In health care organizations, **supply chain** is a new way of conceptualizing medical supply management. A supply chain is defined as “a virtual network that facilitates the movement of product from its production, distribution, and consumption” (McFadden and Leahy, 2000). In considering supply chains, health care managers are not only concerned with how much of each type of supply, and when, they need to purchase and carry in their stockrooms (inventory) to effectively serve their patients; they also are concerned with their relationships with the companies at the upstream source of the products to minimize their overall costs in supply management. The health care manager, as a leader of the provider link in this chain, is in a strategic position and should facilitate collaborative partnerships with the adjacent links of the chain. Let us closely examine the various links in a supply chain from the prospective of a health care provider.

Figure 11.1 depicts the conceptualization of a health care supply chain identifying the upstream and downstream links with respect to providers. Upstream in the next place on the chain lie distributors, who purchase the drugs, medical and surgical devices from the manufacturers and who comprise wholesalers, group purchasing organizations (GPOs) and e-distributors. Downstream are the end users of, or payers for, the products. Providers are those who decide
what to use and whom to use about all these products and secure their availability and end distribution.

**Manufacturers/Suppliers.** Manufacturers of medical supplies can be classified in three categories: 1) drugs and pharmaceuticals; 2) medical-surgical supplies; and 3) devices. Some manufacturers produce supplies in more than one category or in all categories.

Pharmaceutical sales in the United States constitute about 8 percent of national health expenditures. 25 percent of pharmaceutical products are distributed to providers (hospitals and other institutional settings) via distributors. Well-known pharmaceutical manufacturers include Abbott, Aventis Pharma, Bristol-Myers Squibb, Eli Lilly, GlaxoSmithKline, Hoffmann-La Roche, Janssen, Johnson & Johnson, Merck, Pfizer, Schering-Plough, and Wyeth.
Medical-surgical companies produce items such as injection syringes and needles, blood and specimen collection kits, hospital laboratory products, wound management products, and intravenous solutions. 3M, Abbott, Baxter, and Johnson & Johnson are a few of the well-known medical-surgical companies that sell the majority of their products through distributors.

Medical devices can be described as very high priced, technologically sophisticated and advanced apparatus that are used for diagnosis and therapies. The devices are produced and sold in low volumes, and their costs account for about 5 percent of national health expenditures in the United States (Burns, 2002; p. 243). Medical devices include surgical and medical instruments and apparatus, orthopedic, prosthetic and surgical appliances (for example, shoulder, knee, and hip replacements), x-ray apparatus, tubes, irradiation apparatus, electromedical and electrotherapeutic devices. Dupuy, Ortho Biotech, Medtronic, and Zimmer are examples of the companies that manufacture such devices (Burns, 2002; p. 244).

**Distributors, Wholesalers, and Electronic Data Interchange (EDI).** Distributors for medical-surgical supplies are independent intermediaries who operate their own warehouses; they purchase the products from manufacturers and suppliers to sell to providers. Similarly, pharmaceutical intermediaries purchase the drugs and pharmaceuticals from manufacturers and wholesale them to pharmacies or to providers. The intermediaries are called distributors or wholesalers depending on whether the products’ final resale has another layer before reaching the customer (Burns, 2002; p. 127). Distributors in the United States sell products from a wide range of manufacturers and manage over 100,000 different items (Burns, 2002; p. 244). Burns (2002, p. 129) states: “One of the most significant contributions of distributors to the health care supply chain was the deployment of electronic order-entry systems to their customer base.” Linking providers through electronic communication to their distributors is formally defined as electronic data interchange (EDI). EDI provides direct, real time computer to computer electronic transmission of purchase orders, shipping notices, invoices, and the like between providers and distributors. Over 75 percent of distributors use EDI, and 70 to 80 percent of their business volume is handled through EDI (Burns, 2002, pp. 130–131). EDI is also proliferating to manufacturer transactions with other parts of the health care supply chain; more than one-third of their business transactions use EDI. The cost for standardized EDI transactions for a purchase order, as compared to costs with manual systems, saves operational costs for both providers and distributors. For example, a purchase order with standardized EDI costs the provider $11.20, whereas with a manual system it costs $40–$150. For the distributors or suppliers these costs are $3.20 versus $30–$150 per purchase, for EDI and manual systems, respectively. Put together, the total costs for
both parties are $14.40 versus $70–$300, a savings of 500 percent to 2,000 percent (Burns, 2002; p. 134).

Well-known distributors of pharmaceuticals include AmeriSource/Bergen Brunswig, Cardinal Health/Bindley Western, and McKesson, whose market shares are 32, 29, and 27 percent, respectively (Burns, 2002; p. 146).

Medical-surgical supply distributors, with approximately $20 billion in sales, distribute their products to three major provider organizations: hospital/hospital systems, physician offices, and long-term care organizations. Hospital/hospital systems consume 60 percent of medical-surgical supplies, while physician offices consume 25 percent, and long-term care and other facilities consume the remaining 15 percent.

Cardinal Health, Owens & Minor, and McKesson are major distribution companies in the hospital market with their combined market share amounts to 92 percent. Henry Schein and McKesson serve the physician office market, as do PSS, PHCC, and AEH/BBMC. Collectively these distributors cover about 65 percent of the physician market. Over fifty percent of the long-term care market is served by the following distributors: McKesson, Gulf South/Gateway, Medline, and AEH/BBMC (Burns, 2002, p. 154).

**Group Purchasing Organizations (GPOs).** Group purchasing organizations provide a critical financial advantage to providers, especially hospitals and hospital systems, by negotiating purchasing contracts for products and nonlabor services. A typical GPO has many hospital organizations as its members and uses this as collective buying power in negotiating contracts with many suppliers: of pharmaceuticals, medical-surgical supplies, laboratory, imaging, durable medical equipment, facility maintenance, information technology, insurance, and food and dietary products and services. The contracts usually last three to five years, giving providers price protection (Burns, 2002; pp. 60–64).

The overwhelming majority of hospitals participate in group purchasing. Often a hospital belongs to one or more GPOs. The GPOs can be either for-profit and investor owned, or nonprofit. They differ in geographic coverage, size, and scope. Over six hundred GPOs operate in the United States; perhaps half of them focus their business on hospitals. It is estimated that GPOs mediate contracts for two-thirds of the $50 billion spent by hospitals on medical-surgical supplies. The contract negotiations for pharmaceuticals cover almost 90 percent of what hospitals spend on them, or nearly $13 billion (Burns, 2002; p. 70).

Five major nonprofit and two investor-owned for-profit GPOs capture 72 percent of the hospital market among them. The two largest GPOs are Novation and Premier, which are nonprofit. The scope of the contracts maintained by GPOs can be exhaustive, especially for large GPOs like Novation. According to Burns (2002). Novation, with 2,100 members, maintains 1,600 contracts
covering nearly 900,000 items for $14 billion in value. Premier has over 1,800 members and commands contracts for $13 billion in value (Burns, 2002; p. 60). The three other nonprofit GPOs of similar size (in terms of annual revenue of $3–5 billion) are AmeriNet, HSCA, and Consorta. The two investor-owned for-profit GPOs are HCA/Health Trust and Tenet/BuyPower, both with sizes similar to the smallest three nonprofit GPOs (Burns, 2002; p. 64).

Although GPOs function more on the upstream with suppliers, their downstream relationship with their provider membership makes possible clinical standardization, rationalization in stock keeping units (SKU), product bundling, and reduction of utilization and cost (Burns, 2002; p. 59).

**E-Distributors.** E-commerce in health care can be viewed from different perspectives. Here we will concentrate on two aspects: business-to-business (B2B) commerce and business-to-customer (B2C) commerce. B2B e-distribution provides efficiencies in many areas for providers, GPOs, and suppliers in the chain through reduced transaction costs and prices, reduced cycle times with automatic replenishments, deliveries on a JIT basis, and dynamic planning—all the way to upstream forecasting for pull-demand, rather than push-demand sales by suppliers.

Examples of B2B firms are: Medibuy, Neoforma, MedAssets, OmniCell, and Promedix. These firms provide e-Catalog, e-Request for Proposal (eRFP), e-Auction, and e-Specials (limited discounts on some items), which emulate traditional systems on-line and are available to both hospitals and physician offices. Since the mid-1990s, the e-companies have gone through various acquisitions and mergers, and have started carving out parts of the traditional systems’ market share with their on-line systems. However, their future effects on the medical supply trade remain uncertain (Burns, 2002; pp. 297–301).

**Flow of Materials**

It is important to note that depending upon the type of medical supply, the flow of materials in the supply chain may take more direct routes to providers or end users. Suppliers may bypass GPOs by not contracting or negotiating price arrangements. High-end implants and medical devices, specialty items of low volume but high price, are good examples of such medical supplies for which suppliers use direct delivery, usually via express services (like FedEx, UPS, or DHL) or have their own local/regional sales representatives make the just-in-time (JIT) delivery and serve as consultants to physicians. In some cases, the company’s representatives provide technical participation with surgeons in implanting devices surgically. Other cases in which suppliers may bypass GPOs in contracting are for small-volume, esoteric items, and for the brand-name, specialty drugs used to treat...
cancer and cardiovascular problems. Those, however, would not be delivered directly, but by a wholesaler or distributor.

Supply Chain Management Issues for Providers

As was mentioned above, the providers decide, for all products, what to use and whom to use and secure their availability and end distribution of these products. This function of providers in the supply chain link can be characterized as inventory management. Good inventory management is essential to the successful operation of any health care organization, for a number of reasons. One of the most important is the proportion of the organizations’ budget that represents money spent for inventory. Although the amounts and dollar values of the inventories carried by different types of health care providers vary widely, in a typical hospital’s budget 25 to 30 percent goes for medical supplies and their handling. On the national scene, health care supplies constitute 8 to 9 percent of health care expenditures. According to Burns (2002, p. 34), of supply costs, 15 to 23 percent is for pharmacy, 30 to 50 percent is for medical-surgical supplies, and 11 to 24 percent is for equipment. Clearly, medical supplies require significant attention in health care budgeting. Furthermore, a widely used measure of managerial performance is the return on investment (ROI), which is profit after taxes, divided by total assets. Because the inventory of medical supplies may comprise a significant portion of a health care organization’s total assets, reducing its inventories significantly raises its ROI, and hence its position in the financial markets. Health care managers must be able to manage the inventory of medical supplies effectively. This chapter presents concepts that support good inventory management.

Contemporary Issues in Medical Inventory Management

In the current era of health care delivery, when cost-effectiveness is the key measure of performance, health care managers have a number of inventory management options available: traditional inventory management, just-in-time and/or stockless inventory systems, single or multiple vendor relationships, and partnerships with suppliers and GPOs.

A system that is highly effective in one health care organization could be disastrous in another. Familiarity with the systems in use makes it easier to determine which one(s) will be effective for a particular organization.

Regardless of what inventory system and practices an organization uses, certain fundamental changes can optimize the cost-effectiveness of the inventory function. Such changes include the computerization of material functions,
integration of clinical and financial systems, bottom line measurement, and decentralization of the inventory management function. The advent of microcomputers has created opportunities for restructuring routine tasks to improve productivity and performance. For example, orders from institutional users are now transferred via computer, and then go to vendors that can provide on-line confirmations. And these ongoing routine operations create databases of utilization, price, and other information that will facilitate future decision making (for pull-demand on upstream in the supply chain).

The linkage of inventory databases with other clinical and financial data systems in an institution can identify utilization patterns by patient groups, DRGs, physicians, and others. Data analysis, by indicating where large amounts of material resources are being used can focus review efforts. Quantitative measures of utilization patterns are used to assess whether or not cost objectives are being met. Benchmarking the institutions’ costs against other providers’ costs can identify problem areas where efforts should be made to improve performance. Using comparative data from other institutions, health care managers may identify practice patterns or utilization trends that could cut costs.

A computerized inventory management system does free health care managers from traditional routine tasks to focus on material utilization review. Having administrative and clinical personnel review how they use goods when providing health care facilitates a common goal of reducing, altering or even eliminating items of the mix used, although a specified level of quality should be maintained. A new operating philosophy can emerge: the best way to save money on inventory is to decide whether some products or services are even needed. Savings that have been realized by such decisions have ranged from a few thousand dollars on syringes to hundreds of thousands of dollars on specialty beds (Sanders, 1990).

**Just-In-Time (JIT) and Stockless Inventories.** Inventory management in health care organizations is becoming increasingly decentralized. JIT means that goods arrive just before they are needed. An organization practicing JIT places orders and receives deliveries frequently and stores virtually no inventory in a warehouse or stockroom. Hospitals have extended JIT principles to include programs known as stockless inventories. Stockless inventory means obtaining most supplies from a single source (a prime vendor) in small packaging units ready to be taken to the user departments. A stockless system uses little or no space, inventory, or storeroom staff, because the vendor’s warehouse doubles as the partnering hospital’s warehouse. Some vendors even deliver specific quantities of a good directly to the department that ordered it. JIT and stockless inventory require sophisticated management, however, of the data moving between institution and vendor.
Computers help to minimize on hand quantities and automatically generate reorders. The best applications of JIT systems in health care are for highly expensive implants and medical devices. Use of prime vendor purchasing facilitates the process by committing the vendor to the service levels dictated by management in terms of inventory holdings, stock-outs, and deliveries (Krumrey and Byerly, 1995).

Stockless inventory in hospitals parallels JIT programs in industry. Many hospitals use the concept at a lesser level in specific areas; for example, surgical carts that have all the supplies necessary for a procedure arrive just before it is scheduled to begin. Unit dose medication carts are used to refill individual patient bins just before the next dose is needed. Substantial long-term savings can result from applying stockless inventory to these supply groups: computer equipment and supplies, food supplies, housekeeping supplies, linen, maintenance supplies, office supplies, and X-ray supplies.

**Advantages/Disadvantages of JIT and Stockless Inventory.** It should be noted that a stockless inventory program substantially affects many facets of a hospital’s purchasing operations. An advantage is that a supplier may agree to lower unit product prices because of increased volume from a hospital. Besides that, inventory service should improve because of the mutual commitment with suppliers and the intensity of the services provided. Stockless inventory also reduces the number of supplies and the total orders processed. However, the number of staff hours and salary expenses in a purchasing department may not be significantly reduced because only a portion of FTE time is saved by automation (Kowalski, 1991).

Stockless inventory systems typically do not involve all products. They may not reduce total supply expenses, because consumption rates by user departments may remain the same, regardless of who supplies them. Another limitation is that since hospitals typically have from three to ten times the investment in user department inventory that they have in a storeroom, stockless inventory does not necessarily affect most of a hospital’s inventory. Moreover, a stockless inventory is not free. While the hospital may reduce staff, inventory, and space costs, suppliers must be paid for their value-added services, which can range from 3 to 13 percent of the price of a product.

**Single versus Multiple Vendors.** The essence of the purchasing function is to obtain the right equipment, supplies and services, and of the right quality, in the right quantity from the right source at the right price at the right time. Keeping that in mind, the health care manager has to decide whether to use a single source for supplies (if possible) or many different vendors. Each relationship has advantages and disadvantages.
A single source will almost guarantee better pricing, because, as the exclusive supplier the source will have higher volume. If the hospital runs into an unexpected shortage, the vendor will adjust shipping priorities to ensure that the hospital, as a major account, does not get into a stock-out situation. Purchasing from a single source increases the health care organization's influence on that vendor; the health care manager's ideas and suggestions are valued far more. Single sourcing may also allow a health care manager to negotiate small purchases that could not normally be made without paying exorbitant premiums. As a buyer, the manager will be able not only to negotiate with the supplier, but to protect sensitive information, as well. Should the organization become aware of new items or processes, the supplier can obtain and provide such information without revealing to the manufacturer or the distributor who the ultimate customer might be. Finally, because the single source supplier has a much better idea of what an organization's total requirements are, it can recommend more cost-effective ways to handle shipments (Sheehan, 1995).

There are also advantages to multiple sourcing. For one thing, vendors are always looking for steps they can take to encourage customer hospitals to purchase products from them. Most importantly, however, multiple sources protect the hospital's supply lines, since the need for a product can literally mean life or death. A disadvantage of single sourcing is that, in a crisis, a health care organization may feel at the mercy of its supplier. Another important reason for using multiple sources is to encourage competition among them. Notwithstanding rapidly changing technology, few products come on the market without a competing product existing somewhere. Competition at the top of a supply chain creates pressure to improve the product's quality and availability. And of course, competition helps a health care organization to get the best price from the vendor they eventually choose.

Traditional Inventory Management

Any discussion on inventory management must begin with a working definition of what inventory is. **Inventory** can be defined simply as a stock or store of goods, or stock keeping items (SKUs). Hospitals stock drugs, surgical supplies, life-monitoring equipment, sheets and pillowcases, food supplies, and more. Inadequate controls of inventories can result in both under- and overstocking of items. Understocking can result in lost sales because of the dissatisfaction of the physicians or surgeons. For example, physicians could take their patients elsewhere for procedures because the needed supplies—whether brand names or specific items—have been unavailable. More important than lost sales is the risk that understocking might cause a patient death. From a simply a practical viewpoint, on the other hand, overstocking unnecessarily ties up funds that might be more...
productive elsewhere. Overstocking appears to be the lesser of the two evils. However, for excessive overstocking, the price tag can be staggering for interest, insurance, taxes (in some states), depreciation, obsolescence, spoilage, pilferage, and breakage. Those costs, known as holding or carrying costs, can be overwhelming if you are dealing with high-priced inventory such as pharmaceuticals. As an example of excessive overstocking, it is not unusual for health care managers to discover that their facility has a ten-year supply of an item.

Inventory management has two main concerns: 1) the level of service, that is, having the right goods, in sufficient quantities, in the right place, and at the right time; 2) the costs of ordering and carrying inventories. Any prudent health care manager aims to both maintain a high level of service and minimize the costs of ordering and carrying inventory. In other words, the two fundamental decisions are when to order and how much to order. Welcome to the exciting world of inventory management!

Inventories have several functions. Among the most important are to: A) meet anticipated patient demand for medical supplies; B) communicate demand information upstream on the supply chain (to distributors, then to suppliers) in order to smooth manufacturers’ production requirements; C) to protect against stockouts; D) to take advantage of order cycles; E) to hedge against price increases or to take advantage of quantity discounts; and—most fundamental—F) to permit a health care organization’s operations to continue.

Let’s put these basic inventory functions into perspective with an example of what any health care manager would not want to have happen on her or his watch. Imagine the following scenario, in which the health care supply chain manager has to explain to a member of senior management why the emergency room found itself without the syringes.

“Sorry sir, but when she (the patient) came into the ER, we were out of syringes. Our anticipation stocks were depleted because we hadn’t corrected the ordering patterns for seasonal variations. Then, the snow delayed shipments from supplier, and our safety stocks just weren’t good enough! You know we usually order in bulk to take advantage of large economic lot size and lower our ordering cycle. Our last order was especially large because we wanted to hedge against predicted price increases! In the final analysis, our inventory just wasn’t sufficient to permit smooth operations.”

Requirements for Effective Inventory Management

Besides the basic responsibilities of deciding when and how much to order, the other basic responsibility is to establish a system for keeping track of items in inventory. These, then, are the requirements for effective inventory:

1. A system to keep track of the inventory in storage and on order.
2. A reliable forecast of demand.
3. Knowledge of lead times and lead time variability.
4. Reasonable estimates of inventory holding costs, ordering costs, and shortage costs.
5. A classification system for inventory items in terms of their importance.

Inventory Accounting Systems

Inventory accounting systems can be periodic or perpetual. Under a periodic system, items in inventory are physically counted either daily, weekly, or monthly, for the purpose of deciding how much to order of each. An advantage of the periodic system is that orders for many items occur at the same time, which reduces the processing and shipping of orders. However, this system can also produce dilemmas. In addition to a lack of control between reviews, the need to protect against shortages between review periods means carrying extra stock. Health care managers also must decide on order quantities at each review.

A perpetual system continuously keeps track of removals from inventories, so it can always give the current level of inventory for each item (Stevenson, 2002, pp. 545–546). When the amount on hand reaches a predetermined minimum, a fixed quantity, $Q$, is ordered. An obvious advantage of this system is the control provided by the continuous monitoring of inventory withdrawals. Another major advantage is the fixed order quantity; managers can identify an economic order size (discussed later in this chapter). However, even in a perpetual system, a periodic physical count of inventory must still be performed to verify that the reported inventory levels equal the effective inventory levels. The difference between what is reported and what is actually on hand is caused by errors, theft, spoilage, and other factors. For perpetual systems, a disadvantage is the added cost of record keeping and information systems.

Perpetual systems can be either batch or on-line. In batch systems, inventory records are collected periodically and entered into the system. In on-line systems, the transactions are recorded instantaneously.

An example of a perpetual on-line system is the computerized checkout system in grocery stores, where a laser scanning device reads the Universal Product Code (UPC), or bar code, on an item. Such a system also is now used in many health care organizations to track inventories and the as items are used or dispensed for patients. A brief discussion of such systems will help understanding of their importance to a health care organization.

Universal Product Codes (UPCs). The UPCs have been around since late 1970s and are used in industry. A UPC can have up to twenty character numbers that uniquely identify a product, for example, of pharmaceutical or medical-surgical
supply, using bars with different variety and thickness that can be read by scanners. The order of the information in UPDCs identifies the type of product, its manufacturer, and the product itself. In healthcare, the source of UPDCs can be either the Health Industry Business Communications Council (HIBCC) or the Uniform Code Council (UCC). UPDCs can be assigned at unit dose, package, or case level. The pharmaceutical numbering system for UPDC codes is based on universally recognized National Drug Codes (NDCs). UPDCs are an essential part of an electronic data interchange (EDI) system to create efficiencies in materials ordering, handling, and charging, as well as relatively error-free processing. With UPDCs, it is reported that distributors can increase their deliveries six fold, and with half the manpower needed with non-bar-coded systems. Although an overwhelming number of consumer products contain UPDC codes, their implementation in healthcare lags behind the retail and industrial sectors (Burns, 2002; pp. 140–144). Only 26 percent of medical-surgical products can be scanned on nursing units, and only 50 percent of drugs have bar codes for unit doses.

According to the final regulation issued by the Food and Drug Administration (FDA) in 2004, drug manufacturers must adopt bar-coding to single-dose units within two years, and hospitals must eventually implement bedside scanning systems. The FDA estimates, however, that it may take up to two decades for all hospitals to implement such systems because of their high costs: from $500,000 to $1 million. Only a few more than 100 hospitals currently use them. Yet bar code systems would significantly improve the quality of patient care through reduction of medication errors. It is estimated that over a twenty-year period, fully implemented bar code systems would prevent about .5 million medical errors. Moreover, by improving the cost-efficiency of medical supply management, hospitals would also reap $90 billion in savings, which would help to pay for the technology (Becker, 2004).

While health care facilities are catching up with this efficient system of supply management, the remaining materials must be handled the old-fashioned way, entered to ordering systems manually; and their management must be carried in house (by providers) using traditional inventory management methods.

**Lead Time**

Inventories are used to satisfy demand requirements, so reliable estimates of the amounts and timing of demand are essential. It is also essential to know how long it will take for orders to be delivered (Stevenson, 2002; p. 547). Now that health care organizations increasingly rely on their vendors to maintain adequate inventory levels in their facilities, their data relevant to demand must be transferred to their vendors. Health care managers also need to know the extent to
which demand and lead time (the time between submitting an order and receiving it) may vary; the greater the potential variability, the greater the need for additional stock to avoid a shortage between deliveries.

Cost Information

Three basic costs are associated with inventories: holding, ordering, and shortage costs. Holding or carrying costs, as mentioned earlier, relate to physically having the medical supplies in storage. Such costs include interest on the money borrowed to buy the items, insurance, warehousing, security, compliance with industry and government requirements (for example, HIPPA), obsolescence, outdated medications, deterioration, spoilage, pilferage (for example, of IV bags), theft (for example, of narcotics), and depreciation. Holding costs can be calculated either as a percentage of unit price or as a dollar amount per unit. In any case, typical annual holding costs range from 20 to 40 percent of the value of an item. In other words, to hold a $10 item for one year could cost from $2 to $4 (Stevenson, 2002; p. 547–548).

Ordering costs include the time and effort spent to calculate how much is needed, prepare invoices, inspect goods upon arrival for quality and quantity, and move goods to temporary storage or the appropriate diagnostic and therapy units. Because those costs are incurred for each order, they are generally expressed as a fixed dollar amount per order, regardless of order size (Stevenson, 2002; p. 548).

Shortage costs result when an appropriate medical supply is not on hand. They range from the opportunity cost of losing a patient’s or physician’s goodwill, to the risk of lawsuits and even the death of a patient. Such costs could be extremely high, even threatening the financial viability of a health care organization. Shortage costs are usually difficult to measure, and are often subjectively estimated.

Classification System

An important element of inventory management deals with classifying the items in stock according to their relative importance in terms of dollars invested, volume, utilization, and profit potential—to say nothing of the disastrous financial consequences that could result from allowing a stock-out to occur. For instance, a typical hospital carries items such as drugs, biomedical equipment, and linens for beds; it would be unrealistic to devote equal attention to each. Obviously, control efforts should be based on the relative importance of the various items in inventory.

A classic method of classifying inventory is the A-B-C approach. Inventory items are placed in one of three classes: A (very important), B (important), and C (somewhat important), according to a measure of importance such as annual
dollar value. That measure is simply the dollar value per unit multiplied by the annual usage (demand) rate. Health care managers can of course create many categories, depending on the extent to which they want to differentiate control efforts.

With three classes of items, A items generally account for 15 to 20 percent of the items in total inventory, but for two-thirds of dollar usage. B items are moderate in terms of inventory percentage and dollar usage. Finally, the C items may represent two-thirds of the items, but only 10 percent of dollar usage. Although those percentages may vary, for most facilities relatively few items will account for a large share of the value or cost associated with an inventory, and it is those items that should receive a high share of control efforts. Because of their high dollar value per unit, A items should receive the most attention, through frequent reviews of the amounts in stock, as well as close monitoring of their withdrawals from inventory. The C items should receive looser control, and B items be controlled with efforts between those two extremes. The health care manager’s A-B-C analysis should not overemphasize minor aspects of customer service at the expense of major aspects. For example, one would be unlikely to change the importance of a health care item from C to B or A, despite its low cost, if it serves a crucial need of patient care. Table 11.1 illustrates an example of the A-B-C concept.

In this example, items 6, 13, and 14 have relatively high dollar values, so it seems reasonable to classify them as A items. That classification is supported by the calculation of percentage shares in annual dollar volume from all the items.

<table>
<thead>
<tr>
<th>Item</th>
<th>Annual Demand</th>
<th>Unit Cost</th>
<th>Annual Costs</th>
<th>Percent of Total</th>
<th>A-B-C Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20,800</td>
<td>2.50</td>
<td>52,000</td>
<td>1.2%</td>
<td>C</td>
</tr>
<tr>
<td>2</td>
<td>83,200</td>
<td>0.50</td>
<td>41,600</td>
<td>1.0%</td>
<td>C</td>
</tr>
<tr>
<td>3</td>
<td>9,100</td>
<td>37.50</td>
<td>341,250</td>
<td>8.0%</td>
<td>B</td>
</tr>
<tr>
<td>4</td>
<td>13,000</td>
<td>3.50</td>
<td>45,500</td>
<td>1.1%</td>
<td>C</td>
</tr>
<tr>
<td>5</td>
<td>13,000</td>
<td>1.75</td>
<td>22,750</td>
<td>0.5%</td>
<td>C</td>
</tr>
<tr>
<td>6</td>
<td>790</td>
<td>1,290.00</td>
<td>1,019,100</td>
<td>24.0%</td>
<td>A</td>
</tr>
<tr>
<td>7</td>
<td>78,000</td>
<td>0.65</td>
<td>74,360</td>
<td>1.8%</td>
<td>C</td>
</tr>
<tr>
<td>8</td>
<td>114,400</td>
<td>0.95</td>
<td>62,738</td>
<td>1.5%</td>
<td>C</td>
</tr>
<tr>
<td>9</td>
<td>66,040</td>
<td>12.50</td>
<td>78,000</td>
<td>1.8%</td>
<td>C</td>
</tr>
<tr>
<td>10</td>
<td>6,240</td>
<td>2.00</td>
<td>22,880</td>
<td>0.5%</td>
<td>C</td>
</tr>
<tr>
<td>11</td>
<td>11,440</td>
<td>1.50</td>
<td>27,300</td>
<td>0.6%</td>
<td>C</td>
</tr>
<tr>
<td>12</td>
<td>18,000</td>
<td>1,300.00</td>
<td>1,183,000</td>
<td>27.9%</td>
<td>A</td>
</tr>
<tr>
<td>13</td>
<td>315</td>
<td>2,700.00</td>
<td>850,500</td>
<td>20.1%</td>
<td>A</td>
</tr>
<tr>
<td>14</td>
<td>65,000</td>
<td>3.75</td>
<td>243,750</td>
<td>5.7%</td>
<td>B</td>
</tr>
<tr>
<td>Total Annual Costs</td>
<td></td>
<td></td>
<td></td>
<td>4,240,228</td>
<td></td>
</tr>
</tbody>
</table>
Those three items collectively constitute about 72 percent of the annual expenditure on all items. Items 3, 7, and 15 are moderate in their percentage values and could be classified as B items. The remaining items could be classified as C items for their relatively low shares in annual dollar value.

**Economic Order Quantity Model**

The economic order quantity (EOQ) model is frequently used to answer the question of how much to order. EOQ calculates optimal order quantity in terms of minimizing the sum of certain annual costs that vary with the order costs—namely, inventory’s holding and ordering costs. A few assumptions are important for this model: that for an individual item the demand for a period (week, month or year) is known, and that the demand rate is constant throughout the period; that purchase price of the item does not affect order quantity (no high quantity discounts) and that delivery of the item (in quantity) is received at once with a constant lead time.

Before we proceed through the EOQ process, it is important to understand the inventory cycle. As Figure 11.2 illustrates, the cycle begins when an order for \( Q \) units is received. These units are withdrawn from inventory at a constant

![Figure 11.2. The Inventory Order Cycle for Basic EOQ Model.](image-url)
rate over time (depletion or demand rate). When the quantity on hand is just sufficient to meet the anticipated demand during the lead time, a new order for \( Q \) units is submitted to the vendor; that occurs at quantity \( R \), called the reorder point (ROP). Under the assumption that lead time and usage rate are constant, the order will be received at the precise instant that the inventory on hand falls to zero units. Thus orders are timed to avoid both excess stock and stock-outs. However, if those conditions were not the case or if deliveries were expected to be late, as illustrated in cycle 2, the health care manager should keep safety stocks on hand so operations could safely continue until the order is received.

The optimal order quantity reflects a trade-off between carrying costs and ordering costs: as the order size increases, its associated holding cost also increases; on the other hand, ordering costs decrease when keeping higher quantities on hand reduces frequent ordering. Looking at this issue in another way, if the order size is relatively small, its average inventory will be low, and hence have low carrying costs; but the small order size will necessitate frequent orders, which will drive up annual ordering costs. Figure 11.3 shows the relationship between ordering and holding costs with respect to the order quantity, \( Q \).

**FIGURE 11.3. THE ECONOMIC ORDERING QUANTITY MODEL.**

![Diagram showing the relationship between ordering and holding costs with respect to the order quantity, \( Q \). The total cost function is given by \( TC = \frac{Q}{2}H + \frac{D}{Q}S \).](image-url)
After observing these two extremes, it should be clear that the ideal solution is an order size that avoids either a few large orders or many small orders. The basic EOQ model serves that purpose, but the exact amount to order nevertheless will depend on the relative amounts of holding and ordering costs for a particular item, as well as the packaging requirements of its manufacturers and distributors.

The first step of the model is to identify the holding and ordering costs associated with an item, while keeping the model assumptions in mind. **Annual holding cost** is computed by multiplying the average amount of inventory in stock by the cost to carry one unit for one year. The average inventory is one half of the order quantity. As can be observed from Figure 11.2, the amount on hand depletes at a constant rate from \( Q \) to 0 units; here we make one observation at full quantity \( (Q) \) and one at zero quantity, when all items are depleted. However, at any given time the average inventory for a cycle can be calculated by taking the average of these two observations as \( [(Q + 0)/2] \), or \( Q/2 \). The symbol \( H \) is commonly used to represent the average holding cost per unit; thus the total annual holding cost can be expressed as:

\[
\text{Annual holding cost} = \frac{Q}{2} \times H. \quad [11.1]
\]

Holding costs are a linear function of \( Q \); holding costs increase or decrease in direct proportion to changes in the order quantity \( Q \), as shown in Figure 11.3.

Ordering costs, commonly labeled as \( S \), are inversely and nonlinearly related to order size \( Q \). As Figure 11.3 shows, annual ordering costs will decrease as order size increases. For a given annual demand level, the larger the order size, the fewer the orders needed. For instance, if annual demand for knee joints is 200 units and the order size is ten units per order, there must be twenty orders over the year. But if we order \( Q = 40 \) units, only five orders will be needed, and for \( Q = 50 \) units, only four orders will be needed. In general, the number of orders per year, or order frequency, is computed by dividing annual demand \( D \) by order quantity \( Q \), \( D/Q \). Ordering costs are relatively insensitive to order size and pretty much fixed, because regardless of the amount of an order, certain activities (for example, preparing invoices, checking samples for quality) must be done for each order. **Total annual ordering cost** is a function of the number of orders per year and the ordering cost per order and can be expressed as:

\[
\text{Annual ordering cost} = \frac{D}{Q} \times S. \quad [11.2]
\]

If we add holding and ordering costs for every point in their respective graphs, we can determine the **total annual cost** (TC) associated with inventory...

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**Quantitative Methods in Health Care Management**

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management. Figure 11.3 shows this as the TC curve where holding and ordering inventory for a given order quantity \( (Q) \) ordered each time. The total cost can be expressed as the sum of annual holding cost and annual ordering cost:

\[
TC = \frac{Q}{2} H + \frac{D}{Q} S
\]

where

\( D \) = demand, usually in units per year
\( Q \) = order quantity, in units
\( S \) = ordering cost, in dollars
\( H \) = holding cost, usually in dollars per unit per year.

(Note: \( D \) and \( H \) must be in the same units, such as months or years.)

We see in Figure 11.3 that the total cost curve is U-shaped and that it reaches its minimum at the quantity where carrying and ordering costs are equal. The mathematical solution to find this minimum point requires differentiating TC with respect to \( Q \):

\[
\frac{dTC}{dQ} = \frac{dQ}{2} H + d\left(\frac{D}{Q}\right) S = \frac{H}{2} - \frac{DS}{Q^2}
\]

The next step is to set the right hand side of this equation to zero. We can solve for the value of \( Q \) as:

\[
\frac{H}{2} - \frac{DS}{Q^2} = 0,
\]

and rearranging the equation, we get

\[
Q^2 = \frac{2DS}{H}
\]

and

\[
Q_o = \sqrt{\frac{2DS}{H}}
\]

That is the optimum solution for \( Q \) given by the minimum total cost of the TC curve. We will call the point where both costs equal each other, as derived by the above equations, \( Q_o \). And that is the EOQ formula \([11.5]\). It can be used when given annual demand, the ordering cost per order, and the annual holding cost per unit. One can also compute the minimum total cost by substituting \( Q_o \) for \( Q \) in the TC formula. Once \( Q_o \) is known, the length of an order cycle (the length of a time between orders), or order frequency, can be calculated as:

\[
\text{Length of order cycle} = \frac{Q_o}{D}
\]

[11.6]
Holding cost is sometimes stated as a percentage of the purchase price of an item, rather than as a dollar amount per unit. However, as long as the percentage is converted into a dollar amount, the EOQ formula is still appropriate. One final important point regarding the EOQ model: since the holding and ordering costs are estimates, EOQ is an approximate quantity rather than the exact quantity needed. An obvious question one may ask is: given the use of estimates, how stringent is the EOQ measure as an optimal number in minimizing total cost? Figure 11.3 shows us that the total cost curve is relatively flat near the EOQ, especially to the right of the EOQ, which provides flexibility for the Q value to be higher or lower than \( Q_o \) with marginal change in total cost, expressed as \( \Delta C = C'_o - C'_o \). Thus, health care managers can adjust their order sizes around \( Q_o \) according to manufacturers’ or distributors’ packaging requirements without incurring significant increases in total inventory management costs.

Although beyond the scope of this text, there are other, more complicated EOQ models, such as the EOQ model with non-instantaneous delivery and the quantity discount model. For such models, readers are referred to texts that specialize in operations management. What follows below is a typical, basic EOQ model.

**Example 11.1**

An orthopedic physician group practice uses 12cc syringes from Sherwood for their cortisone injections. During each of the last two years, forty thousand of them were used in the office. Each syringe costs $1.50. The physician’s office annually discards, on average, five hundred of the syringes that have become inoperable (broken, wrong injection material, lost). The syringes are stored in a room that occupies 2 percent of the storage area. The storage area constitutes 10% of the leased space. The annual office lease costs $60,000. The group practice can secure loans from a local bank at 6% interest to purchase the syringes. For each placed order, it takes about three hours for an office assistant (whose hourly wage is $9.00 and who receives $3.25 in fringe benefits) to prepare, communicate the order, and place its shipment in storage. In addition, each order’s overhead share of equipment and supplies (phone, fax, computer, stationery paper) is approximately $4.50. In the past, the office assistant always placed 5,000 syringes in each order. The deliveries are made in boxes of one thousand syringes and are always received three working days after the order is placed.

What should be the EOQ for the 12cc syringe?

What are the inventory management costs for these syringes?

What are the investment costs?

How many times in a year should an order be placed?
Solution: To calculate EOQ, we need to estimate the holding and ordering costs.

Annual holding cost
1. Cost of inoperable syringes: $1.50 * 500 = $750.
2. Storage cost: ($60,000 Lease) * .10 (storage area) * .02 (syringe) = $120.
3. Interest on a loan used to purchase 5,000 syringes: 5,000 * $1.50 * 0.06 = $450.

Total annual holding costs = $750 + $120 + $450 = $1,320.
Annual holding cost per syringe: $1,320 / 40,000 = $0.033.

Ordering cost
Office assistant’s time: 3 hours * ($9.00 + $3.25) = $36.75.
Overhead: $4.50.
Total ordering cost: $36.75 + $4.50 = $41.25.

Using formula [11.5] the EOQ:

\[ Q_o = \sqrt{\frac{2DS}{H}} = \sqrt{\frac{2 * 40,000 * 41.25}{0.033}} = 10,000. \]

Total inventory management cost calculated using formula [11.3]:

\[ TC = \frac{10,000}{2} * 0.033 + \frac{40,000}{10,000} * 41.25 \]

or

\[ TC = 165.00 + 165.00 = 330.00. \]

Investment cost:

Investment costs = Order quantity * price of the item, or
\[ = Q_o * p = 10,000 * 1.50 = 15,000.00. \]

Investment cost is the amount committed to purchase the syringes. It is cycled as the cost of the syringes is recovered from patients and/or third party payers.

Order Frequency is calculated using formula [11.6]:

\[ \text{Length of order cycle} = \frac{Q_o}{D} = \frac{10,000}{40,000} = .25 \text{ years or every three months}. \]

In other words, order frequency is four times a year.

Software Solution
We will seek and demonstrate the solutions for the syringe problem using WinQSB inventory theory and the system module. From the initial inventory theory and system menu, the constant demand EOQ model was chosen. Figure 11.4 shows the set up of the data for the syringe inventory case.
The WinQSB results for analyzing and solving this problem are provided in Figure 11.5. The first two columns identify the input data and their values. The third and fourth columns show the results of the analysis, where EOQ is identified as 10,000 units. In addition, the order interval (.25), ordering cost ($165.00), holding cost ($165.00), and total annual inventory management cost ($330.00) are shown.

**FIGURE 11.5. SOLUTION TO SYRINGE INVENTORY.**

![Figure 11.5: Solution to Syringe Inventory](source)

Source: Screen shots reprinted by permission from Microsoft Corporation and Yih-Long Chang (author of WinQSB).
are shown. The last two columns show that for the current practice of ordering five thousand items, the overall inventory management cost is $412.50 compared to that for the EOQ model of $330.00, a savings of $112.50 per year for this item alone kept in the inventory.

Figure 11.6 displays the cost curves for the syringe inventory problem. As can be noticed, the holding and ordering costs intersect where the total cost curve is at a minimum.

When to Reorder

We used the EOQ model to answer the question of how much to order, but not the question of when to order. We will now look at a new model that identifies the reorder point (ROP) in terms of the quantity of an item currently in stock.
The reorder point occurs when the quantity on hand drops to a predetermined amount (see Figure 11.2 and ROP level). This trigger amount usually includes the expected demand during the lead time. There are four conditions that affect the reorder point quantity: 1) the rate of forecast demand; 2) the length of lead time; 3) the extent of variability in lead time and/or demand; and 4) the degree of stock-out risk acceptable to management.

When demand rate and lead time are constant, there is no risk of a stock-out created by increased demand or lead times longer than expected. Therefore, no cushion stock is necessary, and ROP is simply the product of usage rate and lead time as:

\[
\text{ROP} = D \times L
\]  

[11.7]

where

\[D = \text{demand per period, and}\]
\[L = \text{lead time; and demand and lead time must be in the same units.}\]

Example 11.2 illustrates an ROP with constant demand rate and lead time.

**Example 11.2**

An orthopedic surgeon replaces two hips per day. The implants are delivered two days after an order is placed, via express delivery. When should the supply chain manager order the implants?

**Solution:**

Usage = 2 implants daily.

Lead time = 2 days.

\[\text{ROP} = \text{Usage} \times \text{Lead time} = 2 \times 2 = 4.\]

Thus, order should be placed when four implants are left!

When demand or lead time is not constant, the probability that actual demand will exceed the expected demand increases. In that situation, health care providers may find it necessary to carry additional inventory, called safety stock, to reduce the risk of running out of inventory (a stock-out) during lead time. In variable situations, the ROP increases by the amount of the safety stock:

\[
\text{ROP} = \text{expected demand during lead time} + \text{safety stock}
\]  

[11.8]

Here, the expected demand is indicated as an average, so variability of demand is present. Similarly, the expected lead time is variable. Hence the health care facility may run out of stock because of either more than expected demand or more than expected lead time for the shipment’s arrival. The only way to ensure the continuity of operations is to keep an appropriate level of safety stock.
For example, if the expected demand for implants during lead time is ten units, and the management keeps a safety stock level of twenty units, the ROP would be thirty units. The following example illustrates this concept.

**Example 11.3**
A dentist office uses an average of two boxes of gloves (100-glove boxes) per day, and lead times average five days. Because both the usage rate and lead times are variable, the office carries a safety stock of four boxes of gloves. Determine the ROP.

**Solution:** Using formula [11.8],

\[
ROP = \text{2 boxes/daily} \times \text{5 day lead time} + \text{4 boxes} = \text{14 boxes.}
\]

Because of the cost of holding safety stock, a provider must balance that cost with the reduction in stock-out risk that the safety stock provides, bearing in mind that the service level increases as the risk of stock-out decreases. Service level is defined as the probability that the amount of stock on hand is enough to meet demand. A service level of 95 percent means that there is a 95 percent probability that patient demand will not exceed the provider’s supply of service during lead time, or that patient demand will be satisfied in 95 percent of such instances. In other words, service level is the complement of stock-out risk: a 95 percent service level implies a 5 percent stock-out risk. The greater the variability in either demand rate or lead time, the more safety stock is needed to achieve a given service level.

\[
\text{Service Level} = 100\% - \text{Stock-out Risk} \quad [11.9]
\]

WinQSB can analyze problems involving stochastic demand if the demand distribution parameters (mean, standard deviation) are known. It can also analyze problems with lead time and desired service levels.

**Summary**

The providers decide, for all medical-surgical products, what to use and whom to use and secure their availability and end distribution. This function of providers in the supply chain link can be characterized as inventory management. Good inventory management is essential to the successful operation of any health care
organization. Because the inventory of medical supplies may comprise a significant portion of a health care organization's total assets, health care managers must be able to manage the inventory of medical supplies effectively to enhance its position in the financial markets. This chapter presented concepts that support good inventory management.

Exercises

Exercise 11.1

A product used in a laboratory of the hospital costs $60 to order, and its carrying cost per item per week is one cent. Demand for the item is six hundred units weekly. The lead time is three weeks and the purchase price is $0.60.

a. What is the economic order quantity for this item?
b. What is the length of an order cycle?
c. Calculate the total average weekly costs.
d. What is the investment cost for this item?
e. If ordering costs increase by 50%, how would that affect EOQ?
f. What would be the reorder point for this item if no safety stocks were kept?
g. What would be the reorder point if one thousand units were kept as safety stock?

Exercise 11.2

The CHEMSA chemical supply center provides popular sterilization materials for hospitals. The weekly demand for sterilization materials is normally distributed with a mean of two hundred packages. This center is functional for fifty-two weeks a year. The unit purchase cost of the sterilization materials is $15 per package. There are no discounts available for ordering large quantities. A cost study finds that the average cost of placing an order is $50 per order, and the carrying cost is $0.60 per package.

a. Determine the economic order quantity.
b. Determine the average number of packages on hand.
c. Determine the number of orders per year.
d. Calculate the total cost of ordering and carrying for sterilization packages.

Exercise 11.3

A medical supply distributor needs to determine the order quantities and reorder points for the various supplies. A particular item of interest costs $30 to order. The holding
cost of the item is 20 percent of the product cost per year, and the item’s cost is $250. Annual demand for the item is eight hundred units. Lead time for delivery is eight days and constant.

a. What is the EOQ for this item?
b. What is the total inventory management cost for this item?
c. What is the investment cost for the item?
d. What is the reorder point?

Exercise 11.4

WE CARE ASSOCIATES (WCA), a local physician practice group, orders supplies from various distributors. Order quantities of fifteen items have been determined based on past five years of usage. Other relevant information from the practice’s inventory records is depicted in Table EX 11.4. The practice is functional for fifty-two weeks a year.

TABLE EX 11.4

<table>
<thead>
<tr>
<th>Item No</th>
<th>Weekly Demand (Unit/Week)</th>
<th>Unit Cost in $</th>
<th>Carrying Rate of Each Item</th>
<th>Ordering Cost in $</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>400</td>
<td>2.50</td>
<td>15%</td>
<td>12.00</td>
</tr>
<tr>
<td>2</td>
<td>1,600</td>
<td>0.50</td>
<td>16%</td>
<td>6.00</td>
</tr>
<tr>
<td>3</td>
<td>175</td>
<td>37.50</td>
<td>20%</td>
<td>32.00</td>
</tr>
<tr>
<td>4</td>
<td>250</td>
<td>3.50</td>
<td>12%</td>
<td>50.00</td>
</tr>
<tr>
<td>5</td>
<td>250</td>
<td>1.75</td>
<td>18%</td>
<td>12.00</td>
</tr>
<tr>
<td>6</td>
<td>32</td>
<td>2,300.00</td>
<td>2%</td>
<td>35.00</td>
</tr>
<tr>
<td>7</td>
<td>1,500</td>
<td>1.25</td>
<td>14%</td>
<td>10.00</td>
</tr>
<tr>
<td>8</td>
<td>2,200</td>
<td>0.65</td>
<td>17%</td>
<td>6.00</td>
</tr>
<tr>
<td>9</td>
<td>1,270</td>
<td>0.95</td>
<td>21%</td>
<td>5.00</td>
</tr>
<tr>
<td>10</td>
<td>120</td>
<td>12.50</td>
<td>12%</td>
<td>12.00</td>
</tr>
<tr>
<td>11</td>
<td>220</td>
<td>2.00</td>
<td>15%</td>
<td>28.00</td>
</tr>
<tr>
<td>12</td>
<td>350</td>
<td>1.50</td>
<td>14%</td>
<td>18.00</td>
</tr>
<tr>
<td>13</td>
<td>18</td>
<td>5,000.00</td>
<td>2%</td>
<td>25.00</td>
</tr>
<tr>
<td>14</td>
<td>6</td>
<td>6,700.00</td>
<td>2%</td>
<td>50.00</td>
</tr>
<tr>
<td>15</td>
<td>1,250</td>
<td>2.60</td>
<td>22%</td>
<td>19.00</td>
</tr>
</tbody>
</table>

a. Determine the basic EOQ on each item.
b. Provide the ABC classification of these items.
c. Calculate the yearly cost of inventory management.
d. Calculate the investment cost (per cycle) for each item.
e. Explain the difference between inventory management cost and investment cost.
Exercise 11.5

A portion of a hospital pharmacy formulary contains the twenty medications listed in Table EX 11.5.

<table>
<thead>
<tr>
<th>Item No</th>
<th>Description</th>
<th>Unit Price</th>
<th>Weekly Demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Albuterol .083% 3 ml</td>
<td>7.83</td>
<td>25</td>
</tr>
<tr>
<td>2</td>
<td>Alprazolam 1 mg</td>
<td>3.15</td>
<td>35</td>
</tr>
<tr>
<td>3</td>
<td>Bumetanide 0.5 mg</td>
<td>7.42</td>
<td>40</td>
</tr>
<tr>
<td>4</td>
<td>Captopril 50 mg</td>
<td>29.66</td>
<td>10</td>
</tr>
<tr>
<td>5</td>
<td>Cerumenex</td>
<td>9.98</td>
<td>15</td>
</tr>
<tr>
<td>6</td>
<td>Clotrimazale crm 1%</td>
<td>4.38</td>
<td>100</td>
</tr>
<tr>
<td>7</td>
<td>Deltason 20 mg</td>
<td>11.89</td>
<td>30</td>
</tr>
<tr>
<td>8</td>
<td>Diflunisal 250 mg</td>
<td>15.43</td>
<td>15</td>
</tr>
<tr>
<td>9</td>
<td>Fluocinonide 0.05%</td>
<td>9.85</td>
<td>140</td>
</tr>
<tr>
<td>10</td>
<td>Intron A 5 ml</td>
<td>32.23</td>
<td>45</td>
</tr>
<tr>
<td>11</td>
<td>Laxone 0.25 mg 2 ml</td>
<td>36.90</td>
<td>9</td>
</tr>
<tr>
<td>12</td>
<td>Morphine 25 mg 10 ml</td>
<td>32.21</td>
<td>12</td>
</tr>
<tr>
<td>13</td>
<td>Mucosil 10% 10 ml</td>
<td>8.64</td>
<td>20</td>
</tr>
<tr>
<td>14</td>
<td>Mycelex 1%</td>
<td>6.78</td>
<td>215</td>
</tr>
<tr>
<td>15</td>
<td>Propulsid 10 mg</td>
<td>22.90</td>
<td>50</td>
</tr>
<tr>
<td>16</td>
<td>Retin-A 0.1%</td>
<td>19.90</td>
<td>15</td>
</tr>
<tr>
<td>17</td>
<td>Succinylcholn 10 ml</td>
<td>10.65</td>
<td>25</td>
</tr>
<tr>
<td>18</td>
<td>Sucralfate 1Gm</td>
<td>114.00</td>
<td>65</td>
</tr>
<tr>
<td>19</td>
<td>Theophylline</td>
<td>9.80</td>
<td>350</td>
</tr>
<tr>
<td>20</td>
<td>Triamterene</td>
<td>30.81</td>
<td>245</td>
</tr>
</tbody>
</table>

Ordering cost of items is $30 and carrying cost is 5% of the unit price.

a. Determine basic the EOQ on each item.

b. Provide the ABC classification of these items.

c. Calculate the yearly inventory management cost.

d. Determine the investment cost (per cycle) for each item.

Exercise 11.6

SURGERY ASSOCIATES, a local surgery practice group, orders implants from device manufacturers. Order quantities for ten items have been determined based on the past two years of usage. Other relevant information from the practice’s inventory records is depicted in Table EX 11.6. The practice is functional for fifty-two weeks a year.
TABLE EX 11.6

<table>
<thead>
<tr>
<th>Implant Item No.</th>
<th>Yearly Demand (Unit/Year)</th>
<th>Unit Cost</th>
<th>Carrying Rate of Each Item</th>
<th>Ordering Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>104</td>
<td>2,225</td>
<td>12%</td>
<td>6.00</td>
</tr>
<tr>
<td>2</td>
<td>260</td>
<td>5,000</td>
<td>10%</td>
<td>5.00</td>
</tr>
<tr>
<td>3</td>
<td>728</td>
<td>3,550</td>
<td>8%</td>
<td>12.00</td>
</tr>
<tr>
<td>4</td>
<td>1,248</td>
<td>1,205</td>
<td>12%</td>
<td>28.00</td>
</tr>
<tr>
<td>5</td>
<td>104</td>
<td>11,100</td>
<td>2%</td>
<td>18.00</td>
</tr>
<tr>
<td>6</td>
<td>1,040</td>
<td>1,500</td>
<td>20%</td>
<td>32.00</td>
</tr>
<tr>
<td>7</td>
<td>780</td>
<td>1,900</td>
<td>11%</td>
<td>50.00</td>
</tr>
<tr>
<td>8</td>
<td>884</td>
<td>3,700</td>
<td>9%</td>
<td>12.00</td>
</tr>
<tr>
<td>9</td>
<td>780</td>
<td>6,400</td>
<td>2%</td>
<td>35.00</td>
</tr>
<tr>
<td>10</td>
<td>520</td>
<td>2,700</td>
<td>5%</td>
<td>12.00</td>
</tr>
</tbody>
</table>

a. Perform basic EOQ analysis for each item.
b. Classify the implant inventory items according to the ABC analysis.
c. Calculate the yearly inventory management cost.
d. Determine the investment cost (per cycle) for each item.