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MANAGING INVENTORIES: FUNDAMENTALS

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? Shouldn't we be using an "economic order quantity" lot-size formulation for our ordering decisions? What are the relevant costs we should be considering?

Ways to Categorize Inventory and Evaluate Inventory Planning Decisions

Before addressing the questions above, consider the categories used to distinguish inventories in the firm's financial records. The major accounting categories of inventory are:

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.

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3. Finished goods: Completed goods that are being held for sale to customers.
4. Maintenance parts and supplies: Components used to maintain or repair processing 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 it into 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 better lot size decision 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. Which firm has made a better 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 safety stocks' expenses.

Because inventories 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.

Exhibit 1 summarizes by function many of the tradeoffs in costs and the actions management can take to improve the management of inventories in each of the five categories. Breaking down the inventories in a business according to how many dollars of inventory are being used for each function is often useful. Such a classification may, for example, assist one in deciding what approaches might be most effective in determining how to meet the five functions of inventories with the minimal dollar investment and lowest operational expenses.

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 would be advised to pay much more attention in terms of analysis and control to the A items than the others. This ABC classification is sometimes referred to as a Pareto Analysis or the 80–20 Rule.

Objectives in Managing Inventories

The purpose of this note is to address the planning that guides a firm's decisions regarding cycle-stock ordering activities as materials flow from suppliers through a firm's operations to customers. The objective is to develop and implement a management system that can improve the cost effectiveness of the investments in inventory. This note addresses those cost-element considerations that deal with the cycle-stock decisions. Other functional inventory decisions are addressed in separate technical notes.

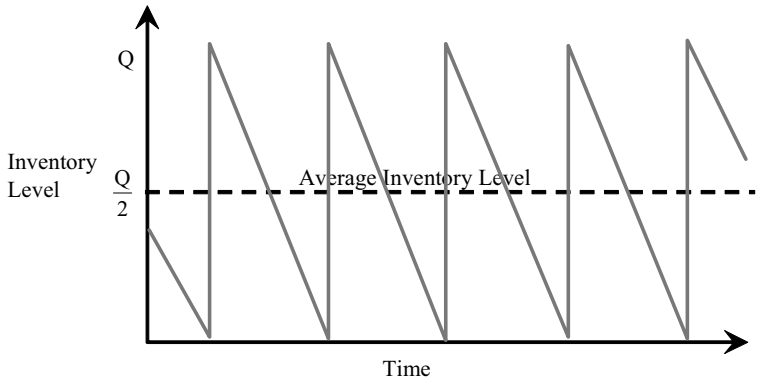
In managing inventories, there can be some competing objectives. Marketing would like to have enough inventory to maximize customer service by always having products available for customers. Finance looks to minimize the investment in inventory. Because the objectives can be conflicting, operations managers 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 efficiency could be improved.

Calculating 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.

Under an assumption of level or constant demand, the inventory level over time will appear as the saw-toothed pattern in **Figure 1**. For example, when an order of size Q arrives, the inventory is at the maximum level (Q, the order size) and then will drop to zero just before the next order is to arrive. Thus, the average inventory level is $Q/2$. The average inventory is referred to as *average cycle stock*, as it represents the inventory stock held between ordering cycles. The cost of carrying a unit in inventory is typically modeled as per-unit cost of the item times some fraction that represents the annual holding-cost charge.

Figure 1: Inventory level versus time.



Let K = annual inventory carrying costs as a fraction of the unit cost. Thus, the annual cost of holding inventory in a steady state system is:

$$\text{Annual Costs of Holding Inventory} = KC\frac{Q}{2}$$

An important consideration is the effect of slower, static ordering situations, where orders of quantity Q are placed less than once a year. In these situations, it's appropriate to calculate the actual average annual inventory for each year being considered, and replace $Q/2$ with this value in the formula. Of course, when modeling inventory holding costs over several years, it is also imperative to consider the time value of money, and discount future costs to present value.

Applying the Inventory Holding Costs Formula: Example 1

Consider a furniture manufacturer that builds wooden tables and uses wooden boards as its primary raw material inventory. The boards cost the company $25 each, they are delivered in order sizes of 50, and the cost of holding the boards averages 15% per year. We can determine the annual cost of holding the boards in inventory:

$$\text{Annual Cost of Holding Boards} = KC\frac{Q}{2} = (15\%)(\$25)\frac{50}{2} = \$93.75$$

Applying the Inventory Holding Costs Formula: Example 2

Now assume the furniture manufacturer orders finishing nails in large quantities in order to take advantage of volume discounts offered by its supplier. The furniture manufacturer

requires 3,000 nails per year, holding costs for the nails is 15% annually, the unit cost is $0.10 per nail, and the order quantity is 6,500. Also, after two years, the table specifications are expected to change, and different finishing nails will be required. Any old finishing nails remaining in inventory will be scrapped. Finally, assume an annual discount rate of 10%. In this case, we expect Q/2 to change each year. Q/2 represents the average inventory between the start and end of each year.

$$\text{Year 1 Cost of Holding Nails} = KC\frac{Q}{2} = (15\%)(\$0.10)\frac{6{,}500 + (6{,}500 - 3{,}000)}{2} = \$75.00$$

At the end of the first year, we expect to have 3,500 nails remaining; at the end of the second year, we expect to have 500 nails left, which will be scrapped. Also, we discount the costs by 10% to bring the second year costs to equivalent value of first year costs.

$$\text{Year 2 Cost of Holding Nails} = KC\frac{Q}{2} = (15\%)(\$0.10)\frac{3{,}500 + 500}{2}\frac{1}{(1+10\%)^1} = \$27.28$$

$$\text{Total Costs of Holding Nails} = \$75.00 + \$27.28 = \$102.28$$

A fair question from the above example is whether the furniture company should scrap the 500 excess nails earlier and save the 15% annual holding cost on those nails. Extra inventory to address demand variation or defective inventory is considered safety stock, calculated separately using methods outside of the scope of this note. In essence, the furniture company in the previous example would be well advised to consider scrapping their excess cycle stock as soon as it becomes clear it will be unneeded, particularly if some value (e.g. selling the nails to another business) can be gained from its disposal.

Exhibit 1

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Inventory Categories by Function

	Function	Tradeoff with the cost of holding inventory	Management actions
Pipeline	To provide for the movement of materials, work-in-process, and finished goods from one place to another. To reflect the time delays in producing, handling, and distributing a product.	Cost of moving, cost of operating, and cost of material-handling equipment.	Change transit or delay times, invest in materials-handling equipment, improve scheduling and loading practices.
Cycle (Lot Size)	To allow for batching of purchased goods or manufactured goods. Cycle stock represents the stock held between reordering cycles. The order costs that do not change with the order size can be spread over more units, and thus the average cost can be reduced as the lot size is increased. In some cases, learning effects also result in a decrease in average cost as the lot size increases. In purchasing, quantity discounts can be realized.	Costs associated with ordering and receiving purchased lots or setting-up manufactured process. Quantity discount opportunity.	Reduce the costs associated with ordering or setting up. Reduce elements of inventory holding costs. Eliminate supplier minimum order size. Reduce forecast errors.
Buffer (Safety)	To protect against uncertainties in supply or demand. To handle unanticipated fluctuations during the replenishment lead-time which cannot or are not handled through corrective actions.	Customer service, downtime costs, overtime costs, and shortage costs.	Change customer-service levels, reduce lead times, and reduce forecast errors.
Anticipation	To cover anticipated changes in demand or supply such as those caused by seasonal demands, promotions, plant vacations, and planned shutdowns.	Cost of varying production activity.	Smooth out changes in demand, varying the production capacity by overtime, undertime, hiring, laying off, subcontracting, etc. Buy ahead or draw down inventories.
Speculation	To deal with anticipated price increases or decreases.	Savings in price.	Change suppliers.