safety stock= (maximum lead time-minimum lead time) x consumption rate

The service level of inventory thus depends upon the level of safety stock. Larger the safety stock, there is lesser risk of stock out and hence higher service level. Sometimes higher service level is not desirable as they results in increase of cost, thus fixing up a safety stock level are critical. Using the past data regarding the demand and lead time data, reliability of suppliers and service level desired by the management, safety stock can be determined with accuracy. Combined safety stock formula for determining the reserve stock is used when there is variability in both demand and lead time and this assumption is more close to reality. Hence the Combined Safety Stock Formula based inventory model is preferred to use here and is given as

Safety Stock $$ss = z \times \sqrt{(\mu_L \times \sigma_D^2 + \mu_D^2 \times \sigma_L^2)}$$

VI. RESULTS & DISCUSSIONS

The company under study has more than 25000 items in its inventory database making it rather difficult to calculate the safety stock of all the items. It is observed that the absence of a proper methodology in the company at present brings about piling up of several items as part of its inventory. As a solution to this the proposed model as part of the study includes the determination of safety stock of critical and small moving inventories based on lead time. This model uses classification system which identify scarce, difficult to procure and easy to procure based on their lead time as 6-12 weeks, 1-5 weeks, and less than 1 week respectively.

VSA category of material is the most critical item whose scarcity results in stoppage of production and its shortage cost is very high. The cost of shortage may vary depending upon the seriousness of the situation. Vital items are the most critical having extremely high opportunity cost of shortage and must be available in stock when demanded. Thus % of risk of shortage of vital group of material has to be quite small, thus calling for a high level of service. Hence we determine the safety stock of VSA category of material. An item is classified as scarce, difficult to procure and easy to procure based on the lead time. If the lead time is a week or less than that it is classified as easy to procure, and if it is from one week to six week it comes under difficult to procure category of material. When the lad time is more than six week it is scarce material.

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Press Board is the most critical item used in the manufacture of transformer whose non availability results in stoppage of production and affects the production schedule. It is an imported item and the lead time of the material is generally 12 weeks .So it is scarce item .The consumption vale of this item is 10% of the total consumption value of all the items. The safety stock of this item is calculated using CSS formula as 12.8 Ton. Average current safety stock maintained by the firm is 15.7 Ton. The extensive analysis of safety stock of some items is calculated because of its increased importance in production and is shown in table VI

TABLE VI SAFETY STOCK OF SELECTED CLASS OF MATERIAL

Sl No	**Item**	**Lead time**	**Safety Stock**		**% reduction in material stocked**
			Current	Using CSS	
1	Press Board	12week	15.7 Ton	12.8Ton	17.61
2	Densified Wood	5week	37 no	30 no	18.91
3	MS Plate	6week	63214kg	58667kg	7.2
4	Gasket	10week	1130.5kg	1090.4kg	3.5
5	Electrodes	1week	8085no	7820no	3.2

VI. IMPLEMENTATION METHOD

The form has to conduct a utility based stock take up with the help of technical experts and reverse Auction can be done for scrap items.Proper documentation procedures for creating the database of inventory which includes order quantity calculation variables is necessary.Periodic inventory review to investigate the price, stock level etc. is necessary in reducing the piling up of excess of inventories.

VII. CONCLUSION

The different parameters used for multi criteria inventory classification were cost, criticality and lead time. The multi-criteria inventory control method is based on the AHP and the logical decision diagrams. By combining these two techniques, a methodology for the composite classification of inventory could be developed. The study could provide different classes of inventories based on multi criteria for a scientific safety stock estimation. Decisions to hold those items in stock can now be based on quantitative and objective information. The proposed model is found to bring down the safety stock maintained in the organization. It is expected that this model could lead to gradual reduction in piling up of inventories.

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