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In order to establish a sound basis for considering inventory control a clear understanding of our goals is necessary. In establishing such a basis this discussion will review, first, the reasons for having an inventory and, second, the objectives that we wish to obtain through control.

INVENTORY CONTROL IN PERSPECTIVE

BUSINESS REASONS FOR HAVING INVENTORY

The most apparent reason for having inventory is to service quickly customer demand for goods. The following items set forth some of the other reasons that may not be as immediately apparent:

- Inventory provides a buffer, or working margin, to separate the various steps in the process of buying raw material, manufacturing goods, storing goods, and selling them.
- The ability to hold inventory allows companies to level the rate of production, thereby obtaining manufacturing economies. In cases where raw material supply is seasonal, inventory storage of raw material is necessary to obtain a regular production rate. When sales are subject to seasonal fluctuation, the ability to carry a finished-goods inventory will allow stability of the production rate.
- Economies in purchasing and shipping are available to companies able to hold inventory.
- In the case of replacement parts that manufacturers no longer produce, wholesalers or distributors may carry inventories to protect future needs of customers.

THE OBJECTIVES OF INVENTORY CONTROL

There are three fundamental inventory-control objectives. The first is a need for maintaining physical control over property. This objective is concerned primarily with protection against loss, damage, and theft, and maintaining adequate information concerning how

much of what is stored where. These are problems relating to inventory storage and the documentation of inventory movement.

The second major objective of inventory control is the financial management of the inventory investment. This aspect of financial control is concerned primarily with balancing the inventory required to support a desired level of sales activity with the availability of working capital. This requires consideration of sales methods, channels of distribution, appropriate levels of customer service, and an adequate financial reporting structure to provide comparison of actual to planned inventory position.

The final inventory-control objective is to have operating control. Obtaining this objective is concerned primarily with how much to make or buy, and when to make or buy; these are questions of optimum order quantity and optimum order point. The discussion that follows will deal primarily with the elements of these operating questions.

DEFINITION OF INVENTORY-CONTROL TERMS

In the discussion of inventory control, several specialized terms are used. To explain their application to this discussion, the following definitions are submitted:

- Lead time—the time interval that starts when the inventory record shows a need to reorder and ends when the same record shows the material ordered has been received
- Safety stock—the amount of inventory carried to provide protection from stock-out conditions during a lead time
- Available quantity—the quantity of inventory on hand and on order, less the quantity committed
- Order point or reorder point—the quantity level at which a purchase order should be issued
- Order quantity or reorder quantity—the quantity required to replenish the inventory according to the reorder quantity rule of the control system
- Usage rate—the rate at which inventory is consumed
- Economical order quantity—the order quantity that results in the lowest combined variable costs related to the separate functions of ordering and carrying inventory

BASIC CONTROL SYSTEMS

With respect to operating control over inventory, there are two basic control systems that provide answers to the order quantity,

order-time questions. The fixed order system is one of the two basic approaches. Under this system a fixed quantity is reordered whenever the inventory drops to a predetermined level or minimum. The time interval between orders will vary according to the rate of usage. The fixed order system is usually advantageous when it is feasible to have continuous monitoring of stock levels. When the demand for an item is subject to seasonal variation or significant random fluctuation, the continuous monitoring ability is particularly important for protection against stock-out occurrences.

The second basic system is the periodic reorder system, under which inventory is reordered at regular time intervals. The quantity of the reorder will vary according to the amount consumed since the last reorder. The periodic reorder system is usually effective with high-value items that economically justify frequent reorder of inventory, and for items that have relatively stable and dependable demand. For high-value items, the cost of purchasing is often insignificant compared to the cost of carrying the stock, making frequent purchase feasible. The more dependable the demand for inventory items, the less the danger of stock-out occurrences. Periodic reordering systems are also effective in the case of low unit value items when the quantities purchased are large in relation to the normal usage, making frequent reordering unnecessary. The cost of frequent reorders of low unit value items is usually high in relation to the cost of carrying the stock.

A common variation of these two methods is the base-stock system. The basis of this system is a review of inventory levels at specific intervals, but reordering only when inventory is at or under established minimum levels, and then ordering in a quantity sufficient to bring the inventory up to a pre-established maximum level. Both the order quantity and the order interval will vary under this system.

Generalized systems of inventory control are occasionally used. A typical system of this type is the dollar-limit approach which establishes specific dollar limits on the amount of stock allowed in inventory. These dollar limits are usually applied to groups of items because they are too costly to maintain if controlled by individual items. These limits are usually established on the basis of inventory turnover objectives. This type of control has several important disadvantages; an over-stock in one item results in an under-stock of another item, economic purchase quantities or manufacturing quantities are fre-

quently missed, and adjustment for changes in price level or business activity is often overlooked.

Inventory-control systems designed for maximum economic precision are usually more expensive to operate than a system of generalized control. Considering this, it is desirable to apply more sophisticated control systems to those areas of the inventory where the greatest benefit can be obtained—the high use-value inventory items. An analysis of inventory activity usually shows that a minority of the items are responsible for a major part of the total value movement; that is, the unit value times the quantity handled. Analyzed on this basis, it is common to find that 20 per cent of the inventory items account for 80 per cent of the annual dollar movement. A 10 per cent improvement in the management of the high dollar movement items can produce a greater total saving than a 30 or 40 per cent improvement in the management of the low dollar movement items. When considering the cost of control, it is apparent that similar emphasis need not be placed on each item in the inventory.

ESTABLISHING REORDER POINTS AND REORDER QUANTITIES

MATHEMATICS

Developing the most effective solutions to problems of all kinds requires a planned, systematic, and analytical approach to the elements of the situation. This can be called a disciplined approach. The use of mathematical techniques in this regard is simply an extension of the disciplined approach by stating the problems in terms of mathematics. Inventory problems lend themselves to statement in these terms. Once stated mathematically, formulae often can be employed to develop optimum answers under given conditions. Mathematics can be applied to inventory-control problems in degrees varying from electronic computer programs to simple formulae determining reasonable reorder points and reorder quantities.

In establishing reorder quantities and reorder points, the following factors must be considered:

- Anticipated or forecasted usage
- The cost of placing and handling orders
- The cost of carrying inventory
- Order lead times

- Safety stock
- The unit cost of the inventory item

These items can be related and considered from a quantitative standpoint through the use of mathematics. In addition, mathematics can provide valuable assistance in establishing a forecast of usage and in determining the most practical safety stocks to carry. In the application of mathematics, as in inventory controls generally, it may be practical to limit its use to the more important use-value inventory items.

DETERMINATION OF REORDER POINT

The determination of the reorder point is the answer to the question *when to make or buy,* that is, at what inventory level should action be taken to replenish stock? Several factors should be considered, estimated, or evaluated to arrive at a sound basis for decision.

- What is the estimated rate of use?
- What is the estimated lead time?
- What quantity of safety stock should be carried to protect against stock-outs resulting from variations in anticipated lead time and usage rates?

Developing a usage forecast is the first step that should be taken in establishing reorder points. Methods of usage forecasting may vary from applying scientific tools of statistical forecasting to management estimates. In many cases, the sales department makes a projection with the aid of the advertising manager and, if available, an economic or market analyst. One or more major customers may be consulted for an expression of intent. The inventory-control group may make a review of historical data to extrapolate trend and seasonal patterns.

A careful study of lead times would include consideration of internal processing as well as supplier and transportation time requirements. Time estimates can be made for the internal work flow related to purchase requisitions, purchase order approvals, purchasing department routines, receiving and inspecting procedures, and movement to storage. Analyses can be made of the dates at which orders were mailed to suppliers with corresponding dates at which goods were received for unloading. In some cases, suppliers should be consulted to determine delivery policies and scheduling practices. Methods of transportation and related time requirements should also be reviewed.

Reorder points, established as the product of lead time and usage rate would result in stock-out conditions occurring in 50 per cent of the instances before the reorder stock is received, that is, stock will arrive *after need* just as often as *ahead of need* because of deviations in planned lead times and usage rates. If this level of performance is not satisfactory, then it becomes apparent that a cushion of extra stock should be provided to protect against unfavorable variations in these planned factors. This extra stock is usually referred to as safety stock and results from reordering for arrival in advance of anticipated need. A simple statement of reorder point quantity can then be expressed as:

Reorder point = (lead time × usage rate) plus safety stock.

Many factors influence the appropriate choice of safety stock quantities, some are difficult to express in quantitative terms. Long lead times result in greater probable time variations; consequently, long lead times tend to require more safety stock than short ones.

The variation in usage rate is a major influence on safety stock allowance. Usage during a given period of time is a product of the number of demands and the quantity or size of the average demand. When the average number of items per sale is small and the number of sales or demands is large, less safety stock is required than when the converse is true.

The reorder frequency also has an influence on the amount of a reasonable safety stock. The more often reorders are placed, the greater the stock-out possibility in a given period of time because the stock-out level is approached more frequently. Consequently, as the frequency of reordering increases, the safety stock must be enlarged.

In establishing the size of the safety stock, consideration must be given to the cost of carrying this inventory. These costs include interest, obsolescence, insurance, taxes, and storage.

Quantitative values can be established for the factors previously discussed as having an influence on a proper safety-stock quantity. A formula can be used to relate these cost and probability factors to establish safety-stock quantities. However, the effect of stock-out occurrences on customer good will is an important factor to consider when setting safety stocks, and it is very difficult to specify in quantitative terms for inclusion in a formula. Safety stock quantities can be developed that should provide a desired level of customer service,

that is, the per cent of the customer demands that can be filled from stock on hand. This is done with data and techniques developed through statistical forecasting, and is outside the scope of this discussion.

From a practical standpoint, most inventory-carrying business concerns would benefit significantly by a relatively basic appraisal of the factors affecting safety stock. Evert Welch in his book *Tested Scientific Inventory Control* presents a simple table which merits consideration.

FACTORS THAT SUGGEST

Large Safety Stocks	*Small Safety Stocks*
• Small number of demands	• Large number of demands
• High quantity usage	• Low quantity usage
• Long lead times	• Short lead times
• Frequent reordering	• Infrequent reordering

For each safety-stock factor, limits of *large* or *small* should be established. A review of the characteristics of inventory items against this list can result in reasonable determinations of whether small, medium, or large safety stocks should be provided.

REORDER QUANTITY

To minimize inventory investment and the related costs of acquiring and owning inventory, practical reorder quantities must also be developed. There is a common tendency to buy too much of the high-cost items, resulting in unneeded inventory, and too few of the low-cost items, resulting in too many orders and stock-outs.

In approaching a solution to the problem of inventory quantities it is essential to understand the origin of the cost of owning inventory. The first is the set-up or ordering cost, the second is the cost of carrying stock, and the third is the cost of shortages or stock-outs. There is an inverse relationship between the order costs and the carrying costs; as one decreases, the other increases. Generally, the carrying cost is more significant than the cost of ordering; it is usually cheaper to order frequently and incur high ordering costs than to order infrequently and incur high carrying costs. Annual carrying costs may range from 10 per cent to 34 per cent of the inventory value.

The result of balancing inventory costs is to arrive at an order

quantity known as the *economic order quantity.* An economic order quantity can be computed from the following formula:

$$E.O.Q. = \sqrt{\frac{2\,A\,S}{B\,I}}$$

A = order costs or set-up cost per order
S = annual sales in units
B = cost per unit
I = annual carrying cost, expressed as a decimal

Although this formula appears to give a sense of precision to the matter of economic order quantity, it is still a difficult question since there are few precise definitions of order costs or carrying costs. The formula is concerned with optimizing the variable costs, since it cannot change the investment in a warehouse or the salaries paid to warehouse supervisors.

Costs of ordering will be principally salaries, office materials, services, expediting, and handling, which tend to move in step fashion rather than in a straight line. One additional order will not have much effect on total order cost, but there is a point in a rising or falling scale of orders where there will be a noticeable change. These costs will likely be found in such departments as purchasing, inspection, accounting, receiving, stores, and trucking. In each, there will be costs that tend to vary with the number of order transactions rather than with the quantity or dollar value per purchase.

The variable costs of carrying inventory are those that vary with inventory size, such as interest, insurance, and taxes. Obsolescence, depreciation, and storage exert an influence on carrying costs, although the manner in which these costs should be applied is controversial. Since obsolescence is specific with respect to items, rather than general, many believe it should be applied selectively among the high value-use items, and as a general factor on the other classes of inventory. Since depreciation and storage both represent decisions made in the past they tend to be fixed costs unless the use of the facilities can be diverted for other purposes. The following table gives a range of values frequently assigned to the categories of carrying cost:

Interest	4 to 15%
Obsolescence and depreciation	4 to 10%
Insurance	1 to 3%
Taxes	1 to 3%
Storage	0 to 3%

The last incremental cost factor to be considered is that arising from unit cost differentials based on volume purchases. This requires a selective evaluation of those items that may be acquired at a sufficient saving in unit cost to offset the increased cost of carrying a larger average inventory.

The difficulty in establishing accurate order cost and inventory carrying cost information should not discourage the use of the economic-order quantity formula. Since the formula takes the square root of the elements of cost, the effect of errors in the values is minimized so that only small differences occur in the resulting order quantities.

INVENTORY HOUSEKEEPING, RECORDS AND REPORTS

PHYSICAL ORGANIZATION OF INVENTORY

Precise systems for establishing reorder points and reorder quantities will fail in total control of inventory unless there is a sound plan for physical management. This includes both documentation of movement and mechanical aspects of handling. There must be dependable methods for recording receipts of stock and issues from inventory with respect to internal control, accuracy, and timeliness. This includes recording transfers from one location to another and from one in-process step to another.

These matters of documentation are well known to accountants, but there are other physical aspects to which accountants may be giving inadequate attention. When stock is placed in storage it is important to identify it clearly, completely, and accurately. Improper identification can result in excessive time in locating stock, duplicate handling, lost production, and shipment of improper stock to customers.

Related to identification is the matter of systematic storage layout. The location of stock should minimize the distances that must be traveled in handling stock receipts and issues. In addition, the location should be logical to reduce the time required to find items. Accomplishing these storage objectives may require the location of items with the greatest movement near the stock transfer exits or entries, locating in close proximity items that often move as a unit, and locating similar items together.

Stock should be readily accessible. In this regard consideration should be given to the size of alleys, visibility of stock, height and depth of shelves, and the types of stock-handling equipment used. Inventory that is hard to reach requires extra handling time, is subject to damage, and may become lost stock. There are degrees of accessibility, and the fastest moving stock should be given priority in this regard.

Large storage areas and storage of large numbers of items may require a location-record file. Such a file can specify the location of each item by alley, bin, and shelf. This device may save a substantial amount of search time.

CONTROL RECORDS

There is a wide choice of methods and systems for recording stock changes. The range covers magnetic tape records at one end of the spectrum to visual bin inspection at the other. Particular methods used should be geared to the size of operation and the facilities available. The use of magnetic tape and computers is common for large concerns. For medium- and smaller-size companies, punch-card facilities or the hand-posting card may provide an adequate means for recording receipts and issues, and observing balances. In both cases, it is usually important to note the quantities on order or in production, and the quantities that may be reserved from general availability.

The use of bin stock cards can be quite adequate in situations where stock is of a non-critical nature or can be replaced quickly. Bin cards can include provision for noting receipts, issues, balance, and reorder points. Their use can be combined with a card requesting reorder which is removed and routed to the purchasing department when the stock level is reduced to a pre-established minimum.

In some control situations decks of cards pre-punched with an identification number are included in the storage location. These cards are then marked with quantities received or issued and routed to an inventory control center for inventory updating on punch-card equipment.

CONTROL REPORTS

In cases where punch-card or electronic equipment is used, it is well to consider preparation of item stock reports showing the volume of movement. This is useful information in studying the use-value

distribution of inventory, the establishment of reorder quantities, and the most desirable location of stock.

Exception-basis reports can usually be prepared at small cost whether using mechanical or manual systems. This would include information such as a report by item of stock-out or back-order occurrences, a report of items having no stock transactions for specified time periods, damage reports, obsolescence write-offs and major variations between book and physical inventories.

SUMMARY

Inventory cost is minimized by purchasing at the optimum reorder point and in the economic-order quantity. These factors take into account usage rates, lead times, safety margins, ordering costs, and inventory carrying costs. The degree of care with which these factors are applied in managing inventory items should depend on the importance of the particular item as measured by its use-value relation to other stock. Inventory-control decisions based on turnover alone do not necessarily result in the most profitable inventory condition. Turnover does not quantitatively consider the factors influencing appropriate reorder points and quantities; it merely attempts to regulate quantity in relation to sales, and when applied to groups of items can result in overstock of some and understock of others.

Inventory-control efforts must include careful consideration of the mechanical aspects of inventory handling and the documentation of inventory movement. The specific methods that should be employed will vary with the size of the organization and the facilities available. The objectives in all cases should be the same: sound internal control, accuracy of information, timely action, and effective physical facilities.