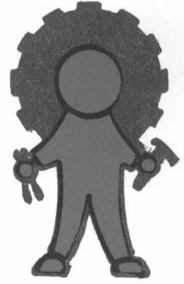


DEPT. OF INDUSTRIAL ENGINEERING
AND OPERATIONS RESEARCH
EXTENSION DIVISION
VA. TECH BLACKSBURG, VA.



XTENSION BULLETIN

MANAGEMENT

A MANUAL INVENTORY CONTROL SYSTEM FOR SMALL COMPANIES

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Finished goods and raw materials inventory frequently represent the greatest dollar investment made by small companies. Effective management of this inventory therefore may spell the difference between success and failure for the business. Because of the importance of the inventory function, this article explores a simplified manual control system suitable for use in small companies that do not have access to a computer and have only limited clerical resources.

There are several basic questions which need to be answered in the design of any inventory control system. These questions are:

- 1) What quantity should be produced on each production run (if it is made) or what quantity should be purchased (if it is purchased)?
- 2) When should the production order (or purchase order) be issued?
- 3) How should the control system be monitored or how should the records pertaining to the system be maintained?

Several other related questions, which will not be addressed in this article, include "make or buy" decisions; when to change production capacity; how to use price breaks; how to handle gradual as opposed to one time shipment; etc. Suggestions will be made for a simple manual control system incorporating procedures for the more important elements of good control.

Question No. 3, "How should the system be monitored?" will be addressed first. Attached is an example of a form (Figure 1) that can be used to maintain a perpetual inventory for each item being controlled. Each production order, purchase, or sale is posted to this form as soon as it becomes available. The perpetual record permits posting of all transactions to show quantities on hand; totals allocated to orders but not shipped, amounts on order; and the net balance remaining. Occasional errors in posting may be made, therefore, periodic physical inventories are needed. The perpetual records are then corrected to accurately reflect the results of the physical count. As each withdrawal is posted, the net balance is checked against the "reorder point" shown at the bottom of the form (block 13). When the net balance on hand falls below the reorder point, the inventory control clerk prepares a production order specifying the reorder quantity (block 14). Upon approval by management, the production order is released to the production supervisor for manufacture. Thus the reorder point acts as a trigger to start replenishment.

The above steps, in conjunction with the inventory control form, provide for monitoring the system and placing an order for the correct quantity of items at the correct time.

Explanation of Entries on Inventory Control Card

- #1 Date of entry.
- #2 Sales order, production order, or other document identification.
- #3 Quantities of items received or manufactured.

- #4 Quantities shipped.
- #5 Physical quantities actually on hand.
- #6 Quantities shown when a purchase order is submitted or production order is released.
- #7 When a part or a complete order is received into stock, quantity entry is made in column #7.
- #8 The remaining quantity to be received or produced at the time of posting.
- #9 When a long lead time sales order is received for a distant shipping date, a reservation may be made in this column.
- #10, #11 Reserve orders actually shipped and quantity still on reserve.
- #12 Quantities unencumbered which are on hand and on order.

Next, a means will be examined to determine when and how much to order. There are a number of costs associated with inventory. The more important ones are:

- 1) The cost of carrying inventory - The cost of maintaining items on hand (includes the interest on money invested in the inventory, taxes, cost of space for storage, i.e., real estate or warehouse, damage, pilferage, insurance, deterioration, obsolescence, etc.). Carrying costs may be expressed as average cents per unit per year or as some percent of the unit cost of the items in storage per year.
- 2) Setup costs - Costs incurred each time a purchase order is placed or a production run is started (equipment setup time, cleanup for the next production run, time to prepare paper work, time to prepare checks for payment, inspection of incoming items, etc.).
- 3) Stock-out costs - These are lost opportunity costs (lost profit from sales missed, loss of customer goodwill, overtime costs to make up for stockouts, etc.). These costs are difficult to estimate. If they can be determined, they are useful in control systems. In the system being proposed in this article inventory stockout costs will not be used but a different method will be employed.
- 4) Actual costs of inventory purchase or expense of labor and materials in parts produced - If we were to draw a chart showing the above costs, they might appear as follows:

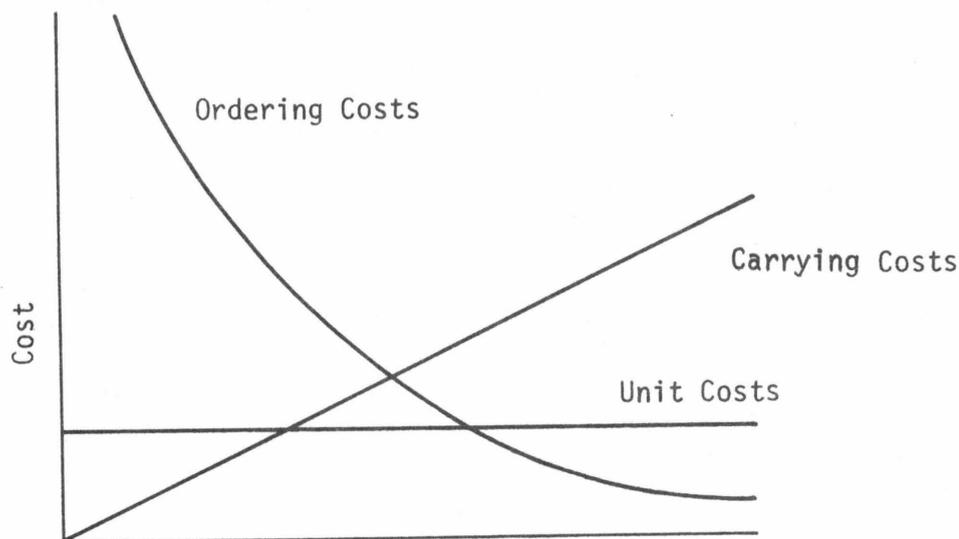


Figure 2 - Inventory Costs

This indicates that a larger lot size means fewer orders placed per year and consequently a lower total setup expense. On the other hand, small lots which must be ordered frequently during the year will result in smaller quantities in storage and hence less total carrying charges for the year. Adding all of these costs lines gives a total inventory cost line as shown below:

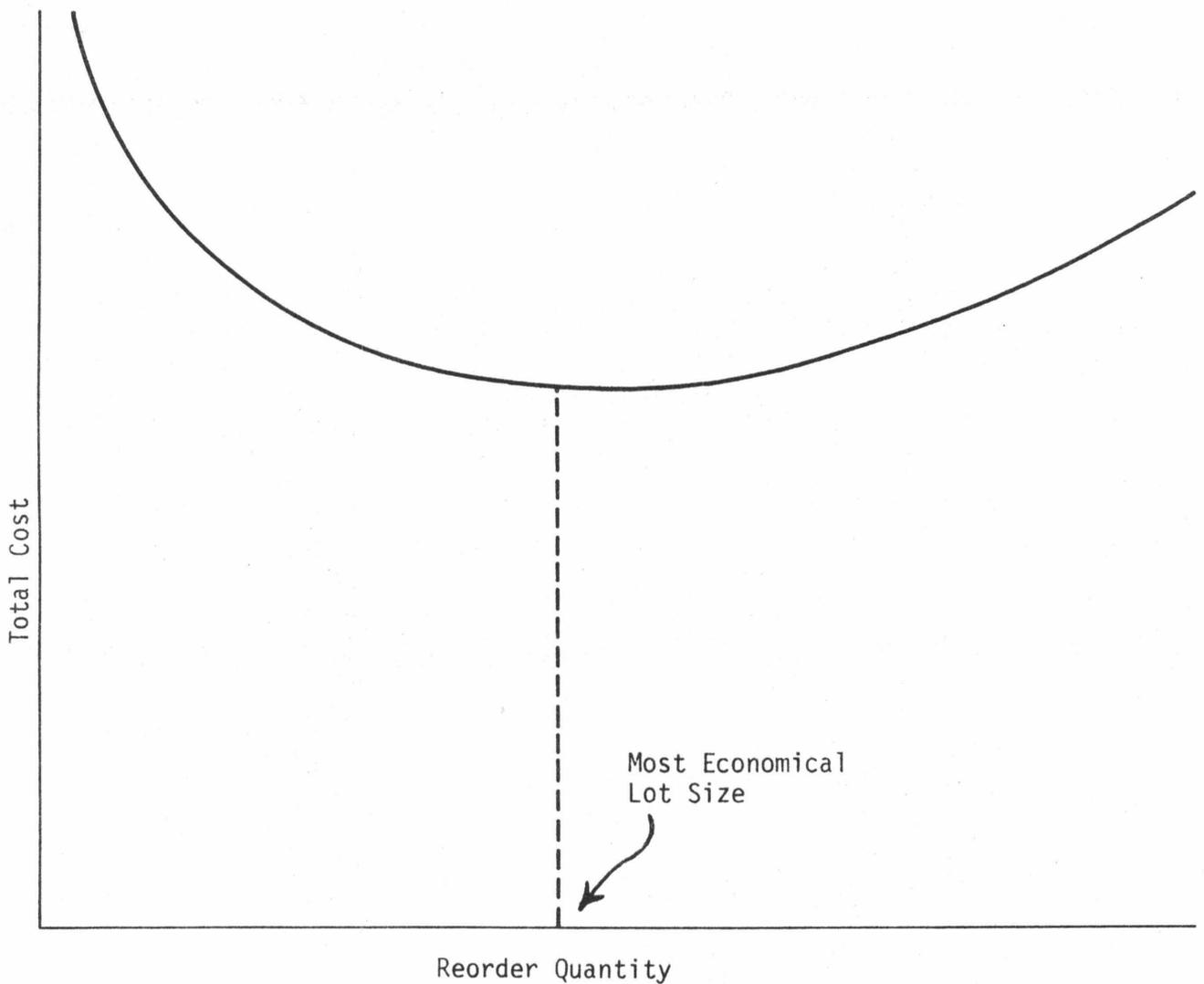
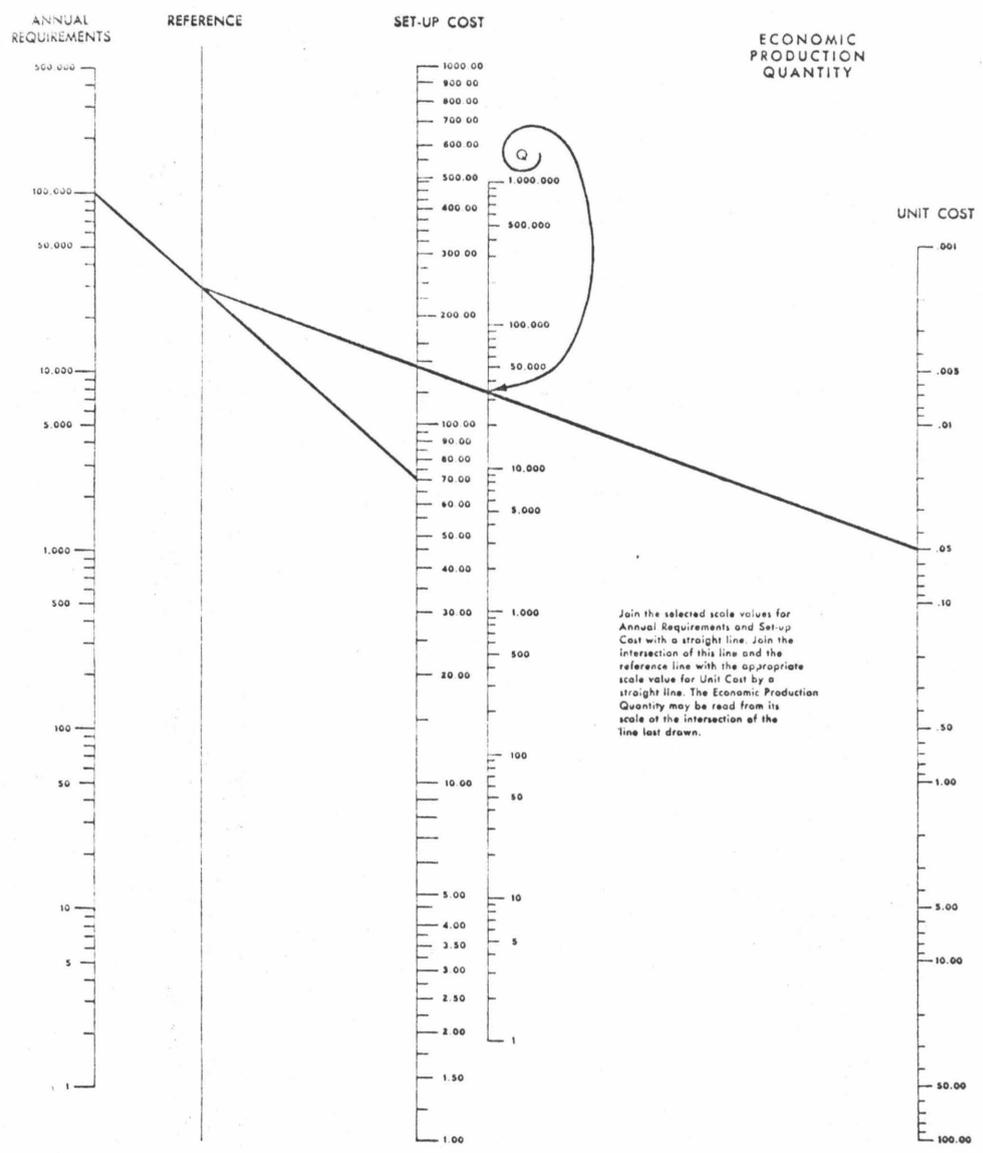


Figure 3 - Total Inventory Costs

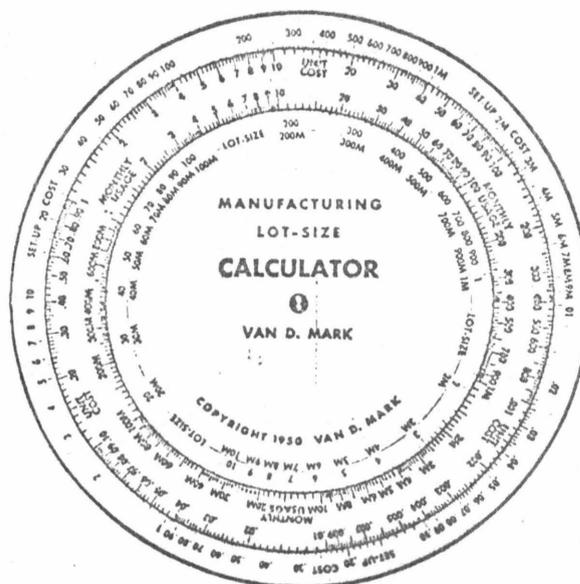
If company policy is to hold operating costs at the lowest possible level, the lot size should be selected which gives the lowest total inventory cost. Any lot sizes which are larger, or smaller, will cost more money. There are many ways to find the best lot size (slide rule, charts, tables, or calculations). Shown below is a so called "nomograph" chart for determining best lot size. It is good only under conditions where the same carrying cost percentage used in preparing the chart applies:

Nomograph Solution



Source: International Business Machines Corp.

Figure 4



Courtesy: VanDeMark, Inc.
2914 Industrial Lane
Garland, Texas 75238

Figure 5

Shown here is a circular slide rule for calculating the best lot sizes. Unless there are a large number of lot sizes to be determined at frequent intervals, the calculation method may be the best. When determined, this figure is entered in Block 14 on the inventory control card. Calculation for lot size is made as follows:¹

See exhibit p 93

$$\text{Best lot size} = \sqrt{\frac{2 \times \text{sales forecast} \times \text{setup cost}}{\text{carrying cost}}}$$

Sales and carrying cost are normally based on one year for ease of calculation and to obtain better average values.

The question of when to order is a little more difficult to handle. It may aid in understanding the problem by drawing another chart as shown below:

¹See Appendix for derivation.

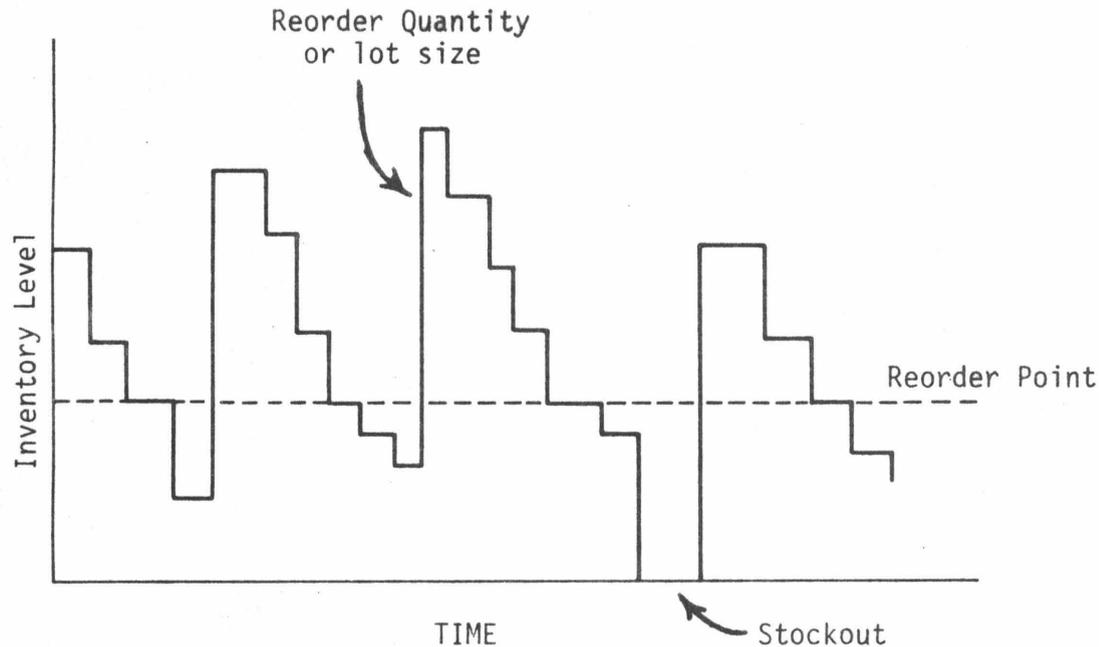


Figure 6 - Chart Representation of Reorder Point and Reorder Quantity

It is assumed that the lead time (time to prepare a production order, release the order, and manufacture the lot) is fairly constant but that the sales demand varies from day to day and week to week. If lead time for replenishment varies greatly, reorder points may be established using averages. Such a process may introduce considerable error, however, in computing safety stocks. More sophisticated computations are available in the bibliography to handle this condition. An order is placed when the stock on hand reaches the reorder point (block 13 on the Inventory Control Card). The reorder point is that quantity obtained by adding safety stock to the amount of sales expected during the lead time. The safety stock provides a buffer to prevent stockouts in periods when sales are higher than anticipated.

There are a number of ways by which a satisfactory quantity for safety stock level can be calculated. One of the easiest methods is through the use of a service level. Service level may be defined as the percentage of stockouts to total orders which management is willing to accept. This policy recognizes that we do not want any item stockout when desired by a customer, but that excessive stocks would be required to give such an assurance as shown in Figure 7. Frequently the manager may state that his inventory policy requires a 90 percent probability of no stockout. This statement is very similar to that made by weather announcers in which they refer to a 90 percent probability of rain. Such a policy means that, unless the business situation, sales, or customer attitudes change, he expects that, out of 100 orders received, an average of 90 will be filled from stock on hand.

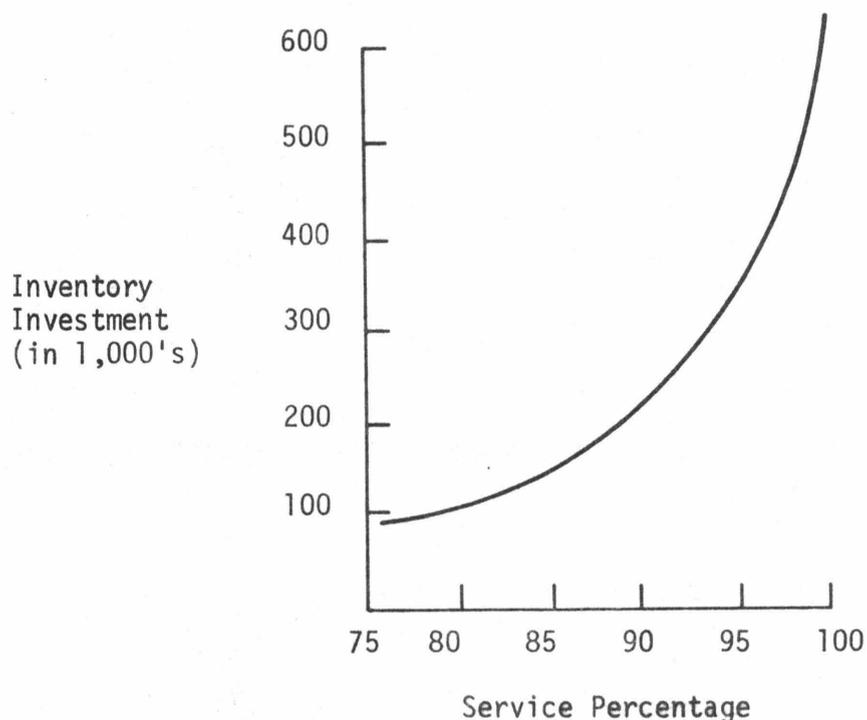


Figure 7 - Inventory Investment for Various Service Levels
(Note that the additional inventory required to improve service becomes enormously greater in moving to very high levels of service.)

The procedure for finding reorder point is as follows:

- 1) If sales are relatively constant:
 - a) Average the sales for each item over some convenient period of time. This will be used as a rough forecast of future sales for a similar period.
 - b) Find replenishment lead time for that item.
 - c) Using the period forecast from paragraph "a" above, find out what sales are expected during lead time from paragraph "b."
 - d) Using past historical data, find out how much sales have varied from forecasts during past periods equal to replenishment lead time. Average these variations.
 - e) Locate the correct "factor" in the table below, Figure 8, to correspond to desired service level. Multiply this factor times the average difference obtained in paragraph "d" above.
 - f) Add the safety stock obtained above and the forecasted sales during lead time. The resulting total will be used for reorder point.

Service Level or Assurance of No Stockout	Multiplier Factor
50%	.00
55%	.15
60%	.31

65%	.49
70%	.65
75%	.84
80%	1.05
85%	1.30
90%	1.60
95%	2.06
99%	2.90

Figure 8 - Factors of Determining Safety Stocks

Example of reorder point calculation: A query to production found that replenishment lead time is two weeks for a normal order. Furthermore, sales are totaled at the end of each week.

<u>Time Period</u>	<u>Actual Sales</u>	<u>Forecast (Avg. Sales)</u>	<u>Difference Between Forecast and Actual Sales</u>
week 1+2	1000	988	12
3+4	1000	988	12
5+6	800	988	188
7+8	950	988	38
9+10	1100	988	112
11+12	850	988	138
13+14	975	988	13
15+16	1000	988	12
17+18	1100	988	112
19+20	<u>1100</u>	<u>988</u>	<u>112</u>
	9875		749

Figure 9 - Sales and Forecast Data

$$\text{Average sales during replenishment lead time (2 weeks)} = \frac{9875}{10} = 988$$

$$\text{Average difference between sales and forecasts} = \frac{749}{10} = 75$$

$$\text{Usage during lead time} = 988$$

$$\text{Safety stock (average difference x factor)} = 75 \times 1.60 = \underline{120}$$

$$\text{Reorder point for 90 percent service level} = 1108$$

The example given is valid where the general level of sales is relatively constant. If there is a trend up (or down) a different forecasting method may be required. Only two of the numerous methods available will be included here. These methods are:

- 1) Projection Forecast - Draw a chart showing past sales and the time period involved. Then draw a line which most closely fits the sales as marked on the chart:

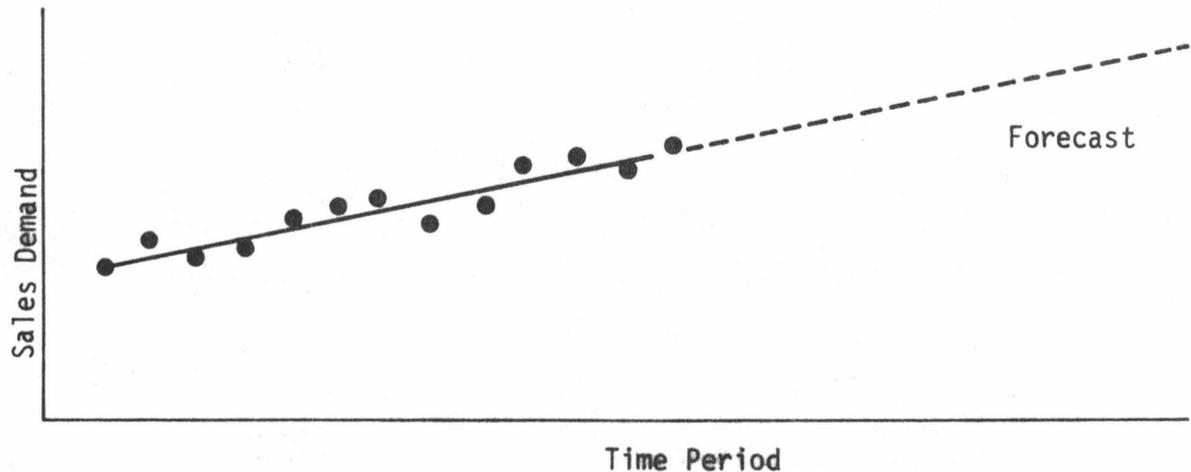


Figure 10 - Forecast Using Chart

The reorder point and lot size are determined by using the forecasted sales from the line drawn. Differences between sales and forecast for calculating safety stock are found from the difference between the line and the points plotted.

- 2) Moving Average Forecast - Instead of using the total average of past sales for a forecast of coming sales, an average using only a constant number of the most recent months may be used. For example, we might average only the last four periods. In the data given above the average would be (using most recent four period sales):

<u>Week</u>	<u>Sales</u>	
13+14	975	Forecast = $\frac{975 + 1000 + 1100 + 1100}{4}$ = 1044 (average for last four time periods)
15+16	1000	
17+18	1100	
19+20	1100	

instead of 988 which was the average using all sales data available. The next period a new forecast would be made using the most recent sales figure. Any number of periods can be used to obtain the average, however, a shorter number may be desirable when a sharp trend exists.

In all of the forecasting procedures, periodical updating and accuracy checks are needed.

The production lot sizes in some kinds of manufacture may be dependent upon the size or capacity of the equipment. For example, batch operations

may depend on the volume of mixing containers. Where the lot size can be easily varied, calculations to obtain best lot size may appear as shown in the following example:

Annual Sales = 10,000 items

Setup Costs for each new lot = \$25.00

Carrying Costs per year per unit = 10% of the unit cost

Unit Cost (materials + labor) = \$1.81

$$\begin{aligned} \text{Best Lot Size} &= \sqrt{\frac{2 \times \text{annual sales} \times \text{setup cost}}{\text{carrying cost}}} \\ &= \sqrt{\frac{2 \times 10,000}{.10 \times 1.81}} = 332 \quad \text{Use 330} \end{aligned}$$

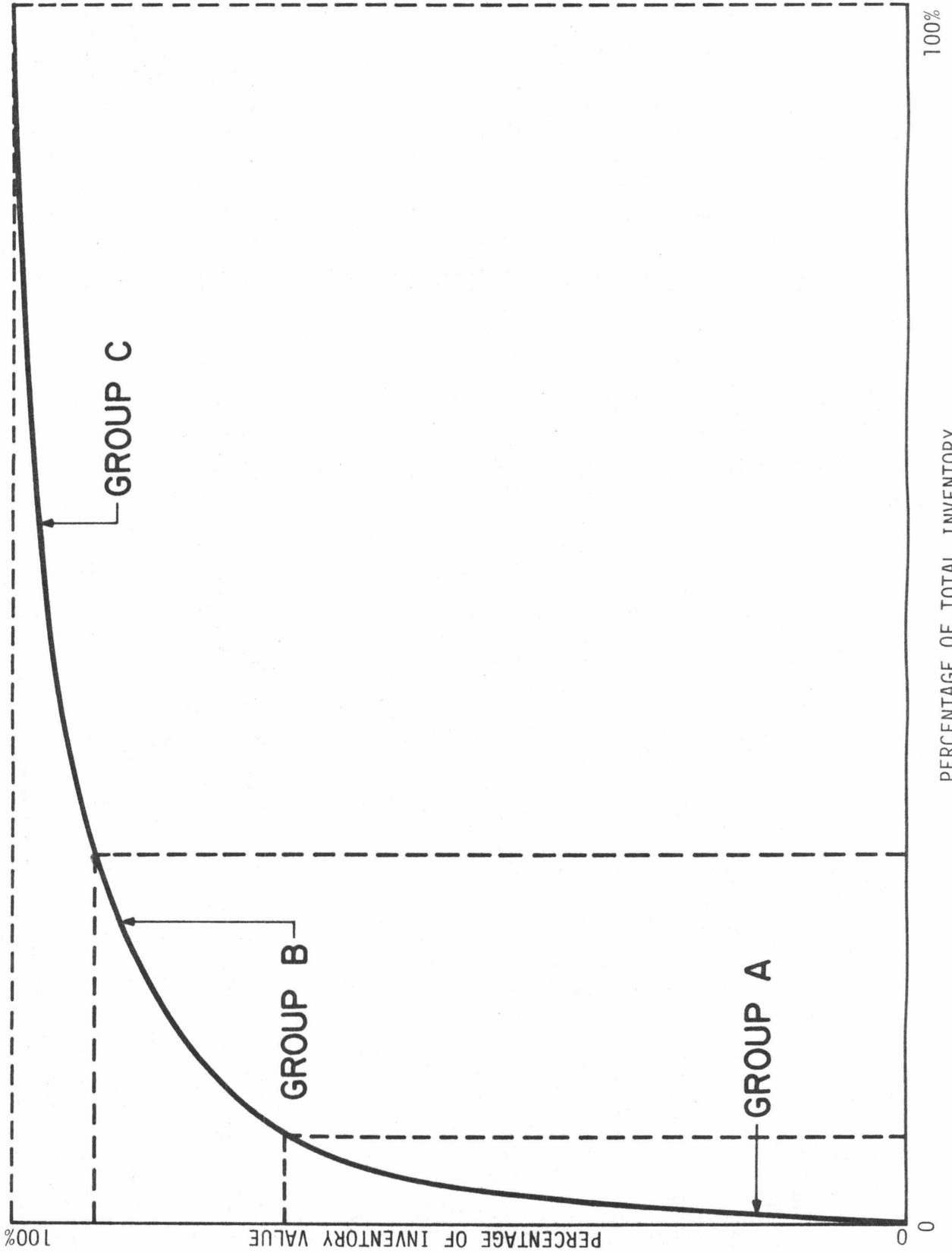
Thus we have developed in the above steps a means of determining lot size (how much to order), usage during lead time and safety stock (when to reorder), and how to monitor the system and maintain records.

An important concern of management is how well inventory control is performing and whether its efficiency is improving or going down. Yardsticks to measure performance constitute a quick means of providing this information. Some yardsticks available consist of ratios or indices while others may be cumulative totals prepared at regular intervals by clerical personnel such as:

- 1) Inventory Turnover = $\frac{\text{total sales}}{\text{average value of inventory}}$
- 2) Stockout Ratio = $\frac{\text{number of orders out of stock}}{\text{total number of orders}} = 1 - \text{Service level}$
- 3) Weighted Stockout Ratio = $\frac{\text{dollar value of stockouts}}{\text{total dollar sales}}$
- 4) Performance Ratio = $\frac{\text{orders behind schedule}}{\text{total orders}}$
- 5) Ratio of Inventory Costs = $\frac{\text{total inventory costs of all kinds}}{\text{total dollar sales}}$

Although the above procedures are greatly simplified approximations of much more complex computer applications, they still involve a significant amount of clerical work. Following are some steps which can further reduce the workload while still giving acceptable results.

The "ABC" method can be used to analyze inventory to reduce the work load. This procedure divides inventory items into three groups on the basis of value as shown in Figure 11. In most inventory situations, it is found that a few products (group A) account for the greater cost, the bulk of the items (group B) accounts for a smaller amount of the total cost, and a large number of items (group C) accounts for a small proportion of the



PERCENTAGE OF TOTAL INVENTORY
Figure 11 - ABC Analysis

inventory costs. The real payoff of any improvements occurs in the group A items. Improved controls can be used on group B and C but will result in much less significant savings. Therefore, management efforts should be concentrated on those items in group A. Record keeping and procedural computations for group B and C may be much less detailed. In other words we may run large safety stocks in group C and check records less frequently because the added inventory carrying loss is low. However, we watch items in group A very closely. This step alone greatly reduces the total clerical workload of system control.

The second shortcut method is to classify inventory items into families. A family is any group of products which have similar sales, costs and production requirements. Reorder point and lot sizes can be calculated for the family and then applied individually to each item in that family. Using values obtained, the perpetual inventory cards are employed in the usual fashion. Such a shortcut is feasible because there is a range for both lot sizes and reorder points through which there is little change in total inventory costs. If desired, a trial and error method of calculating total costs can be used to determine the width of this range. (This test is referred to as a sensitivity analysis.)

Comments Relative to Models Used

This article is a much simplified, rough approximation of several well known mathematical models used in inventory control. Several assumptions have been made to keep the application of the techniques easy. These assumptions may or may not be valid in specific situations. This section will present the more important model concepts for those who would like to see the justification for steps presented earlier. For a more precise approach, the nature of resupply lead time and customer demand distribution must be determined. Usually the normal, poisson, or negative exponential probability distributions have been found to fit typical inventory demands. Finding the correct distribution can be accomplished by comparisons with theoretical distributions using Chi-square or Kolmogorov-Smirnoff tests.

In the steps given, resupply delivery lead time is assumed to be constant and demand normally distributed, again for simplicity and the fact that many situations are reasonably close to this assumption.

The cushion or safety stock against stockouts is given by the expression:

$$CS = n \cdot \sigma_D$$

where

n = value, determined from probability tables, needed to assure the desired service level.

σ_D = standard deviation of demand during lead time.

The factors for determining safety stocks in Figure 8 were obtained by multiplying "n values" from the normal probability tables by 1.25 since, for the normal distribution, standard deviation may be estimated by:

$$\sigma_D = 1.25 \text{ MAD}$$

$$\text{MAD} = \frac{\sum |D_i - E_i|}{N}$$

where

D_i = actual sales per stock replenishment period, i , for an extended number of periods N .

E_i = forecast for period i .

If resupply lead time cannot be considered a constant, the following formula applies:

$$\sigma_D^2 = \bar{L} \sigma_d^2 + \bar{d}^2 \sigma_L^2$$

where

\bar{L} = mean lead time in days.

σ_L^2 = variance of lead time.

\bar{d} = mean demand per day.

σ_D = variance of demand during lead time.

Reorder is placed each time inventory on hand is depleted to the reorder point:

$$\text{ROP} = \bar{d}L + n \sigma_D$$

Best lot size was obtained by taking the first derivative of the total inventory cost equation:

$$\text{TIC} = \frac{D}{Q} C_S + C_U D + C_H \frac{Q}{2}$$

where

D = demand rate.

Q = lot size.

C_S = cost of placing or receiving an order.

C_H = cost of carrying a unit of inventory.

$$\frac{d(\text{TIC})}{dQ} = -\frac{DC_S}{Q^2} + \frac{C_H}{2}$$

$$Q_0 = \sqrt{2DC_S/C_H}$$

The nomograph and slide rule shown perform the same function as that shown in the last equation.

RETURN TO: R. J. CRAIG, IEOR DEPT., VPI & SU, BLACKSBURG, VA. 24061

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