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MANAGING INVENTORIES: PERIODIC REVIEW SYSTEMS

The management of inventories is an important task in nearly every type of organization, from manufacturing firms to hospitals and restaurants. In many manufacturing businesses, in fact, inventory is the single largest asset on the balance sheet. Inventory accounts for nearly 40% of the current assets of the typical manufacturing company and for 50% to 60% of the current assets in wholesaling and retailing industries. Redesigning the elements of a firm's inventory management system is often the key aspect in improving a firm's working-capital position and its return on assets.

Fundamental questions come up in every inventory system—what is the appropriate order quantity for replenishment of the items recently consumed? Should we order more than we need in the near term in order to get a volume discount from this new supplier? Should we issue a factory production order for several months' supply of an item in order to spread large machinery changeover and set-up costs across a large lot size? Should we be making more or less than our historical standard batch size because the firm's working capital costs have recently fallen sharply? How does a change in the item's manufacturing costs alter our order quantity rules in our computer-based ordering system? What are the relevant costs we should be considering?

Inventory Planning Processes

Operations managers need to understand the reasons for holding inventory and quantify the tradeoffs for their specific contexts. Although there are many formulae used to optimize (not minimize) a firm's investment in inventory, it is important to recognize that inventory decisions are made in a broader context. Effective managers do not delegate critical business decisions to a "black box" of forecasting and inventory target-setting algorithms.

In many companies, monthly cross-functional meetings ensure alignment around the inventory investment. The meetings, variously referred to as the S&OP (which stands for "sales and operations planning") or SIOP (which stands for "sales, inventory, and operations planning") review the prior month's sales against the company's revenue budget as well as the latest sales forecast and production plans of future months. The meeting participants then discuss possible corrective action, such as increasing or decreasing production if sales do not appear to align to the forecast. The participants might also explicitly decide to allow inventories to grow or shrink against plans. Sales might be managed by putting certain customers on allocation or by deciding to launch a promotion to either control or expand sales. In some companies, the goal of cross-functional alignment is extended to cross-enterprise alignment via collaborative planning, forecasting, and replenishment (CPFR).

These decisions entail significant tradeoffs. For example, at one U.S. appliance manufacturer, a decision to change the "line rate" at a facility entailed invoking "temporary layoffs" of plant workers. At a fast-growing consumer products company, a failure to quickly react to shortfalls in retail sell-through led to an excessive six-month-plus inventory investment of product sourced from China with a three-month lead time. The decisions to change purchases or production plans demand a deep understanding of the economic tradeoffs at a macro level, not just the SKU level where production-planning systems operate. While decisions should not be delegated mindlessly to computers, using computers wisely can enable better decisions. For example, a company that provided branded kitchenware to mass-market retailers invested in a new enterprise resource planning system to improve the management of its increasingly complex product line. However, the systems failed to deliver the results promised by the software provider. Upon investigation, a consultant determined that the users of the system did not understand the underlying logic for determining both the timing of orders and the amount that should be ordered: 80% of the SKUs were calculating the recommended orders based upon the system default parameters rather than ones reflecting the specific economics of the company and its products.

Ways to Categorize Inventory and Evaluate Inventory Planning Decisions

Setting appropriate inventory targets requires more than simply considering the categories used to distinguish inventories in the firm's financial records. Accounting records typically categorize inventories into four types:

1. Raw material: Components, subassemblies, or materials that have been purchased and are waiting to be placed into production.
2. Work-in-process: Parts or products in various stages of completion throughout the manufacturing operation, including raw material that has been released for initial processing and partially processed units that have had labor and overhead added and are being stored for use at a later time.
3. Finished goods: Completed goods available for sale to customers.
4. Maintenance repair and operating (MRO) supplies: Components consumed in day-to-day operations and to maintain or repair facilities and equipment.

The same physical good may be in a different category for different companies. For example, steel sheeting may be a finished good for a steel manufacturer but is a semi-finished good to a company that fabricates cabinets for consumer microwave ovens. In vertically integrated companies, what may be a finished good for one division may be a raw material to another division. This aspect explains why, in the annual reports of many companies, the balance sheet does not separate out inventories into raw material, work-in-process, and finished goods.

Categorizing inventories according to the function they provide for the firm's operations helps a manager to evaluate inventory investment planning decisions using a costing approach. Five major categories of function are:

1. *Cycle-stock inventories*: *to allow for batching of purchased goods or manufactured goods*. Cycle stock represents the average inventory carried between reordering cycles. For example, the firm may believe it is prudent to manufacture a particular item in a batch size of 3000 units even when forecast usage is 300 units per week. Any number of considerations could have driven this lot size decision of 3000 units. Another firm manufacturing the same type of item with a similar weekly demand of 300 units could choose to produce in a batch size of 600 units. The inventory that is carried between order cycles is very different. How does one assess the lot size decisions made by these two firms?
2. *Pipeline inventories*: *to provide for transit of inventory*. Pipeline stock is the inventory moving from one point to another. Some firms seek to minimize the transit time and ship with an air-express overnight mode. Another firm may be willing to experience a longer transit time and ship by ground transportation. Also, some firms take possession of inventory early—perhaps upon departure from a supplier in China—while another may not take possession until the inventory arrives at a port or even at its own factory. How does a firm make the best choice?
3. *Safety-stock inventories*: *to protect against uncertainties in supply or demand*. Because of unanticipated fluctuations in demand, one firm may hold two extra pallets of finished goods of an item, while a competitor with the same expected demand conditions could chose to protect itself against demand uncertainties by holding four pallets of the item. Which policy is better?
4. *Seasonal inventories*: *to smooth a mismatch between demand and supply*. Two firms facing a similar back-to-school business high-volume demand season could choose very different planning rules for meeting demand. Firm A might choose to produce at a constant rate during the year, building seasonal inventory in anticipation of the large demands in August. Another firm might be willing to alter its production work force during the year to match the seasonal low to high swings in demand. Which planning method is better?
5. *Speculation inventories*: *to deal with special buying circumstances.* Why do some firms speculate and buy ahead while others do not venture into this area?

Each of these five operational situations represents alternatives for dealing with the planning and control of inventories. The choices made by a firm create functional inventories that would be carried as inventory investments. Such investments may require out-of-pocket costs to a firm. For example, typical components of inventory holding costs may include:

Capital costs:	Interest on money tied up in the inventory;
Possession costs:	Insurance, property taxes, obsolescence, spoilage, deterioration, pilferage, warehouse labor, and information record keeping; and
Facility costs:	Property taxes, insurance, rental fees, maintenance, equipment, and labor.

While inventories do create inventory holding costs, there are circumstances where the economic benefits are significantly greater than the carrying costs' consequences. Volume purchase discounts may be substantial. Large scrap losses and multiple hours of set-up expenses associated with starting-up equipment can be averaged out over large batch sizes. Expensive transportation may be cheaper than the costs of inventory tied up in the transport system. Investments in better forecast information may reduce demand uncertainties and permit reduced investments in safety stock expenses.Because inventory management decisions can often involve concrete tradeoffs among a variety of cost factors, the "appropriate" decision is guided by a "cost analysis" of the various consequences.

Another useful way to categorize inventory is an ABC Classification. Each item in inventory is classified as either an A part, a B part, or a C part, often by ranking the items based on annual dollar sales. Thus, A items are considered the highest-valued items, while the C items are the least valued. It is not unusual for 10 percent of the items that are classified as A to account for 60 percent of the total-dollar value. The B items may account for 20 percent of the items while being 30 percent of the total dollar value, and C items might account for 70 percent of the items but only 10 percent of the dollar value. Thus, a business may pay more attention in terms of analysis and control to the A items than the others due to the financial implications of getting them right. This ABC classification is sometimes referred to as a Pareto Analysis or the 80–20 Rule.

Objectives in Managing Inventories

In managing inventories, there can be competing objectives. Marketing would like to have enough inventory to maximize customer service by always having products available for customers. Finance looks to minimize the investment in inventory. Because the objectives can be conflicting, operations managers must be cautious about pursuing coordination policies that contribute to the overall success of the firm. The operations manager seeks actions that allow multiple objectives to be approached. For example, in a manufacturing operation, if the time to change over from production of one product to another can be reduced, it may be possible to reduce the lot size, which reduces the investment in inventory. Smaller lot sizes could mean shorter manufacturing lead-times, which would allow customer lead-times to be reduced and that, in turn, should improve customer service. Finally, if change-over times are less, then more time can be spent producing products rather than changing over the equipment, so operating output could be increased.

The Periodic Review System

The periodic review system assumes that an item's inventory position is reviewed regularly by an inventory planner—at fixed time intervals of length *P*, e.g., weekly, monthly—and a decision is made on the replenishment order quantity *Q*. This system is sometimes referred to as a fixed-period system. Another common name for the Periodic Review System is an "order-up-to" system, because of the process rule of *"*ordering up to*"* a predetermined target level (*T*), each time the inventory review of an item is performed.

The review period, *P*, can be determined by convenience (e.g., review multiple items from a given category or supplier every two weeks), through internal practices that have historically governed the procurement process, or through analyzing the tradeoffs between the cost of ordering and the cost of holding inventory. Many organizations will use a weekly review period for its simplicity and convenience, particularly on frequently ordered items that come from a few key suppliers. An example could be the ordering of packaging and shipping containers from two suppliers. The inventory planner might review and place orders for all items sourced from supplier A on Tuesday and then do the same for all items sourced from supplier B on Thursday of each week. Such a practice establishes a purchasing routine for ordering and receiving of shipped goods. Cost models that balance the costs of ordering more or less frequently can also be developed.

In the Periodic Review System, two numbers, the review period (P) and a target level (T), coupled with information about an item's current inventory position, completely determine when to order (every P time periods) and how much of an item to order (Q). The target level can be set based on historical demand, the review period, the order lead time, and the desired service level. Q will be the amount needed to bring the inventory position to the desired target level. Because the inventory position will vary and P remains fixed, the actual order quantity Q will likely vary in successive time periods.

Calculations for Order Quantity *Q*

Figure 1 is a graph of the inventory for an item being managed with the Periodic Review System. At the review points, the sum of item's current on-hand inventory and on-order quantities less any backorders is calculated to represent the item's inventory position, (I_P):

$$(I_P) = \text{On-hand inventory} + \text{On-order quantities} - \text{Backorders}$$

The target level, T, is the desired amount of inventory to cover anticipated demand over a time interval equal to the length of the review period (P) and the supply lead-time (L). Once an order is placed, another review/ordering activity is not undertaken until P time periods later, and then the firm must wait L periods for delivery of an order quantity. Thus, the time interval for inventory planning is $P + L$ periods. It is over this inventory-planning interval ($P + L$ periods) that the firm must hold stock to meet forecast demand and protect for demand uncertainties.

The target inventory, ***T*,** is calculated as the forecast of demand during the review period plus the forecast of demand during the supply lead-time period plus an amount of safety stock:

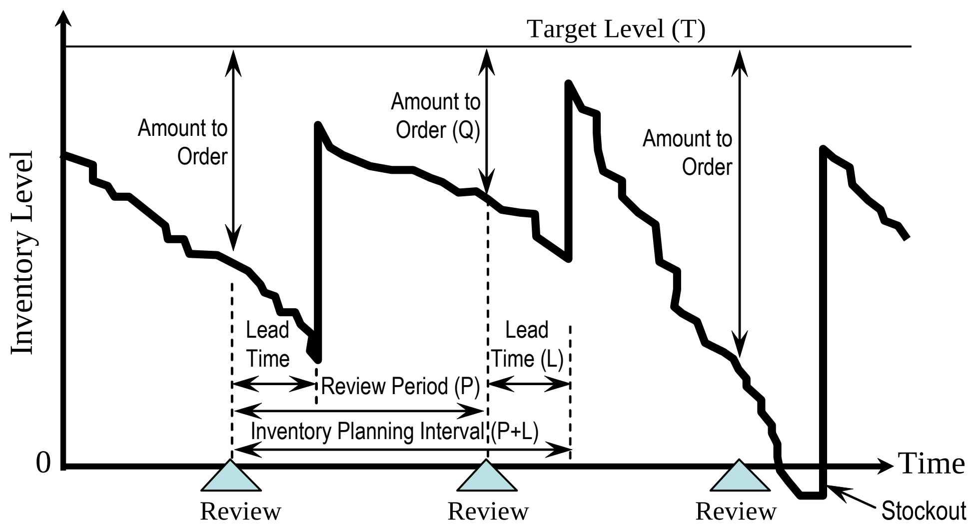
$$T = \text{forecast of demand (during } P + L \text{ time periods)} + \text{Safety Stock}$$

The amount to order (Q) is equal to the difference between the target level T and I_P:

$$Q = T - I_P$$

Since usage from inventory typically varies during each review period and P remains fixed, the actual order quantity Q will likely vary from period to period. (See Amount to Order in **Figure 1**.)

Figure 1. Periodic review system.



Calculations for Safety Stock (SS)

Rarely can future periods' demand be forecast precisely. Thus, holding safety stock inventory will be necessary in order to protect against the uncertainties of demand or the unreliable delivery of the orders that have been placed with a supplier or the firm's internal operations. 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 stockout is usually very difficult to specify. Instead, managers will typically select an order-service level and then establish safety stock utilizing the service level and information from the customer- order data bases.

The amount of safety stock (*SS*) may be determined through statistical tools or by judgment-based, fixed-time supply rules. When statistical methods are used to calculate a value for an item's safety stock, two planning parameters are required for the calculations:

1. A measure of order service, P_1 is a planning parameter that establishes the desired percentage (P_1) of inventory planning intervals with *no stock out occasions*. The inventory-planning interval (as presented in the previous section) extends over $P + L$ periods. For example, if P_1 = 95%, then the probability is 95% that order demand will not exceed the inventory during the inventory planning interval of $P + L$ periods. The likelihood of a stock out is 5%.

2. A measure of demand uncertainty, the standard deviation, is calculated from historical order data or from analyses of forecast errors. The relevant time interval for safety stock protection is the inventory-planning interval of $P + L$ periods; thus a statistical calculation of demand variation must cover the $P + L$ interval (the standard deviation = σ_{P+L}). If the historical order data are not available for the appropriate $P + L$ period of time, then the inventory planner will have to estimate the standard deviation based on assumptions about the probability distribution for demand. If it is reasonable to assume the demand distributions for successive periods are identical and independent (each period's distribution has a mean of μ_d, and a standard deviation of σ_d) then the mean and standard deviation for the inventory planning interval ($P + L$) is:

$$\text{Average demand over P + L periods} = D_{AVG} = (\text{P + L}) * \mu_d$$

$$\text{Standard Deviation over P + L periods} = \sigma_{P+L} = \sqrt{P+L} * (\sigma_d)$$

If the demand is normally distributed and the standard deviation of demand during the time interval of the review period plus lead-time is given by σ_{P+L}, then the formula for safety stock is given by the equation:

$$\text{Safety Stock } (SS) = z * \sigma_{P+L} \tag{1}$$

Where z is the "service factor constant" associated with the value of P_1, the percentage of inventory-planning intervals with no stockout occasions. The value of z tells us the number of standard deviations of protection to have for safety stock.

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

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

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

As an example, suppose an item has a supply lead-time of three weeks and a weekly review period. Assume the probability distribution of demand during the planning interval, i.e. review period + lead-time interval is normally distributed with a mean of 100 units and a standard deviation, σ_{P+L} of 25 units. If management specifies a 90% service level for P_1, then the amount of safety stock using equation (1) above is:

$$\text{Safety Stock } (SS) = z * \sigma_{P+L} \qquad (1)$$

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

Annual cost calculations

The annual costs for managing inventory with the periodic review system can be calculated as the sum of three cost components:

Annual ordering costs + Annual purchase (manufacturing) costs
+ Annual inventory holding costs

The costs of carrying (holding) inventory are typically modeled as the cost of carrying a unit in inventory for a year times the average inventory level for the year. There are two categories of inventory-carrying cost: out-of-pocket expenses and opportunity costs. Out-of-pocket expenses include such items as the cost of storage space (rental or alternative-use value), insurance costs, costs associated with obsolescence, spoilage, or theft, and taxes. Opportunity costs are the costs of forgone opportunities for the money that is invested in inventory, i.e., the money invested in inventory that could be used in other areas of the company to earn some return.

For the periodic review system that includes on-hand inventory held as cycle stock and safety stock, the annual cost equation can be written as:

$$\frac{52}{P}S + CR + KC\frac{Q_{avg}}{2} + KC(SS) \qquad (2)$$

52 = number of weeks in a year

P = length of the review period, stated in weekly periods

S = cost of ordering, independent of the size of the order

C = cost per unit purchased (or manufactured)

R = annual demand requirements in units

K = fraction of unit cost associated with carrying inventory for one year

Q_{avg} = average order size = $(R/52) * P$

$\frac{Q_{avg}}{2}$ = average cycle stock on-hand

The terms of Equation 2 are explained in the table below. If appropriate, other inventory categories, such as pipeline stock, could be included in (2).

Term	Description
$\frac{52}{P}S$	Annual costs of placing orders every P periods
CR	Annual costs of the items used
$KC\frac{Q_{avg}}{2}$	Annual inventory holding costs associated with the cycle stock
$KC(SS)$	Annual inventory holding costs associated with safety stock

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A Numerical Example for Annual Costs Calculations

Sample problem

Consider the inventory management procedures for cylinders of medical gases (such as oxygen, nitrous oxide, blood gas mixtures, carbon dioxide, etc.) at a community hospital. In order to simplify the ordering and delivery-return processes, a periodic review system for the gas cylinders is used such that the hospital receives a delivery of the gas cylinders of each type in a single delivery every Thursday morning, at the start of the business day. The quantity delivered is determined from a replenishment order that is called in by the hospital purchasing department on Monday, three days before, also at the start of the business day. (The medical gases' supplier picks up the empty cylinders after delivering the full cylinders.)

One of the products is oxygen-filled cylinders. The average daily usage of size AA oxygen cylinders averages six cylinders per day (seven days per week). The standard deviation of daily demand is 1.2 cylinders. The hospital supply room has 20 oxygen cylinders tanks on hand on Monday, February 26, and there are no units on order. How many tanks should the hospital order to be delivered on Thursday? What are the total costs?

Assume that each oxygen cylinder costs $30 and that the hospital uses a holding cost of 15% per dollar value of the item per year. The ordering costs associated with the placement and receipt of the oxygen gas cylinders is $50.

Problem solution

In this example, the review period, *P*, is given as one week or seven days. This has been determined by the joint replenishment policy for all of the medical gases from the supplier.

The target level, *T*, is defined as the forecast of demand during the review period plus the lead-time plus a safety stock quantity. The review period is seven days, and the lead-time is three days. The target level, *T*, must therefore cover an inventory-planning interval of 10 days. The average of demand (assuming a steady usage rate) for the 10-day period is given by 10 days$*$6 cylinders per day = 60 cylinders.

The safety stock should provide protection for higher than expected demand over the 10-day period. This amount of protection is calculated taking into consideration demand variation (standard deviation of demand during the time interval of the review period and lead-time period) and service policy. Because the demand variation has been calculated from daily demand data, the calculation must scale the daily demand standard deviation to the time frame covering the review period and lead-time period. The standard deviation of demand over a 10-day period is given by the (square root of 10 days) ∗ (the standard deviation of daily demand) = 3.162 ∗ 1.2 = 3.79.

The target inventory level, T, is therefore (60 + z ∗ 3.79), where z is determined by setting a specified percentage inventory-planning intervals in which the hospital would not like to run short of oxygen. Assume that the hospital is willing to be short of oxygen only 1% of the intervals. Therefore, P_1 = 99% and z = 2.33. The safety stock = 2.33∗3.79 = 8.8, which we round to 9. The target inventory becomes 60 + 9 = 69. Because there are 20 cylinders on hand on Monday morning and none on order or backordered, the hospital would order 49, to be delivered on Thursday.

The cost of the system for a one-week review period (using a weekly time-period perspective) are:

$$\frac{52}{P} S + CR + KC \frac{Q_{avg}}{2} + KC(SS) \qquad (2)$$

Note: average order size $Q_{avg} = (R/52) * P$ = (6∗365)/52 ∗ 1 = 42 cylinders (rounded); thus

$$= (52/1)*50 + 30*6*365 + 0.15*30*(42/2) + 0.15*30*(9)$$
$$= 2{,}600 + 65{,}700 + 94.5 + 40.5$$
$$= \$68{,}435$$

Since usage from inventory varies during any review period and P remains fixed, the order quantity Q will vary from period to period. In this particular weekly order period, the hospital purchasing department would order 49 cylinders.