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MANAGING INVENTORIES—REORDER POINT SYSTEMS

Inventories account for a significant percentage of the current assets of companies in industries ranging from hospitals and restaurants to manufacturing, wholesaling and retailing firms. So, managing inventories is often the key aspect of improving a firm's working capital position and its return on assets. An inventory-management system is a set of procedures for managing the items in inventory. The focus in this note is on one such system—the Reorder Point System. Other inventory management systems and concepts have been addressed in separate technical notes.

The selection of a system for an item or group of items depends, in part, on the *type of demand* experienced by the item. There are two basic types of demand, forecast demand and scheduled requirements demand.

Forecast Demand[1]

Orders may arrive at unpredictable intervals and call for quantities whose magnitude cannot be precisely predicted ahead of time. Examples of such orders include service parts orders, distributor orders placed upon a factory warehouse, or customer demand at a retail facility. When the arrival time and quantity required for each order are unknown, stocks must be held in anticipation of demand. The principal management concern is to maintain the proper quantity of each item held—given that too much stock absorbs a disproportionate share of the firm's assets, and too little stock reduces customer service. Forecasts are thus necessary and must be based on historical order rates and anticipated changes in future usage.

One approach to forecasting the next period's demand is based upon the prior period's demand. A simple average of historical data can be calculated and used as an estimate of the next period's demand. Such an averaging approach smoothes the random fluctuations and provides a usable estimate when demand is stable. More frequently, however, demand is growing or declining over time. In such situations, the historical data is analyzed for trend movements, using moving average techniques or least squares regression techniques. These two

[1] Also called "independent demand" by some authors.

techniques require considerable quantities of historical data and numerous computations. For companies with a large number of items to forecast on a frequent basis, the cost of data storage and computational time for such analyses would be prohibitive. For recurring forecasts of large numbers of items, the exponential smoothing technique provides forecasts at a much lower cost.

The day-to-day planning and control of inventory under forecast demand conditions is accomplished by a stock-replenishment planning system. The inventory planning and control objective is to keep enough stock on hand to cover expected demand for each item between successive replenishment orders (cycle stocks) and to provide additional stock as protection against unpredictable demand variations (safety stocks). By checking the level of stock on hand and on order every time an item transaction occurs, or by periodically reviewing inventory levels, a decision can be made as to whether there is enough inventory to cover projected average usage during the expected stock-replenishment lead-time.

The key tasks in a stock-replenishment planning system are to:

1. Project item demand, using statistical forecasting methods;
2. Calculate replenishment order quantities and the time of reorder execution by considering quantity discount and freight rate schedules, ordering and receiving costs, inventory holding costs, and service performance standards;
3. Determine safety stock requirements, based on replenishment lead time, a specified level of order service, and forecast demand; and
4. Report on a timely basis the stock status and performance history of each item of inventory.

Scheduled Requirements Demand[2]

Inventory systems may be managed based on complete knowledge of the timing and quantity of future inventory withdrawals. This knowledge is derived from a predetermined schedule of the firm's production and/or shipping requirements. Examples include purchase orders for materials and parts to meet a firm's customer order schedule or shop orders calling for the fabrication and assembly of finished goods built in advance of a seasonal peak in customer demand, or shipping orders that will place finished products in distribution warehouses on a known schedule. Inventory-stock withdrawals are calculated in advance according to a known backlog of orders. This type of demand is called scheduled-requirements demand.

Analysis of a shipping schedule for final products produces a detailed list of all of the raw materials, subassemblies, and parts needed and the time at which they are needed. This analysis is called "exploding" the master schedule, and the requirements generated are called "time-phased requirements." The delivery of the purchased items or the completion of the fabrication

[2] Also called "dependent demand" by some authors.

and subassembly work required for final assembly can be planned precisely. The receipt of purchased and manufactured items at each stage of production is timed to coincide with specific needs as derived from a preset production plan.

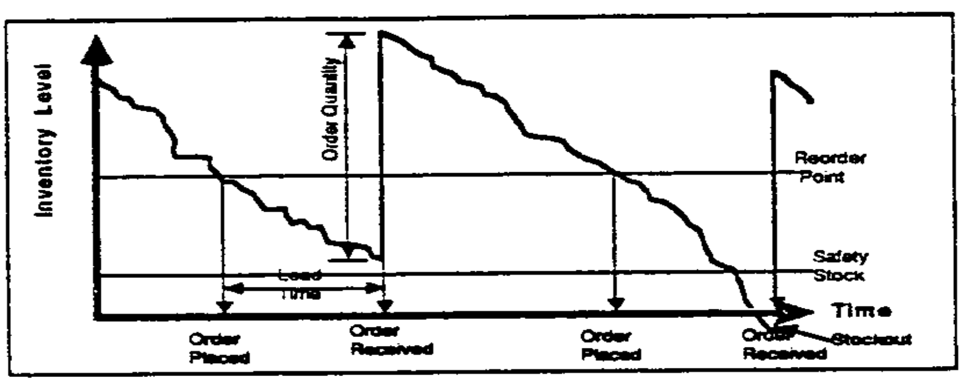
The day-to-day process of determining time-phased requirements and preparing action documents to meet these requirements is called material-requirements planning (MRP). Because items are ordered to match discrete period-by-period planned usage rates, the need for buffer stock is reduced considerably compared to the forecast demand situation where order uncertainties must be covered.

Stock Replenishment Planning: Reorder Point System

The reorder point system specifies that a fixed replenishment order quantity (ROQ) of an item be ordered whenever the amount of inventory for the item first becomes less than or equal to a reorder point (ROP). Thus, for an item being controlled with this system, two numbers, the ROQ and the ROP, completely determine when to order and how much to order. **Figure 1** is a graph of the inventory level for an item being controlled with a ROP system.

When the amount of goods on order and on hand falls to the reorder point, an order of size ROQ is placed. The on-hand and on-order amount is called "inventory position." The ROQ can be determined by past practice, by judgment, or by using an economic-based formula. In any case, it is a fixed amount that typically does not change, except perhaps after an annual review. This order is assumed to arrive after the lead-time passes, thus increasing the inventory by the ROQ amount.

Figure 1: Reorder Point System



The reorder point (ROP) is set equal to the expected demand during the lead-time plus some amount of safety stock. The amount of safety stock can be determined through statistical analysis or by judgment.

ROP = Expected Demand During Lead-Time + Safety Stock

In this system, the time between replenishment orders may vary, depending on how the demand varies, but the amount ordered typically remains fixed. The average number of orders per year is the annual requirement divided by the reorder quantity. This system requires that the inventory level for an item be reviewed whenever a demand occurs.

The ROP system is occasionally referred to as a two-bin system because one way of implementing the system is to keep the SKUs in two bins. All demands are initially satisfied from the first bin. When this bin is empty, it is time to reorder the item. During the reorder lead-time, using items in the second bin satisfies the demands. Thus, the amount of stock kept in the second bin equals the reorder point quantity.

The ROP system is a very simple system to understand and implement. The reorder quantities and reorder points should be reviewed periodically and set in a systematic, rational manner. Unless modified, the system does not allow joint ordering from suppliers where several items can be ordered at the same time from one supplier.

Moreover, in order for this system to work well, the demands must be uniform over time. Therefore, unless the system is modified in some way, it will not function well when demand is highly seasonal or trending up or down.

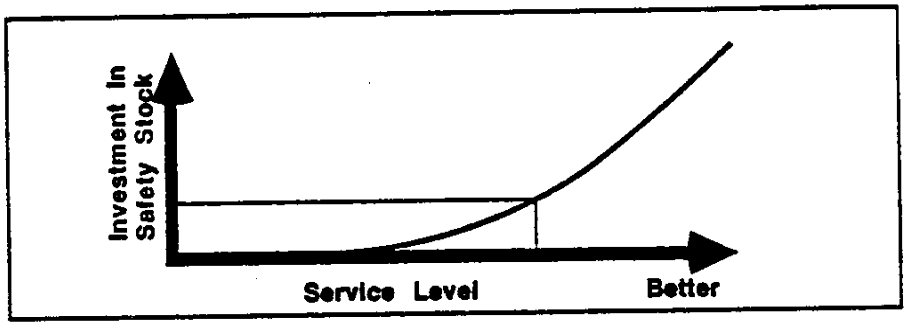
The quantity ordered in a Reorder Point system can be determined using the Economic Order Quantity (EOQ) which has been discussed in a separate technical note.

Decision Rules for Determining Safety Stocks

In the management of inventory, when the demand cannot be forecast precisely, holding extra inventory, called safety stock, may be necessary in order to protect (as a buffer) against the uncertainties of demand on the unreliable delivery of the orders that have been placed with a supplier or the firm's internal operation. Conceptually, the correct amount of money to invest in safety stock for an item is a tradeoff between the cost of stocking out and the cost of holding inventory. Practically, the cost associated with a stock out is usually very difficult to specify. Instead, organizations typically identify some measure of service and then set safety stock levels by specifying a constraint regarding the identified measure of service.

Figure 2 displays the usual relationship between the investment in safety stock and the service level. It is a managerial decision as to where on this curve the organization wants to be. By specifying the service level, the organization is implicitly trading off the costs of stocking out and the costs of carrying inventory.

Figure 2: Tradeoff between Safety Stock and Service

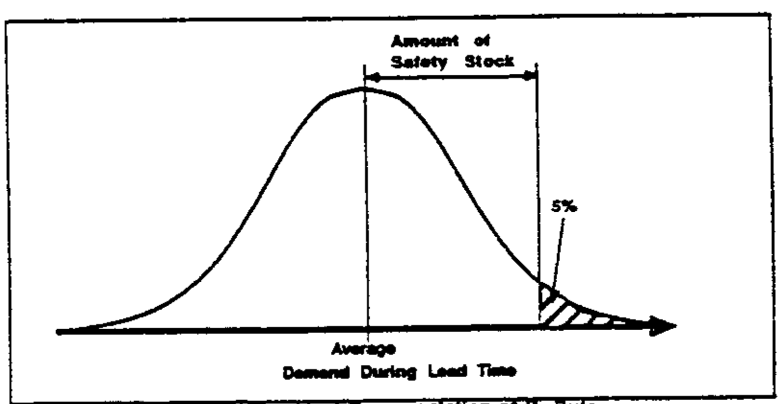


Setting Safety Stock Levels Using Percent of Replenishment Cycles with No Stock Out

In this section, we will give the formula and discuss the rules that will constrain service consistent with a target measure of service P_1. P_1 is specified: percentage (P_1) of replenishment cycles with no stock out occasions. The probability distribution of the demand during the lead-time is assumed to follow a normal distribution.

To use this rule, the organization must specify the desired percentage P_1. For example, if P_1 = 95 percent, then on average 5 percent of the replenishment cycles will experience a stock out. **Figure 3** shows a distribution of demand during the replenishment lead-time and an amount of safety stock that would yield a 95 percent service level.

Figure 3: Graphical Representation of P_1 Rule



In this situation, if the standard deviation during the lead-time is given by σ_u, then the formula for safety stock is given by:

$$\text{Safety Stock} = ss = k\sigma_u$$

where k is the "service factor" associated with the value of P_1. The value of k tells us the number of standard deviations of protection to have for safety stock. The following table shows the value of k for various P_1 service levels. This table is the familiar table of areas under a normal probability distribution and standardized normal deviates.

Values of k for P_1

P_1 (Percentage of Replenishment Cycles With No Stock Out Occasions	k (service factor)
50	0.00
60	0.25
70	0.52
80	0.84
85	1.04
90	1.28
95	1.64
96	1.75
97	1.88
98	2.05
99	2.33

Microsoft Excel can be used to determine a specific k service factor from a given P_1 and vice versa. To do so, use the following functions:

$$k = \text{NORMSINV}(P_1/100)$$

$$P_1 = \text{NORMSDIST}(k) * 100$$

As an example, suppose an item has a lead-time of one month, and the probability distribution of demand during the lead-time is normally distributed with a mean of 100 and a standard deviation of 25. If management specifies a 90 percent service level, then the amount of safety stock is:

$$ss = 1.28\ (25) = 32 \text{ units}$$

If a reorder point system is being used to control inventory, the reorder point (ROP) is the average demand during the lead-time plus the safety stock. Thus for our example:

$$ROP = 100 + 32 = 132$$

That is, a reorder quantity would be ordered when the inventory position (on-order and on-hand) level reaches 132.

Setting Safety Stock Using a Fixed-Time Supply

One common rule found in practice for setting safety-stock levels is to use a fixed-time supply, e.g., a one-month supply. While this rule is very simple and easy to understand, it does not directly relate to common measures of service used in business. Furthermore, it typically results in significantly different measures of service for different items. For example, consider two items with identical annual demands, lead times, and order quantities, but one item has more uncertainty of demand during the lead-time; its standard deviation of demand during the lead-time is greater. A fixed-time supply of safety stock would result in the same amount of safety stock being held for both items, but clearly significantly, different levels of service would be provided.

As an example of how we can work backwards from a given safety stock amount to compute the implied service levels, consider the example used earlier:

R=1200 (annual requirements)
Q=300 (order quantity)
σ_u=25 (standard deviation of lead-time demand)

Suppose a fixed-time supply of safety stock of 1/2 month were used; then:

$$ss = \frac{.5}{12}(1200) = 50$$

The percentage of replenishment cycles with no stock outs is given by:

$$k = \frac{50}{25} = 2, so\ P_1 = 97.72$$