# A New Inventory Model for Maintenance Organizations

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## INTRODUCTION

In our daily life, we observe that a small retailer knows roughly the demand of his customers in a month or week, and accordingly places orders on the wholesaler to meet the demands of his customers. But this is not the case with a manager of a big departmental store or a big retailer, because the stocking in such cases depends upon various factors, such as demand, time required between orders and actual receipts' etc. So the real problem is to have a compromise between overstocking and under stocking. The study of such type of problems is part of the field of material management or 'Inventory Control'.

In broad sense, inventory may be defined as the stock of goods, commodities, maintenance spares or other economic resources that are stored or reserved in order to ensure smooth and efficient running of business affairs including maintenance of assets.

We will now focus on inventory of spare parts required for running a preventive maintenance organization efficiently and effectively.

## CONVENTIONAL INVENTORY MODEL

A well-known inventory model is the concept of economic ordering quantity. The concept is that management is confronted with a set of opposing costs as the lot size (q) increases; the carrying charges ($c_1$) will increase while the ordering costs ($c_3$) will decrease. On the other hand, as the lot size (q) decreases', ordering costs ($c_3$) will increase. The Economic Order Quantity (EOQ), which is the optimal order quantity, is:

$$\text{Optimal q (EOQ)} = \left(\frac{2C_3R}{C_1}\right)^{1/2}$$

where:

*R is the uniform demand rate.*
*$C_1$ is inventory carrying charge.*
*$C_3$ is ordering cost.*

## DRAWBACKS OF THE CONVENTIONAL ELEMENTARY INVENTORY MODEL

It is not suitable for maintenance organizations, which require a variety of spare parts for keeping the plant, machinery and equipment in good condition. In maintenance activities, certain parts require renewal either periodically or urgently depending upon certain situations / contingencies. A break down in the machinery due to non-availability of required materials disrupts the organization and has a multiplier effect on operating costs, leading to shrinkages in the profit margins of business enterprises.

## GENESIS FOR A NEW INVENTORY MODEL

In the maintenance sphere, carrying costs and ordering costs are relatively less important than the timely availability of spares that ensures high uptime of productive machinery and accessories.

Keeping the above factors in view, we have developed a new inventory model which depends on actual rate of consumption of a spare part in a year and its required period of renewal/replacement for keeping up the functional efficiency of the sub-assembly/ assembly / system for preventing sudden breakdown of the machinery. Transport organizations like Indian Railways, State Transport Corporations and all industries have well streamlined 'stores organizations' as a subset of their overall maintenance organizations for initiating and overseeing material management / inventory control of all maintenances spares. Thus the concept of consumption rate and 'Periodicity of renewal' are the substitutes for carrying costs and ordering costs. Due to tremendous advancements in manufacturing activities by firms and also due to expansion of industry with availability of more and more firms, there is no paucity for reliable suppliers and distributors of spare parts across the country. The technique of JIT

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(Just in Time) has caught the imagination of Indian business and any spare part can be obtained at the required point of time. In the present inventory model, the consumption rate of a spare part is not uniform-it fluctuates between maximum and minimum in a month and sometimes it can be zero, either due to no necessity for drawal by the consumer or out of stock position.

Based on the author's practice as a maintenance engineer in service positions in the Indian Railways, a new inventory model for taking care of the above phenomena / discrepancies was deployed, which forms the substance of this paper.

For developing a suitable inventory system, the following objectives are set forth.

a) To evolve a materials procurement policy by correlating past consumption trends, present expectations and future requirements with regard to the utility of different spare parts for integrating preventive maintenance with sound material control.

b) To ensure proper material flow and control by identifying, drawing and issuing the materials to work centers needing them in consonance with necessary maintenance and safety standards for plant, machinery, equipment and prime movers.

**Development of a New Inventory Model (NIM):**

In the following, we develop a new inventory model for preventive maintenance organizations stocking spare parts, such as bearings, belts, brake blocks, springs, electrical brushes, etc., which are vital for running the operations.

1**. Evaluation of expected monthly consumption (e)**

• Maintains Tally/Ledger cards highlighting monthly consumption / utilization of each store item.

i. From the Ledger cards, expected monthly consumption / utilization (a), can be worked out as follows:

Let $a_1$ = monthly consumption of an item / spare part in the first month.

Similarly let $\mathbf{a}_n$ = monthly consumption of the same item in the $\boldsymbol{n}^{th}$ month

Hence, monthly average consumption/utilization in one year (a) = $\frac{a_1+a_2+ \ldots\ldots a_n}{12}$

ii. From the above Ledger cards, locate the maximum monthly consumption (b), in the above 12 month period.

Similarly, identify the minimum monthly consumption (c) for the same item in the same 12 month period.

Now we have three quantified consumptions / utilizations on a monthly basis representing the universe of 12 months .

Thus, we have:

a = the average or most likely monthly consumption.

b = the maximum monthly consumption, against a particular month.

c = the minimum monthly consumption, corresponding to a particular month.

The expected monthly consumption (e) is a function of a, b and c and beta distribution can be used to compute it:

$$e = \frac{b+c+4a}{6}$$

**2. Utilization coefficient (u):**

The conventional inventory models do not take into cognizance trends in the utilization of the stores. To overcome this, month-wise utilization coefficient is evaluated first.

$$\left.\begin{matrix}\text{Utilization coefficient}\\ \text{for any item in a month}\end{matrix}\right\} \text{(un)} = \frac{\text{Utilization during the } \mathbf{n}^{th} \text{ month}}{\text{Ground balance at the close of the month}}$$

Utilization during the $\mathbf{n}^{th}$ month

Hence, utilization coefficient ($u_n$) in the $\mathbf{n}^{th}$ month = $\left(\frac{a_n}{g_n - a_n}\right)$

Sum of utilization coefficients for the year under study $(S_n) = u_1 + u_2 + \text{------} + u_{12}$

$$= \sum_{n=1}^{12} u_n$$

Average utilization coefficient $(\bar{u}) = S_n / 12$

**3. Maintenance coefficient (m) is now found based upon actual requirement of the item for a period of one year (for ensuring trouble-free service).**

It can be seen that the maintenance coefficient for a particular spare part is introduced by top management based on (i) ideal maintenance requirement forming the preventive maintenance schedule. (ii) Actual usage of machinery in service. (iii) Availability of items in stores. Thus consumption of an item is not uniform. It fluctuates from month to month since engine/machine/equipment parts are replaced only on basis of their condition in order to ensure both functional efficiency and quality conformance.

**4. Utilization ratio(r): For taking into account the overall scenario, the ratio between maximum utilization *(b)* and minimum utilization *(c)* is introduced**

Thus $r = b/c$ for any year

**5. Procurement coefficient (p) for the item is taken as the geometric mean between practice and theory variables i.e, (u), the utilization coefficient and (m), the maintenance coefficient.**

$$p = (um)^{1/r}$$

**6 Revised Annual procurement (RAP) depends upon procurement coefficient (p) and the expected utilization coefficient (e)**

Hence Revised Annual Procurement (RAP) = (pe)

**Flow Diagram for the above Inventory model**:

• Find expected monthly consumption (*e*) of an item / spare part using beta distribution from the most likely average consumption (***a***), the maximum monthly consumption(b) and the minimum monthly consumption (c) by using the formula

$$e = \frac{b+c+4a}{6}$$

↓

• Find the average utilization coefficient (u) by comparing availability of an item with its actual utilization.

↓

• Judge/quantify maintenance coefficient (m) by comparing the present procurement action with ideal /situational procurement action.

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• Find utilization ratio (r) by comparing minimum monthly consumption with maximum monthly consumption for a given item, in the year under study

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• Evaluate procurement coefficient (p) as $r^{th}$ geometric mean between u and *m*.

$$P = (um)^{1/r}$$

↓

• Find Revised Annual Procurement (RAP) from ***p*** and ***e*** above

RAP = ***pe***

**Applications of the Above Inventory Model:**

• Maintenance organizations both big and small can apply this method and reap the benefits of time as well as cost saving.

• Government undertakings can cut down ordering costs and position Annual plans for procurement action, thereby minimizing the number of orders.

• Although there may be some increase in carrying costs, this is more than off-set by greatly reduced ordering costs. For preventive maintenance, availability of materials, at the right time and place, assumes more importance. As a result, overall profit potential receives a fillip due to synergy.

A sample worksheet for making out RAP (Revised Annual Procurement) for bearings used by a typical repairs and maintenance organization is given below.

**DATA:**

| Month No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Consumption of bearings at the beginning of the month (Nos.) | 8 | 10 | 12 | 6 | 16 | 20 | 18 | 24 | 4 | 7 | 5 | 10 | 140 |
| Ground Balance of bearings (Nos') | 140 (*) | 132 | 122 | 110 | 104 | 88 | 68 | 50 | 26 | 22 | 15 | 10 | - |

(*) Carried forward from previous year (20 Nos) + Receipts from purchase for the current year (120 Nos.) = 20+120 = 140 Nos.

Take ideal requirement in a year for trouble-free service of the machinery in which bearings are fitted as 180 Nos. This figure is based on Machine manufacturer's recommendation as well as management judgment.

## CALCULATIONS

**1. Find expected monthly consumption (e) using beta distribution.**

Average monthly consumption (most likely consumption) of bearings

$$(a) = \frac{a_1+a_2+a_3 \ldots\ldots a_n}{12} = \frac{140}{12} = \frac{35}{3} \text{ Nos.}$$

Maximum consumption in a month (b) = 24 Nos.

Minimum consumption in the month (c) = 4 Nos.

$$\text{Expected monthly consumption (e)} = \frac{b+c+4a}{6} = \frac{24+4+4(35/3)}{6} = \frac{224/3}{6} = \frac{224}{18} = 112/9$$

Expected Total Annual consumption (E) = ( 112 /9 ) x 12 = 448/3 Nos.

**2. Find Consumption coefficient (u)**

| Month | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Consumption during the month($a_n$) | 8 | 10 | 12 | 6 | 16 | 20 | 18 | 24 | 4 | 7 | 5 | 10 |
| Ground balance at the beginning of the month ($g_n$) | 140 (*) | 132 | 122 | 110 | 104 | 88 | 68 | 50 | 26 | 22 | 15 | 10 |
| Consumption coefficient $U_n = a_n/(g_n-a_n)$ | $\frac{8}{132}$ | $\frac{10}{122}$ | $\frac{12}{110}$ | $\frac{6}{104}$ | $\frac{16}{88}$ | $\frac{20}{68}$ | $\frac{18}{50}$ | $\frac{24}{26}$ | $\frac{4}{22}$ | $\frac{7}{15}$ | $\frac{5}{10}$ | $\frac{10}{0}$ |
| | 0.0606 | 0.0820 | 0.1091 | 0.0577 | 0.1819 | 0.2941 | 0.3600 | 0.9231 | 0.1819 | 0.4667 | 0.5000 | indeterminate |

**Sum of consumption coefficients : 3.2171**

$$\text{Average consumption coefficient (u)} = \frac{u_1 + u_2 + \ldots\ldots u_{12}}{12}$$

Ignoring $u_{12}$, since it is indeterminate,

$$u = \frac{0.0606 + 0.0820 + \ldots\ldots +0.5000}{11} = \frac{3.2171}{11} = 0.2925$$

(Please note that consumption coefficient is the ratio between consumption during the month and ground balance at end of the month)

**(3) Find consumption ration (r)**

$$r = \frac{\text{maximum consumption in a month}}{\text{minimum consumption in a month}}$$

$$r = 24/4 = 6$$

**(4) Find maintenance coefficient (m):**

$$m = \frac{\text{ideal requirement of bearings for trouble free service of machinery}}{\text{Stock of stores at the beginning of the year (out of purchase only)}}$$

$$= \frac{180}{120} = 1.5$$

(NOTE: Ground balance carried forward from the previous year should not be reckoned.)

**SUMMARY OF THE DERIVED INFORMATION:**

* Expected consumption $e = \frac{112}{9}$ Nos.
* Utilization coefficient $u = 0.2925$
* Consumption ratio $r = 6$
* Maintenance coefficient $m = 1.5$

**5. Calculation of procurement coefficient (p)- p is the $r^{th}$ geometric mean between u and m**

$$p = (um)^{1/r} = (0.2925 \times 1.5)^{1/6}$$

$$= (0.4388)^{1/6} = 0.8718$$

$$p = 0.8718$$

**(6) Calculate Revised Annual Procurement (RAP) from expected annual consumption (E) and procurement coefficient (p).**

Revised Annual Procurement (RAP) $= E \times p$

$= (448/3) \times 0.8718 = 130.19 = 132$ (next multiple of 4, since there are four quarters)

(Earlier procurement was for 120 nos. Hence, there is an increase of 12 nos. for the present year)

## RESULT

It is clear that the revised annual requirement of bearings works out to 132 nos., as against the earlier procurement of 120 nos. The additional 12 nos. have the potency to keep the machinery and plant in the best fettle, achieving saving both in time and cost dimensions.

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