Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS) 4(1):115-120
 (ISSN: 2141-7016)
jeteas.scholarlinkresearch.org

Inventory Management: Pivotal in Effective and Efficient Organizations. A Case Study

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Abstract
The problem of determining what to order, when to order, how much to order and how much to stock so that costs associated with ordering and holding are optimal without interrupting production or sales, have been one of the major challenges facing manufacturing industries in the world. This paper employed classical (Q, R) inventory policy in determination of optimum order quantity, optimum reorder point and optimum safety stock for the raw materials that will ensure smooth operation in the industry under study. In this study, a simplified continuous inventory control model that can give an instant update of inventory status was proposed. This model was coded in Excel tool pack and was confirmed to give instant update of inventory level at any point in time. The simplified continuous inventory control model proposed will help in solving the problem of overstocking and understocking of both raw materials and finished products in Eagles Height Industries Ltd. Nigeria and similar manufacturing industries.

Keywords: Inventory management, (Q, R) inventory policy, ABC analysis, Inventory control model.

INTRODUCTION

Nowadays, companies evolve in an industrial environment with an increasing competition. The works, Grossmann (2005), Azizul and Anton (2009) stressed that survival of companies in this competitive world depends on effective management of their inventory. In any manufacturing industry, there must be some inventory of raw materials, work-in-process and finished products that are maintained in order to keep the factory running; and effective management of the inventories is crucial for growth and survival of such industry. Inadequate control of any of these inventories can result to both under and overstocking of items. Telsang (2001) and Stevenson (2009) supported the overall goal of inventory management as to have what is needed, when it is needed and to minimize the number of times one is out of stock.

Eagles Height Industries ltd, Nigeria is having the problem of overstocking and under stocking of both raw materials and finished products. This problem has been occurring as a result of arbitrary method of inventory management in the industry. This ineffective management has led to tying up of fund when they overstock; shutting down production system when they run out of stock of raw materials; and lost sales and dissatisfied customers when they run out of finished products.

To solve the problem of overstocking and under stocking in the industry under study, there must be a planned approach of determining what to order, when to order, how much to order and how much to stock so that the costs associated with ordering and holding are optimal without interrupting production and sales. There are various inventory models existing in the literature due to ranging peculiarities of production inventory, and no particular inventory model has general application to entire variety of inventory situations. Such inventory models can be appreciated in the works, Silver et al (1998), Zipkin (2000) ,Cachon and Terwiesh (2005). Due to the uncertain nature of demand in this company, there is a need to observe the inventory level at all times. Hence, this study concerns itself particularly with (Q, R) inventory system. (Q, R) inventory policy involves ordering a fixed quantity (Q) of a material whenever the inventory level reaches the reorder point (R).

Also, another important aspect of inventory management is that items held in inventory are not of equal importance in terms of money invested, profit potential, sales or usage volume, or stock out penalties. Therefore, a more reasonable approach would be to allocate control efforts according to the relative importance of various items in inventory as observed by Martin and Stanford (2007). They also noted that ABC Analysis provides an important analytical framework for inventory management. In ABC classification, inventory items are usually divided into three classes according to their turnover ranking and labelled A (Very important), B (Moderately important) and C (Least important), as reported by Berniker and McNabb (2005). However, Prasad (1999), Hossein and Ajeet (2008) observed that the actual number of categories may vary from organization to organization, depending on the extent to which a firm wants to differentiate control efforts. ABC Analysis is used in this study to classify inventory items according to their relevance in the industry.

This study aimed at ensuring effectiveness and efficiency of inventory management in manufacturing sector. Based on that, this study achieved the following objectives: (1) determined and analyzed the optimum order quantity and optimum reorder point that minimized inventory costs (2) determined the optimum safety stock (3) compared the cost of stock out to the cost of holding a safety stock (4) developed a simplified computerized inventory control model/system that gives the update of inventory status at any point in time (5) classified inventory items

This study utilized (Q, R) inventory policy in a single item single supplier situation to jointly determine the optimum order quantity, optimum reorder point and optimum safety stock that minimized inventory costs. Also an algorithm that determined the optimum order quantity and optimum reorder point iteratively is proposed. Moreover Microsoft Excel was applied to develop a simplified computerized inventory control model/system that provides the update of inventory status at any point in time. The above scope of study equips the reader with robust tools for effective and efficient management of inventories.

METHODOLOGY

Research Design

In this case study, twelve months demand (usage) of raw materials and sales of finished products covering the entire year 2011 were collected from the Production and Marketing Departments, and other information concerning ordering and holding of materials were obtained through direct observation and interview in Eagles Height Industries Ltd, Nigeria. The data collected were analysed using classical (Q, R) inventory policy and ABC Analysis. Classical (Q, R) was used to obtain the optimum order quantity, the optimum reorder point and the optimum safety stock that will minimized inventory costs. ABC Analysis was utilized to classify finished products in order of their importance. Also, a computerized inventory control model/system that can give inventory status at any point in time was developed in Microsoft Excel package.

Method of Data Analysis

(Q, R) Inventory Policy

(Q, R) inventory policy is based on order quantity, reorder point system, whereby fixed quantity is ordered whenever the inventory level reaches the reorder point.

The (Q, R) inventory model adopted in this study follows the development in Silver and Peterson (1985) and Jensen and Bard (2001). In their model, the demand is uncertain while the lead time is assumed known and constant. Inventory level is observed at all times, and when the level declines to some specified reorder point, R, an order is placed for a lot size, Q. The order arrives to replenish the inventory after a lead time, L and the possibility of stock-out during an order cycle is considered in the model.

The expected total inventory cost for (Q, R) inventory policy is given as;

$$C(Q,R) = \text{Inventory holding cost} + \text{ordering cost} + \text{shortage cost} \quad (1)$$

$$\text{The inventory holding cost} = \text{average inventory} \times \text{holding cost per unit} = \left(\frac{Q}{2} + (R-u)\right)C_s \quad (2)$$

Where: C_s is the holding cost per unit, (R-u) is the safety stock and u is the mean demand during lead time.

$$\text{The inventory ordering cost} = \text{number of order per unit time} \times \text{ordering cost per order} = \frac{D}{Q}C_o \quad (3)$$

Where; D is the average rate of demand (usage) per unit time.

Stock-out cost is the cost resulting when demand exceeds the supply of inventory. It is the cost incurred whenever there is a stock-out.

$$\text{Stockout cost} = \text{number of order per unit time} \times \text{stoctout cost per unit} = \frac{D}{Q}C_s \quad (4)$$

Combining these cost terms in equations (2), (3) and (4), equation (1) which is the general model of (Q, R) inventory policy becomes;

$$C(Q,R) = C_h\left(\frac{Q}{2}(R-u)\right) + \frac{D}{Q}C_o + \frac{D}{Q}C_s \quad (5)$$

There are two variables in this cost function, Q and R. The essence of this study is to determine the optimum policy that minimizes cost.

To minimize the total cost, the partial derivative of the total cost in equation (5) with respect to each variable is taken and set equal to zero.

Taking Partial derivative of C(Q, R) with respect to Q and rearranging ,we have

$$Q^* = \sqrt{\frac{2D(C_o+C_s)}{C_h}} \quad (6)$$

Where Q^* is the optimum order quantity

Taking Partial derivative of C (Q, R) with respect to R and rearranging, we have;

$$\frac{\partial C_s}{\partial R} = -\frac{C_h Q}{D} \quad (7)$$

The solution for the optimum reorder point depends on the functional form of the shortage (stock-out) cost. A shortage will occur if the usage during the lead time is greater than R. This probability is defined by:

$$P_R = P\{x > R\} = \int_R^\infty f(x)\,\partial x = 1 - F(R) \qquad (8)$$

According to Silver and Peterson [12]

$$C_s = \pi P\{x > R\} = \pi \int_R^\infty f(x)\,\partial x \qquad (9)$$

The partial derivative of eq. (9) with respect to R is

$$f(R^*) = 1 - F(R^*) = \frac{C_h Q}{\pi D} \qquad (10)$$

$$C_s = \pi f(R^*) \qquad (11)$$

Where: π = fixed cost per stock-out independent of number of items short, $f(R^*)$ is optimum stock out risk and $F(R^*)$ is the optimum service level.

Therefore equation (6) can be written as;

$$Q^* = \sqrt{\frac{2D(C_o + \pi f(R^*))}{C_h}} \qquad (12)$$

Algorithm

An iterative algorithm is proposed to jointly determine the optimum order quantity and optimum reorder point. This is shown below.

Step1. We use $Q_i = \sqrt{\frac{2C_oD}{C_h}}$, which is the well known EOQ as the initial estimate. Let $i = 0$ and call this value Q_o

Step 2. We use equation (10) with $Q = Q_i$ to find $f(R)$. Call this $f(R)_i$.

Step3. Use equation (12) with $f(R) = f(R)_i$ to find Q_{i+1}. If $Q_i = Q_{i-1}$ and $f(R)_i = f(R)_{i-1}$ then stop, otherwise set $i = i + 1$, go to step 2.

Then optimum reorder point is;

$$R^* = u + \sigma z \qquad (13)$$

$$u = DLT \qquad (14)$$

$$\text{Optimum Safety Stock, } Ss = \sigma z = R^* - u \qquad (15)$$

Where: σ = Standard deviation of lead time demand, z = number of standard deviations and LT is the lead time.

The cost of holding optimum safety stock for one day =

$$\frac{C_h \times Ss}{365} \qquad (16)$$

The standard deviation of lead time demand can be obtained as;

$$\sigma = \sigma_d \times \sqrt{LT} \qquad (17)$$

Where; σ_d is the standard deviation of monthly demand

Equation (5) can be written as;

$$C(Q^*, R^*) = C_h\left(\frac{Q^*}{2} + (R^* - u)\right) + \frac{D}{Q^*}C_o + \frac{D}{Q^*}\pi f(R^*) \qquad (18)$$

ABC Classification

ABC Analysis classifies items based on their annual usage value (turnover) into: A = very important, B = moderately important and C = least important. The annual usage value is computed using;

$$\text{Annual usage value} = \text{Annual demand} \times \text{unit cost} \qquad (19)$$

A- Items generally account for about 10 to 20% of the number of items in inventory but about 60 to 70% of annual usage value. At the other end of the scale, C- items might account for 50 to 60% of the number of items but only about 10 to 15% of the annual value of inventory. This forms the classification rule used in this study.

RESULTS AND DISCUSSION

(Q, R) Inventory Policy

The following data were collected as regards ordering and holding of raw materials in the industry under study: ordering cost, C_o (N 15,000), holding cost, C_h (12% of the unit price of each raw material), fixed cost per stock out, π (N 33,000), the lead time is three days and the demand during lead time is uniformly distributed. The industry works for an average of 288 days per annum. The annual demands or usage of raw materials in the year 2011 and cost of raw materials per ton are shown in table 1 below. Figure 1 is the diagrammatical representation of the annual demand or usage.

Table 1: 2011 Monthly Demands of raw materials

Month	Resin (tons)	Stabilizer (tons)	Cal Carbonate (tons)	Stearic (tons)	Tita (tons)
Jan	93.940	3.758	37.576	0.376	0.251
Feb	89.796	3.592	35.918	0.359	0.239
Mar	110.518	4.421	44.207	0.442	0.295
Apr	104.301	4.172	41.720	0.417	0.278
May	83.164	3.327	33.266	3.333	0.222
Jun	104.992	4.200	41.997	0.420	0.280
Jul	110.518	4.421	44.207	0.442	0.295
Aug	98.084	3.923	39.234	0.392	0.262
Sep	117.425	4.697	46.970	0.470	0.313
Oct	99.880	3.995	39.952	0.400	0.266
Nov	103.887	4.155	41.555	0.416	0.277
Dec	62.166	2.487	24.866	0.249	0.166
Cost of raw materials per ton(N)	250,000	242,000	561,390	280,000	503,400

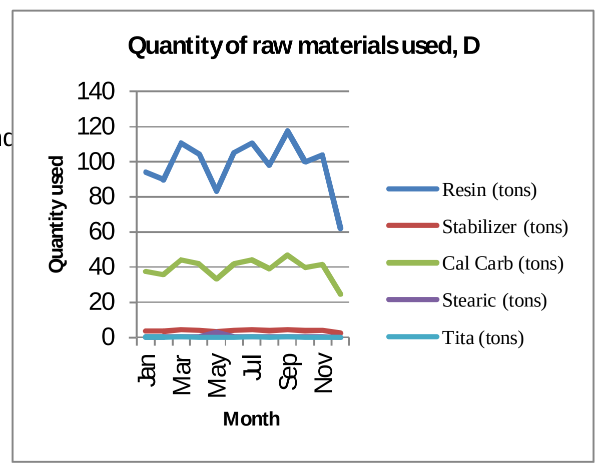

Figure 1: Monthly Demand (usage) of raw materials

The optimum order quantity and optimum service level for each raw material are obtained jointly using the proposed iterative algorithm in section 2.2.1. The optimum reorder point, the standard deviation of lead time demand, the optimum safety stock, the cost of holding safety stock for one day and the total inventory cost for raw materials (resin, calcium carbonate and Stabilizer) are obtained using equations (13), (17), (15), (16) and (18) respectively. The results obtained from the analysis are shown in table 2 below.

Table 2: Summary of optimum order quantity, reorder point, safety stock and inventory costs for raw materials.

Material	$Q^*(tons)$	$R^*(tons)$	C(Q,R) (N)	Ss (tons)	C(Ss) (N)	σ(tons)
Resin	35.346	21.888	112,390.84	9.61	789.86	5.005
Calcium carbonate	23.092	8.354	64209.50	3.443	664.66	2.002
Stabilizer	5.690	0.569	29,756.56	0.078	14.40	0.113

Since the three raw materials are often ordered separately, ordering the optimum order quantity of each material whenever it reaches its computed optimum reorder point will minimize both total inventory cost and stock out risk in each case. Also, from the monthly usage in table 1, the demand or usage is not deterministic, it varies. And from table 2, the cost of holding safety stock is very much cheaper than the stock out cost, therefore, holding the above computed optimum safety stock for each raw material will act as buffer or cushion against out-of-stock situations. The other raw materials because of the little quantity of them being demanded annually can be ordered twice in a year or quarterly. Making use of these optimum parameters will ensure smooth operation in the industry, minimize or totally eliminate out-of-stock situation.

Proposed Computerized Inventory Control Model

To ensure that materials are at the right place at the right time and in the right quantity, and also to avoid stock out which will always result to lost production, lost of customers' goodwill and lost of revenue to industries, a computerized inventory control model that will continuously update the Production or Sales Manager on the status of his inventory at any point in time is proposed. Figure 2 below represents (Q,R) inventory policy.

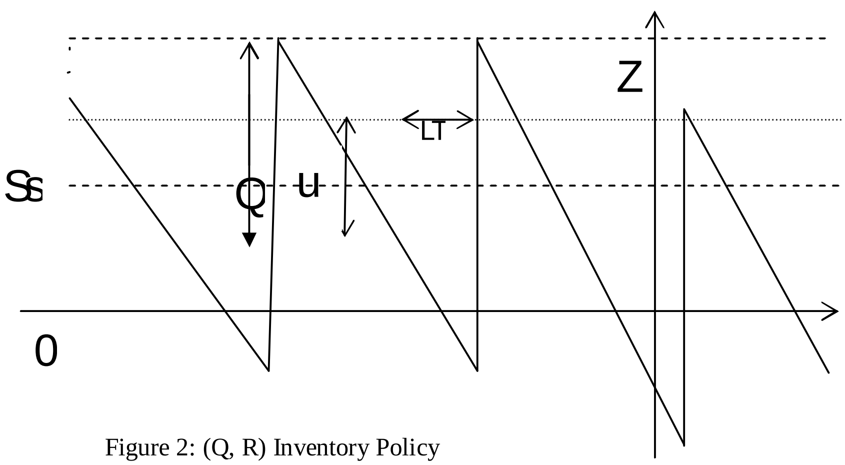

Figure 2: (Q, R) Inventory Policy

From the figure 2 above, a simple model which can at any point in time give the update of inventory position in the company can be generated.

Initial or inventory level is; $Z = Q^* + Ss$ (21)

Inventory level at any point can be determined using the model;

$Z_j = Z_{j-1} - X + Q^*$ (22)

Where: Z_j=current inventory level

Z_{j-1} = previous inventory level

Q^* = optimum order quantity which may either be 0 or 35.346 tons (for resin). It is 35.346 tons when there is new stock otherwise it will be 0 ton

X = daily usage which ranges from 0 to 8 tons.

Coding the above model in Microsoft Excel worksheet, a system that can give an update of inventory level for the production and marketing departments is obtained. Once the daily usage or receipt is keyed into the system, it will give an automatic update of inventory level. This simplified computerized continuous inventory review system will keep both the production manager and marketing manager abreast of the true position of the materials without going through the rigorous exercise of counting the quantity of materials in the warehouse, and it will help to eliminate out of stock situation normally experience in the industry. This model have been tested and confirmed to give instant update. Table 3 shows the computerized inventory control worksheet.

Table 3: Simplified Computerized Inventory Control Excel Worksheet

Day	Previous Inventory Level (Z_{j-1})	Quantity brought into the stock (Q^*)	Daily Usage (X)	Current Inventory Level (Z_j)
Day 1				
Day2				
Day 3				

ABC Classification of the Finished Products

To determine the control measures for the finished products, ABC Analysis was employed in the classification of the products. The following products denoted by P_{10} to P_{100} are classified into A(very important), B(moderately important) and C(least important) using ABC Analysis. Table 4 shows the finished products, unit price and annual naira value in each case. Table 5 shows the ranking of the products using the decision rule in section 2.2.2.

Table 4: Annual naira value of finished products

Product	Annual demand	Unit price(N)	Annual naira value(demand x unit price)
P_{10}	2401	520	1248520.00
P_{20}	28382	350	2110500.00
P_{30}	3273	810	2651130.00
P_{40}	6030	340	9649880.00
P_{50}	68503	385	26373655.00
P_{60}	10333	965	9971345.00
P_{70}	6332	830	5255560.00
P_{80}	51884	1500	77826000.00
P_{90}	6431	2150	35326650.00
P_{100}	6055	1020	6176100.00

Table 5: ABC ranking of finished products

Ranking	Product	Annual naira usage	Cum annual usage	Cum %	Class
1	P_{80}	77826000.00	77826000	44.07	A
2	P_{90}	35326650.00	113152650.00	64.08	A
3	P_{50}	26373655.00	139526305.00	79.01	B
4	P_{60}	9971345.00	149497650.00	84.66	B
5	P_{20}	9649880.00	159147530.00	90.12	B
6	P_{100}	6176100.00	165323630.00	93.62	C
7	P_{70}	5255560.00	170579190.00	96.60	C
8	P_{30}	2651130.00	173230320.00	98.10	C
9	P_{40}	2110500.00	175340820.00	99.29	C
10	P_{10}	1248520.00	176589340.00	100.00	C

Table 6: Summary of ABC Analysis of Finished Products

Class	Products	% of Products	Amount per group(N)	%
A	P_{80}, P_{90}	20.00	113152650.00	64.08
B	P_{50}, P_{60}, P_{20}	30.00	45994880.00	26.04
C	P_{100}, P_{70}, P_{30}, P_{40}, P_{10}	50.00	17441810.00	9.88

From table 6, P_{80} and P_{90} contributed 20% of the items and 64.08% of the annual naira value of the finished products, and are classified as A-category. P_{50}, P_{60} and P_{20} contributed 30% of the items and 26.04% of annual naira value of the finished products, and are classified as B- category. P_{100}, P_{70}, P_{30}, P_{40} and P_{10} contributed 50% of the items and 9.88% of annual naira value of the products, and are classified as C category. The A- items should receive closer attention through continuous review of amounts on hand and control over withdrawals. The C- items should receive only lose control, and B items should have controls that lie between the two extremes.

CONCLUSION

The need for effective management of inventories in PVC manufacturing industries have been explored using Eagles Height Industries ltd as a Case Study. The problems of overstocking and under stocking in the industry have been studied and from the analysis of data collected, the optimum parameters that will ensure smooth production have been determined for the industry under study using (Q,R) inventory model and the proposed iterative algorithm. They are: the optimum order quantity, the optimum reorder point, the optimum safety stock, and the cost of holding safety stock for each of the materials. The cost of holding safety stock determined was compared with the cost of experiencing an out-of-stock situation and it was observed that it is better, safer and cheaper for manufacturing industries to hold optimum safety stock than to run out of stock. Also, the computerized continuous inventory review model developed which have been tested and confirmed to give the update of inventory status, will help to eliminate the problem of out of stock situations in the industry.

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