

Selection
Procurement
Distribution
22 Managing distribution
23 Inventory management
24 Importation and port clearing
25 Transport management
26 Kit system management
Use

CHAPTER 23

Inventory management

Summary	23.2
23.1 Introduction	23.3
23.2 The context of an inventory management system	23.4
23.3 Stock records and standard reports	23.4
<i>Stock records • Activity reports and performance monitoring</i>	
23.4 Selection of items to be held in stock	23.7
23.5 Service level and safety stock	23.8
<i>Service level to operating units • Methods for setting safety stock levels</i>	
23.6 Inventory control models and reorder frequency	23.11
<i>Annual purchasing • Scheduled purchasing • Perpetual purchasing • Drawing down from framework contracts • Combinations of annual, scheduled, and perpetual purchasing</i>	
23.7 Factors to consider in calculating reorder quantity	23.16
<i>Factors in the reorder formula • Projecting demand • Integrating experience and other factors</i>	
23.8 Standard reordering formulas	23.19
<i>Minimum and maximum stock-level formula • Consumption-based reordering formula</i>	
23.9 Mathematical models for reordering	23.21
<i>Economic order quantity • Economic order interval • Exponential smoothing • Standard deviation of consumption and lead time</i>	
References and further readings	23.23
Assessment guide	23.24

ILLUSTRATIONS

Figure 23-1	Balancing benefits and costs in inventory management	23.8
Figure 23-2	Safety stock requirements to maintain various service levels	23.9
Figure 23-3	Ideal inventory control model	23.11
Figure 23-4	Impact of reorder interval on average inventory	23.12
Table 23-1	Value of average inventory by service level and procurement pattern	23.16

BOXES

Box 23-1	Performance indicators used by commercial firms	23.6
Box 23-2	Estimating safety stock	23.10
Box 23-3	Economic order quantity and order interval	23.22

COUNTRY STUDY

CS 23-1	Scheduled purchasing in the eastern Caribbean	23.14
---------	---	-------

SUMMARY

This chapter discusses inventory management—the management of the routine ordering process. Seven basic issues must be considered for effective, efficient inventory management—

- The supply system's purpose and the type of distribution system
- The records and reports that will provide the foundation for inventory management
- The selection of items to be stocked
- The balance between service levels, including stock-out costs, ordering costs, and stock-holding costs
- The policy on when to order
- The policy on how much to order and methods for determining reorder quantities or reorder intervals
- The control of costs associated with inventory management (ordering, stockout, and stock holding)

The type of inventory management system needed depends first on the context—different systems are used for dependent demand systems (manufacturing) and independent demand systems (distribution of finished goods). Similarly, a different system may be needed in a push system as opposed to a pull system (see Chapter 22), although ordering has to be done in both push and pull systems. Clearly, most inventory management for pharmaceutical supply concerns the distribution of finished goods.

Accurate and current stock records are essential to good inventory management. They are the source of information used to calculate needs, and inaccurate records produce inaccurate needs estimations (and problems with stockouts and expiry). Each inventory system should monitor performance with indicators and produce regular reports on inventory and order status, operating costs, and consumption patterns.

The primary reason for holding stock in a pharmaceutical supply system is to ensure availability of essential items almost all the time. The selection of items to stock should be based on their value to public health and on the regularity and volume of consumption. VEN (vital, essential, nonessential) and ABC analyses are useful tools for defining which items on the formulary list must be held in stock (see Chapter 40). Although ABC analyses are often based on the value of the medicines, for inventory management, ABC analyses based on order frequency and volume are also important.

Key issues in inventory management are service level and safety stocks. The *service level* is the measurement of service from a supplier or from a warehouse, with

the goal of never having stockouts. The principal determinant of service level is safety stock—the higher the level of safety stock in the warehouse, the higher the service level. However, excessive safety stocks cause excessive inventory-holding costs. The basic method for setting safety stock is multiplying the lead time by the average monthly consumption, but adjustments may be needed to cope with variations in consumption and lead-time patterns. The other key determinant is the turnaround time with the supplier or the warehouse, that is, the time taken to fill and deliver an order once it is received by the supplier or the warehouse. This turnaround time is a component of the overall lead time that is used by the user-level stockholder to determine inventory levels.

The ideal inventory model is the optimal stock movement pattern, in which inventory levels are as low as possible (without risking stockouts) and optimized, consumption patterns are consistent, and suppliers always deliver on time—but this model is rarely achieved in practice. As described in Section 23.6, the three common inventory models used in pharmaceutical supply systems are defined by how often regular orders are placed with suppliers—

- Annual purchasing (one regular order per year)
- Scheduled purchasing (periodic orders at set times during the year)
- Perpetual purchasing (orders are placed whenever stock becomes low, or when stock levels reach predetermined reorder levels)

Average inventory levels (and holding costs) are expected to decrease with more frequent orders.

The basic formulas for calculating order quantity are relatively simple; two useful formulas are minimum-maximum and consumption based. Both incorporate several essential factors—

- Average monthly consumption
- Supplier/warehouse lead time
- Safety stock
- Stock on order
- Stock in inventory
- Stock back-ordered to lower levels

The more complicated mathematical formulas, such as economic order quantity and exponential smoothing of demand, do not necessarily lead to better services than the simpler approaches and are not recommended for most pharmaceutical supply systems.

Whichever formulas are used, purchase quantities should be adjusted to take into account factors such as seasonal demand, expiry dates, expected changes in use or prices, currency fluctuation, and availability of storage space.

Key ways of minimizing total costs include—

- Lowering order processing, purchase, or delivery costs through efficient procurement
- Lowering stock-holding costs through good store-keeping practices
- Controlling stock levels and minimizing stockouts by using effective inventory control techniques
- Minimizing financial costs through use of attractive financing methods

Primary considerations in promoting efficiency are the costs of purchasing and holding stock in inventory. A regular and accurate stock count and standard methods for valuing the inventory are needed to determine the base inventory value. Other relevant costs are the operating costs associated with procurement and with holding inventory.

The objective of good inventory management is to maintain a steady supply to operating units (and patients) while minimizing the costs of holding inventory and managing procurement. Compiling information on the total costs of inventory management (pharmaceutical acquisition costs, inventory-holding costs, purchasing operations costs, and shortage costs) allows managers to evaluate strategies for reducing costs.

23.1 Introduction

Inventory management is the heart of the pharmaceutical supply system; in fact, the nonspecialist might say that inventory management *is* pharmaceutical management. That would be simplistic, as the other chapters of this book demonstrate, but without a healthy inventory management system, the pharmaceutical supply system as a whole will not be viable.

Inventory management for pharmaceutical supply sounds easy—all that must be done is to order, receive, store, issue, and then reorder a limited list of items. In reality, the task is difficult, and in many countries, poor inventory management in the public pharmaceutical supply system leads to waste of financial resources, shortages of some essential medicines or overages of others resulting in expiration, and decline in the quality of patient care.

“Sick” inventory management systems generally feature subjective, ad hoc decisions about order frequency and quantity, inaccurate stock records, and a lack of systematic performance monitoring. These problems are directly related to lack of knowledge and appreciation of what inventory management means as well as to ineffective management. In many cases no systematic procedures and rules exist to guide staff, a problem compounded by lack of understanding of the basic issues of proper inventory management on the part of managers.

Seven basic issues must be carefully considered when an inventory management system is being initially designed or upgraded—

1. Definition of the context in which the inventory management system must function
2. Determination of the types of stock records and inventory reports needed

3. Selection of items to be stocked as standard items
4. Maintenance of appropriate service levels for different classes of items
5. Adoption of a decision rule or a model for determining when to reorder
6. Adoption of a decision rule or a model for determining how much to reorder
7. Identification and control of inventory management costs using product classification systems such as ABC analysis, VEN analysis, level of use, and other cost-minimizing techniques. (See Chapter 40 for further details on minimizing costs.)

To address these issues, managers may use mathematical formulas and models to set policies concerning stock levels, reordering frequency, and reorder quantity. Because inventory management is so vital in maintaining supply systems—public or private—a number of formulas have been developed over the years, some fairly simple and others using complex mathematical models that not only are difficult to construct, but also are hard to solve. In the great majority of pharmaceutical supply situations, the simple models, formulas, and methods work as well as the complex models, so the simple approach is emphasized in this chapter.

One goal of inventory management is to achieve a reasonable balance between holding costs, on the one hand, and purchasing and shortage costs, on the other. In order to maintain this balance, the relevant costs need to be identified and quantified and then examined for how they interrelate. This analysis allows managers to see the “big picture” in the system and consider the effect of potential changes. Chapter 40 illustrates different approaches to controlling costs in pharmaceutical management.

23.2 The context of an inventory management system

Before defining rules for inventory management, the context in which an inventory management system operates must be defined. Two factors are relevant—*independent* versus *dependent* demand, and the use of “push” versus “pull” systems for distribution.

One factor that defines the context is whether the inventory system supports a supply system in which clients (health facilities) order finished products from a warehouse or other supply source, or whether the system supports primarily internal manufacturing; this factor determines whether the system is an independent demand system or a dependent demand system. The fundamental inventory management concepts and resulting procedures are quite different for the two systems.

Independent demand systems are applicable to the management of procurement and distribution of finished goods. The order intervals and quantities are derived from forecasts based on historical consumption by clients, tempered by knowledge of expected changes in consumption. Inventory levels are set to provide a defined level of service to clients, at an acceptable cost.

Dependent demand systems manage inventory requirements for raw materials and supplies based on what is needed for production in a manufacturing or repackaging operation. They are also known as *materials requirement planning systems*. Ordering intervals and quantities as well as inventory levels depend on projected production schedules. The just-in-time system is an example of inventory management in this context.

Because a typical pharmaceutical supply system is involved mainly in the procurement and distribution of finished pharmaceutical products, this chapter focuses on the independent demand system. However, in some pharmaceutical supply situations (such as local manufacturing or repackaging), a dependent demand system would be more appropriate. Readers who need information on dependent demand systems can find sources in References and Further Readings (Dear 1990; Waters 2003).

The other factor that defines the inventory management context is whether the distribution system is a pull system or a push system. In the *pull system*, operating units order medicines from a warehouse or supplier according to local determination of need. In the *push system*, a central authority orders medicines from suppliers and determines the quantities that will be shipped to the operating unit, based on the annual distribution plan and on information transmitted to the warehouse about need at the operating unit. The best-known example of a push system in pharmaceutical supply is the ration kit system, discussed in Chapter 26. Note that a push system has some features of a dependent demand system—a plan is set for distribution

to operating units, and procurement is done to carry out that plan.

The inventory management methods discussed in this chapter can be applied in either a pull or a push system. In certain complex systems involving multiple levels of storage located, for example, at central, provincial, district, and health facilities, both push and pull systems may be at work in different levels of the system. Both systems may possibly be used at the same time for limited periods, for example, when introducing a limited push system to supplement supplies while addressing inefficiencies in the pull system.

Before readers go further, they may find reviewing the procurement glossary at the end of Chapter 18 useful. It contains commonly used terms that have a specific meaning in the discussion of inventory management.

23.3 Stock records and standard reports

This section discusses the types of stock records and reports that form the foundation of effective inventory management.

Stock records

Stock records are the core records in the inventory management system. They are the primary source of information used in the various reordering formulas discussed later in this chapter; they are also the source of data used to compile performance reports discussed in this section. Stock records can be either manual or computerized. Commonly used manual stock records include—

Vertical file cards: File cards are stored vertically in alphabetical or numerical order in a card file or drawer.

“Kardex” system: File cards are stored in a visible-edge record-tray system, with names and stock numbers on the lower edge, overlapped to provide an index.

Bin cards: File cards are physically kept with the stock. This system makes a visual check easy, serves as a reminder to keep records, and serves as a backup to records previously described. If a product has two different batches with two different batch numbers and expiry dates, two sets of bin cards should be maintained. However, only one stock card containing information on both batches needs to be used.

Ledger system: Records are kept on ledger sheets in a bound or loose-leaf book.

Many supply systems maintain two stock records for each item to improve accuracy and accountability. Typically, a bin card is kept with the stock, combined with a ledger, Kardex, or computer system kept in the central office. The use of these record systems in a large warehouse is discussed in

Chapter 44, and the maintenance of stock records in health facilities is treated in Chapter 46. Examples of manual and computerized stock records can be found in those chapters.

In most supply systems, computerization is desirable if the local situation can afford and support automation. Use of computers is an efficient way to manage inventory with perpetual or periodic purchasing; moreover, a good software program, properly used, makes information retrieval and reporting much easier than a manual system (see Chapter 50). However, much depends on the type of software program used, how well the system is operated, and the accuracy of data entry. In most pharmaceutical supply environments, stock can still be controlled with manual records, if necessary.

The key point about stock records, whether manual or computerized, is that they must be current and accurate. Managing the reordering process well is impossible if stock movement cannot be tracked.

Several factors contribute to inaccurate stock records; some are entirely avoidable, but some are not—

- High-volume, repetitious entries lead to occasional entry errors just by the nature of the task.
- Medicine names and descriptions are similar—ten items may be different forms of the same medicine, and an entry may be made for the wrong form, or different strengths of the same item may be confused.
- Duplicate entries for receipts or issues may be caused by duplicate paperwork provided separately to different clerks.
- Spoiled or junk stock may be destroyed but not written off the records.
- Theft produces inaccurate records, except when they are deliberately altered to conceal the theft.
- Physical stock counts may be rarely or never taken, they may be inaccurate, or the records may not be reconciled after stock counts.
- Sloppy storekeeping and warehouse practices may make carrying out accurate stock counts difficult and prevent reconciliation of physical stock with recorded stock, especially when stock of the same item is stored in different locations.
- Clerical and stock management staff may be poorly paid, poorly trained, and poorly motivated.
- Supervision of warehouse staff or clerical staff is often minimal, and management may make limited or no effort to reconcile discrepancies.

Automation and newer technologies, such as bar coding, reduce some of the problems related to inaccurate data entries, but this technology is still expensive to implement and does not solve all the problems. The best way to promote greater accuracy is better training and closer supervision, with spot checks of records and stock status by supervisors.

Stock counts are important, both for reordering purposes and for determining the inventory value. Some pharmaceutical supply systems still never count stock and rely totally on inventory records, but most systems have a policy of conducting stock counts at least annually (although they may not really be carried out every year). The best approach to tracking the quantity actually in stock is *cyclic counting*.

In cyclic counting (sometimes known as continuous counting or perpetual inventory), the entire inventory is divided into counting groups, and one group is counted each week (or each month), with reconciliation of discrepancies; another group is counted the next week (or next month), and so forth. A cyclic counting program provides for every item in the inventory to be counted at least once a year and for a reconciliation to be carried out between physical and recorded stock. A regular, cyclic stock-counting procedure is generally accepted as superior to an annual stock count. Two main reasons account for the change to cyclic counting—

1. With an annual stock count, a whole warehousing and distribution operation is shut down for a day or two to a week or more. This procedure disrupts the supply system and causes frustration for warehouse and financial staff, who must rush to get the whole process completed as quickly as possible.
2. When discrepancies are found in an annual count, tracing exactly where the problem arose during the year is difficult, so the records are simply corrected to reflect actual stock, and any losses are written off.

Cyclic counting, in contrast, can take place without interrupting normal operations. With more frequent counting, tracking down the source of discrepancies may be possible. Moreover, more frequent counting may make it harder for staff to pilfer stock.

One method of cyclic counting is to assign the counting frequency and timing by ABC category (defined in Section 23.4), counting A items three or four times a year, B items twice, and C items once; any B or C items that are prone to disappear may be worth adding to the A category.

For best results, the staff members who perform the stock counts should not be the ones to reconcile discrepancies; a system of rotating different staff members through both functions helps maintain the integrity of the process.

Activity reports and performance monitoring

The most accurate stock records have little value if the information in them is not compiled in reports for use by the managers who make purchasing and stock management decisions. Two similar but separate types of reports are useful: periodic analyses and routine reports.

The inventory management system's health can be measured periodically using standard performance indicators. Box 23-1 lists performance indicators commonly used by commercial firms. The assessment guide at the end of the chapter cites indicators that have been tested in public supply systems.

Routine reports on purchasing and inventory management activities should be produced monthly to quarterly in a computerized system and at least annually in a manual system. The following lists illustrate the types of reports that are useful for improving inventory management.

Storage facilities should report on—

- Stock position—stock on hand and on order, globally and by item, reported as absolute quantities and in terms of months' worth of consumption; listing inventory by descending stock value and also by descending (or ascending) number of available months of consumption is also useful
- Beginning and ending inventory value, and the average inventory-holding costs
- Value of all supplies received and issued during the reporting period
- Changes in inventory value and any discrepancies noted during stock counts
- Value of stock adjustments carried out during reconciliation

- Consumption patterns for all stock items and an ABC analysis of consumption—with computer assistance, this analysis can be done globally and for each operating unit
- Service level from suppliers to medical stores and from medical stores to health facilities
- Medicines at risk of expiry in inventory and an estimate of how much stock is likely to expire before it can be used
- Quantity and value of obsolete stock waiting for disposal and stock destroyed or junked

Purchasing and financial departments should report on—

- Budget status—year-to-date expenditures versus targets, and amount remaining
- Purchases and expenditures, broken down by supplier and by operating unit
- Summaries of accounts payable to suppliers
- Status of outstanding orders
- Comparison of expected and actual lead times for completed orders
- Supplier performance
- Comparison of actual purchase price and projected cost
- Comparison of actual items purchased and original needs projections

Box 23-1

Performance indicators used by commercial firms

Inventory management performance indicators are used in commercial companies throughout the world to measure how effectively inventory is being managed; these indicators can and should be used in public pharmaceutical supply systems when data are available.

Net sales to inventory (also called *inventory turnover*): The total value of medicines distributed, minus write-offs, divided by the value of the inventory. The higher the ratio, the lower the average inventory level (and average holding cost). Most private companies would expect a turnover ratio of twelve or higher; in public pharmaceutical supply systems, the ratio is dictated to some extent by the purchasing model, but a ratio of at least six is realistic in most cases.

Inventory shrinkage: The sum of beginning inventory value plus purchases, minus the sum of the cost of goods sold, plus ending inventory value. Ideally, this figure would be zero, but any value less than 10 percent of inventory value is within expectations in most public pharmaceutical supply systems.

Expense ratio: Total operating expenses divided by net sales (or value of medicines distributed). In one view, the lower this ratio, the more efficiently services are being managed.

Service level: The percentage of items ordered or requested that is filled from stock by the supplier or warehouse. From the public health viewpoint, the higher the service level, the better, as long as inventory costs do not rise to insupportable levels.

Average inventory-holding cost: The average cost of holding inventory as a percentage of average inventory value. In a public pharmaceutical supply system, 30 to 40 percent is a reasonable target.

Incremental ordering cost: The average incremental cost of placing each order. In a private company in an industrialized country, this might be 100 to 200 U.S. dollars per order. It should be considerably lower in most public pharmaceutical supply systems.

- Operating costs attributable to stock management and to purchasing

Accurate reporting is possible with either a manual or a computerized information system, but the information is much more readily compiled with computer assistance. Again, source data for the reports—stock records and purchasing records—must be maintained accurately and kept up-to-date. The key is for senior managers to demand these sorts of reports, use them in making policy decisions, and take corrective action when reports are not produced.

23.4 Selection of items to be held in stock

Stock must be held for several reasons—

To ensure availability: In the typical pharmaceutical supply system, one cannot forecast demand with complete accuracy or be certain about suppliers' performance. Proper inventory management allows the absorption of fluctuations in supply and demand and reduces the risk of stockouts.

To maintain confidence in the system: If stockouts occur regularly, patients and staff lose confidence in the system, and patient use drops for both curative and preventive services.

To reduce the unit cost of medicines: Ordering medicines in bulk allows quantity discounts from suppliers and reduces shipping and port-clearing costs.

To avoid shortage costs: If emergency orders are needed to cope with stockouts, the unit cost is likely to be much higher than for a regular order. Also, when a pharmaceutical sales program is operating, stockouts result in lost revenue, because clients go elsewhere for medicines.

To minimize ordering costs: Purchasing costs increase when items are ordered frequently. These costs include salaries and benefits for purchasing and accounting staff members, office space costs, utilities, supplies, and other costs associated with tenders and regular orders.

To minimize transport costs: Medicines can be delivered less frequently, enabling transport resources to be used more economically.

To allow for fluctuations in demand: Changes in demand for specific medicines are often unpredictable, and an adequate inventory allows the system to cope with demand fluctuations.

Obviously, pharmaceutical supply systems need to hold a certain level of inventory; however, holding high stock levels has disadvantages (see Figure 23-1). Substantial capital can be tied up in inventory and thus be unavailable for other purposes. As inventories become larger, the costs for personnel, utilities, insurance, storage facilities, and other costs

of holding stock increase. High inventory levels also increase the likelihood of losses caused by spoilage, expiry, obsolescence, and theft. These adverse effects of high stock levels compel managers to practice proper inventory management by balancing stock-holding costs, ordering costs, and stock-out costs; otherwise, supply systems would simply hold large quantities of stock at all levels so that no chance of shortages would exist.

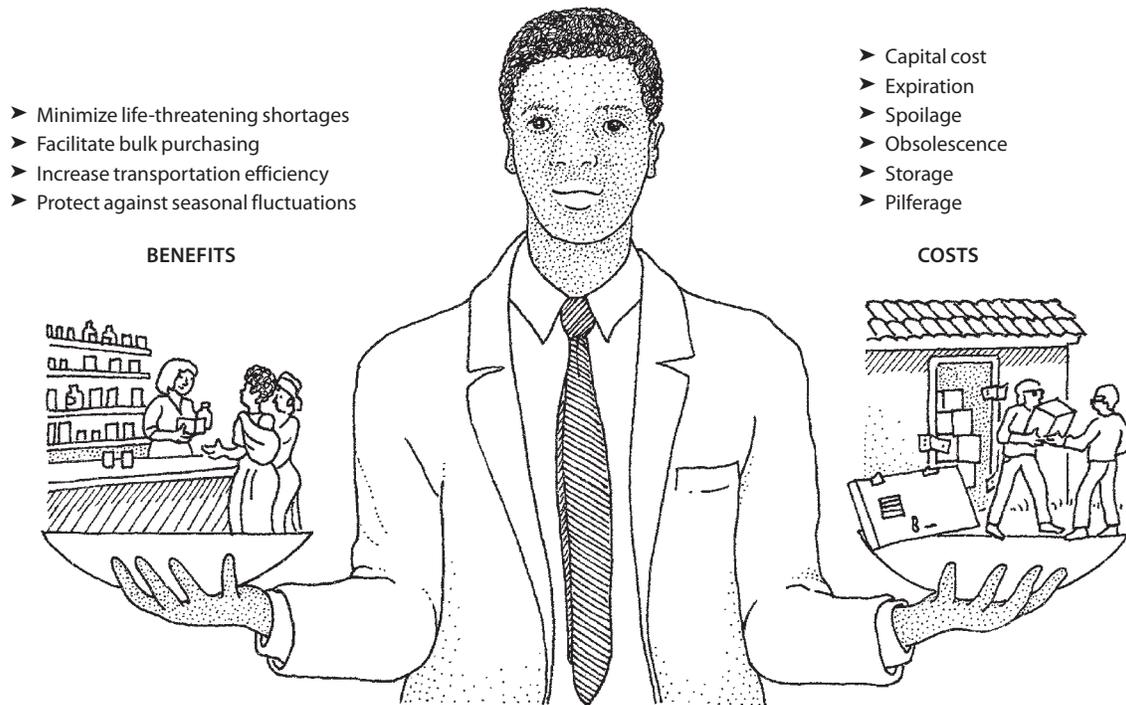
Most pharmaceutical supply systems try to regularly stock all items that are on the formulary or essential medicines list (see Chapter 16). In many cases, items that are not on the approved list but that are regularly requested by physicians are also routinely held in stock. Often no differentiation is made between vital and nonessential items, between high-cost and low-cost items, or between items that move quickly and those that are rarely used. This lack of discrimination often leads to an accumulation of slow-moving stock and excess capital tied up in inventory.

One way to decide which items should be stocked is to look at records of stock movement in and out of the storage facilities and identify the high-volume items that definitely need to be stocked, as well as items that have shown little or no movement in the past year. A good tool for reviewing stock movement is ABC analysis, which categorizes items by the volume and value of consumption during a specific period of time, usually one year. Class A items—10 to 20 percent of items, representing 75 to 80 percent of expenditures—are mostly high-volume, fast-moving medicines. Class B items are usually 10 to 20 percent of items, and 15 to 20 percent of expenditures. Class C items often represent 60 to 80 percent of the items but only about 5 to 10 percent of the total expenditures; these are the low-volume, slow-moving items. Thus, class C is a good place to look for items that might not be needed in stock at all times.

The VEN system is another method for categorizing stock, as vital (V), essential (E), or nonessential (N). This system is sometimes modified to two categories—V and N. VEN analysis is often used to prioritize procurement when not enough funds exist to purchase all items requested. The system can also help determine which items should be kept in stock and which can be ordered when needed. Clearly, V medicines would be more likely to be regular stock items than N medicines. Both ABC and VEN analyses are discussed in detail in Chapter 40.

Not all medicines have to be stocked at each level of the system. One way of classifying stock versus nonstock items is according to the approved level of use. For example, a medicine such as aspirin would be a stock item at all levels of the system, but a third-generation cephalosporin or a drug used in cancer chemotherapy might be a stock item only in tertiary-care hospitals. Classifying medicines according to their eligibility for routine use at each level helps minimize stock levels and ensure that only qualified staff members prescribe dangerous or expensive

Figure 23-1 Balancing benefits and costs in inventory management



medicines. Another option is to stock slow-moving items only at the central level, then consolidate orders and distribution.

Finally, the issue of local availability must be kept in mind. If a medicine is vital to patient care (even if rarely used) and it cannot be obtained quickly when needed, that medicine will probably need to be kept as a stock item. When no local sources of supply exist and all medicines are imported, with long lead times, all medicines need to be held in stock somewhere in the system. In most countries, however, opportunities exist to purchase some medicines as needed from local sources, and considering which of those items need to be constantly held in stock is worthwhile.

Whichever approaches are used to designate stock and nonstock items, some scheme is needed for periodically reevaluating the stock status. If the system is computerized, the software can be programmed to automatically recategorize items at specified intervals based on recent patterns of stock movement.

23.5 Service level and safety stock

After the decision has been made about which items will be routinely held in stock and which will be ordered only when they are needed, the discussion turns to how much stock should be held at each level of the system. Different points of view are likely to exist: stock controllers and clinical staff

may feel that inventory levels should be high, to avoid shortages; financial managers, however, hope to minimize inventory levels to hold down costs.

One of the most common ways to measure the performance of a commercial supplier or public warehouse is to calculate the service level provided to clients. Suppliers try to balance service level and the costs of holding stock. The single most important factor in establishing that balance is the average stock held by the supplier and, in particular, the safety stock.

Service level to operating units

The *service level*, in its most simple form, is the percentage of individual items ordered from a supplier or warehouse that is issued from stock on hand. It is measured by counting the total number of items issued and dividing by the total number of items requested.

$$\text{Service level} = (\# \text{ items issued} \div \# \text{ items requested}) \times 100$$

If twenty products are listed on a request, and ten units of each product are requested, 200 items are on the order; if only 170 items are issued, the service level is 85 percent. When assessing the annual service level of a supplier, the key is the total number of items requested on all requisitions and how many of those items were supplied from stock on hand at the supplier's warehouse.

Some commercial suppliers (and public warehouses) are prone to making partial shipments. When an order is received, an initial shipment is made with part of the request; later, one or more additional shipments are made with the remainder of the order quantity. For purposes of measuring the service level, only the initial shipment after each order should count.

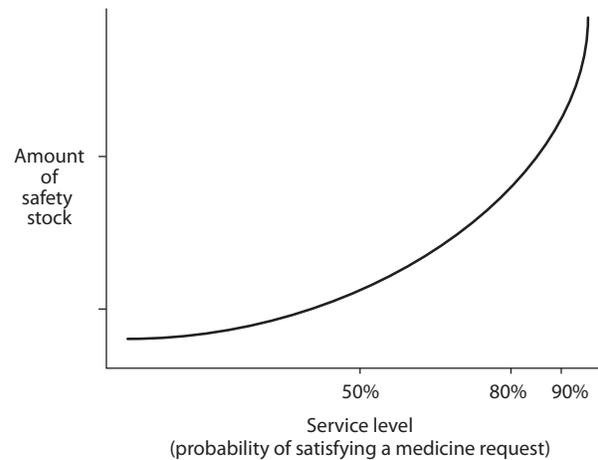
In some supply systems, counting all items requested and issued is too time-consuming, and a count of line items (the number of different products ordered, disregarding order quantities) is used. This scheme makes it hard to decide how to count line items when only part of the request was shipped. Suppliers would argue that any of an item shipped should count as a full shipment for service-level measurement, but many clients would disagree. Systems have evolved to measure line-item service level in categories, for example, the percentage of line items that falls into the categories “none issued,” “part issued,” and “issued in full.”

Other ways to measure service level include—

- The percentage of individual items or line items requested that are *delivered* within the promised lead time (this can be useful when delivery times vary).
- The value of all items shipped from stock as a percentage of the value of all items ordered.
- The percentage of full orders completely filled from stock. Two variations exist—in one, either the whole order is shipped or not; in the other, performance is categorized as discussed for the line-item method.
- The percentage of time that a product was found to be in stock during a period of one year. For example, if a product was found to be out of stock for 36 of 365 days in a year, the service level could be calculated as $(365 - 36) \times 100 \div 365$, equal to a service level of 90 percent.
- The percentage of *products* that are supplied (e.g., if 100 products are ordered and 70 are supplied in any quantity, the product service level is 70 percent).
- The percentage of *units* supplied (e.g., if 100 boxes of ampicillin vials were ordered and 70 were supplied, the unit service level is 70 percent).
- A strong overall measure of service combines product service and unit service (e.g., 70 percent \times 70 percent equals a 49 percent service level).

Whatever measure is used, what is meant by a reasonable service level? Many private-sector pharmaceutical wholesalers promise 95 percent service levels to customers (although they do not always fulfill this promise). Is this level sufficient? The point to remember is that every percentage point decrease in service level by a supplier or warehouse represents a corresponding increase in shortages at the client facility. If a supplier promises a 95 percent service level, 5 percent of the requested items are not expected to be shipped immediately (implying a potential 5 percent stock-

Figure 23-2 Safety stock requirements to maintain various service levels



out at the receiving facility). If the level drops to 90 percent, it follows that 10 percent of the items are not being shipped when they are needed. A public-sector pharmaceutical supply system should strive for a 100 percent service level, at least for vital items; setting lower goals might be reasonable for nonessential medicines and supplies.

Service level is directly determined by the average inventory level, and particularly by the average level of safety stock, held by the supply source. Figure 23-2 illustrates the typical relationship between safety stock and service level from a supply source (either commercial or public).

Note in Figure 23-2 that although the safety stock requirements increase as the service level increases, the relationship is not linear. As the service level increases above 80 percent, the amount of additional safety stock needed to produce a further increase in service level rises steeply. The amount of safety stock required to achieve a 99 percent service level may be double that required to achieve a 95 percent service level. For example, where a safety stock of 2,000 units is needed to achieve a service level of 95 percent, 4,000 units may be needed to raise the service level to 99 percent.

For both the supplier and the client, the balance between cost and service is really a matter of trade-offs. If the supplier cannot or will not maintain adequate inventory levels to sustain an acceptable service level, the client will either have to change suppliers or have to increase safety stock levels at the receiving units. For the supplier, the trade-off is between incurring higher inventory costs to maintain the promised service level and running the risk of shortage costs, as clients go elsewhere for service.

In commercial enterprises, safety stock levels are set using standard formulas that incorporate knowledge about demand patterns, inventory costs, sales income lost from stockouts, and other factors. If a stockout occurs, it is normally accepted as the cost of tight inventory control. In

Box 23-2 Estimating safety stock

The minimum safety stock needed to avoid a stockout is the quantity of stock used on average during the average lead time from the supplier. Thus, if an order is placed as soon as the stock level falls to the safety stock level, if demand is no greater than average during the lead time, and if the supplier delivers within the average lead time, a stockout will be avoided.

The most common method for estimating safety stock needs is to determine the average lead time for each item from the current supplier and the average consumption (per month or per week). If stockouts occurred, consumption must be adjusted to what would have been used, as described in Chapter 20, Section 20.4.

In calculating the amount of safety stock, it is also important to consider warehouse storage capacity. It is no use to order the appropriate amount of safety stock if the warehouse does not have the space for it.

The formula for setting the basic safety stock (SS) level is lead time (LT) multiplied by the average consumption (C_A)—

$$SS = LT \times C_A$$

For example, if the average lead time is three months and the average monthly consumption is 1,000 units, the minimum safety stock would be 3,000 units.

Unfortunately, consumption patterns are not always smooth, and suppliers do not always deliver within the average lead time, so most supply systems increase the basic safety stock—at least for critical items—to cope with variations in consumption and lead time.

The simplest approach for coping with varying consumption and lead time is adding an arbitrary multiplier to the basic formula for safety stock; member countries in the Organisation of Eastern Caribbean States Pharmaceutical Procurement Service, for example, multiply the basic safety stock by 1.5 for vital items, to protect against stockouts.

Another simple way of adjusting the safety stock for variable consumption is to review a one-year period and determine the maximum quantity consumed during

the average lead-time period for the current supplier of the item and the average quantity consumed during that same lead-time period. For the example cited above, the average consumption during the three-month average lead-time period was 3,000 units; suppose that for any three-month period during the year, the highest consumption was 4,000 units. Using this method, the minimum stock level would be 3,000 units, and the additional safety stock allotment would be 1,000 units.

The information from lead-time analysis (see Chapter 40) can be used to predict the next lead time, as follows—

$$DD_E = DD_P + (OD \times OD\%)$$

where—

DD_E = expected delivery date

DD_P = promised delivery date

OD = average overdue period in days

OD% = percentage of orders overdue

Chapter 40 cites an eastern Caribbean supplier that had a contract lead time of 45 days but was late on 50 percent of shipments, with an average delay of 43 days. According to the formula above, this supplier has an expected delivery date of 66.5 days, calculated as—

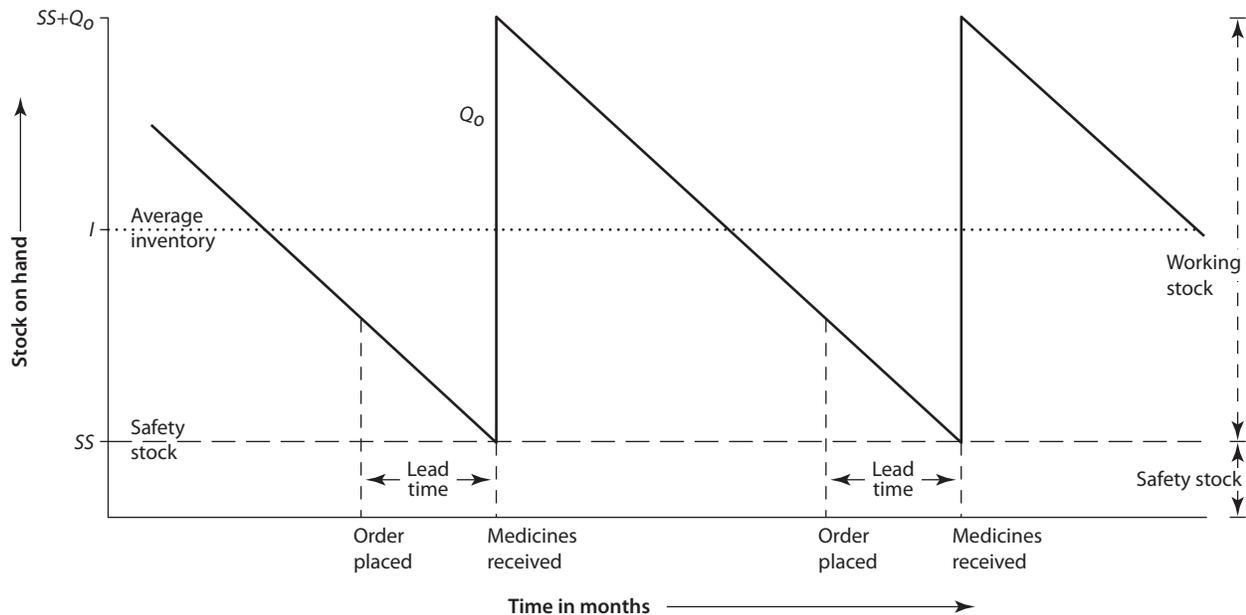
$$DD_E = 45 + (43 \times 50\%) = 66.5$$

When calculating safety stock needs for products from this supplier, using a lead time of 66.5 days would be safer than using 45 days.

When both consumption and lead times are highly variable, some commercial firms use a mathematical approach using the standard deviation of the average consumption and the average lead time to set safety stock levels (see Section 23.9).

Note that all these adjustments tend to increase inventory-holding costs by increasing the safety stock level; therefore, it is important to monitor consumption and lead-time patterns continuously and adjust safety stock to the lowest levels compatible with current patterns. In a computerized inventory control system, this adjustment should be done automatically by the software.

Figure 23-3 Ideal inventory control model



public pharmaceutical systems, the cost of additional safety stock must be weighed against the potential adverse health and political effects of stockouts.

When one designs or restructures an inventory management system, safety stock policy is an important consideration. The policy may differ at each level of the system, between products, or between different facilities at the same level (depending on VEN and ABC classification systems, lead times, and consumption patterns). The objective is to provide maximum service levels throughout the supply system with minimum necessary *total* safety stock.

Methods for setting safety stock levels

Many ways exist of estimating the level of safety stock required to achieve specific service levels. All consider two major factors: average consumption and average lead time. Box 23-2 discusses simple methods for estimating safety stock needs. In most supply systems, the more complex mathematical models for estimating safety stock needs will probably not provide any significant advantage over simple methods (see Section 23.9).

23.6 Inventory control models and reorder frequency

The ideal inventory control model is shown in Figure 23-3. In this ideal model, pharmaceuticals are issued in response to demand, but stockouts are not permitted; the stock on hand steadily declines until the point at which an order

must be placed. The stock on hand consists of two components, the working stock and the safety stock (SS). In the ideal model, the supplier performs according to plan, the shipments arrive on time, the quantity ordered (Q_0) is received, and the inventory level is back to its starting maximum point ($Q_0 + SS$). Working stock varies from zero to the quantity ordered and represents the stock used to satisfy demand between deliveries. Note that in the ideal model, the average working stock is half of the order quantity—

$$\text{Average working stock} = \frac{1}{2} Q_0$$

The average inventory (I) or average stock on hand is the safety stock plus the average working stock—

$$I = SS + \frac{1}{2} Q_0$$

To reduce the average inventory and thereby reduce the inventory-holding costs, the working stock, the safety stock, or both should be lowered. When medicines are used at a constant rate, the line in Figure 23-3 representing stock on hand declines with a constant slope. Large, infrequent orders lead to high average inventory levels. The average working stock can be reduced by placing smaller orders more frequently. The average inventory can also be reduced by cutting the safety stock, but this method increases the chance of stockouts. Alternatively, stock-holding costs could be reduced by minimizing the individual cost components that make up inventory-carrying costs, as illustrated in Figure 23-1. These improvements would be possible

through improved storekeeping practices and better financial management.

As illustrated in Figure 23-3, any inventory control model used to manage purchasing must address the following issues—

1. Safety stock—how much stock will be kept in reserve to prevent stockouts
2. Reorder frequency—the period of time between each order for an item (also known as the procurement period)
3. Reorder quantity—the number of units specified when an order is placed

In addition, storage capacity—the amount of space available for storage—needs to be considered when determining target stock levels and ordering and replenishment frequency. As is made clear in Figure 23-4, the policy on reorder frequency has a major influence on average stock levels and inventory-holding costs, as well as on service level.

Different inventory control models based on reorder frequency have been developed to fit various situations. Two ways to classify these models are—

1. *Periodic review model*: In periodic review models, orders can be placed only at specified intervals, and the item is ordered at every interval.
2. *Perpetual review model*: In perpetual review models, orders can be placed at any time; the user (or a minimum stock level) determines when to order and how much to order.

In pharmaceutical supply systems, the most common inventory control models are—

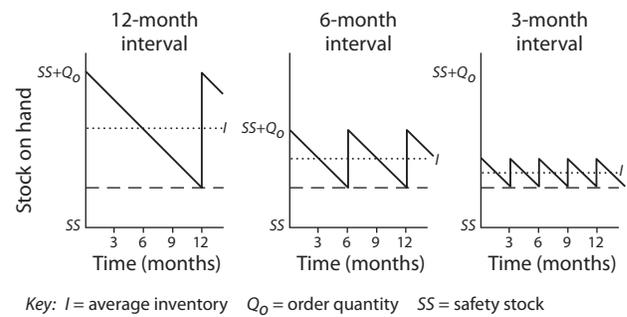
- Annual purchasing—a periodic review model with the interval set at once a year
- Scheduled purchasing—a periodic review model in which orders are placed at prescribed intervals (such as weekly, monthly, quarterly, biannually)
- Perpetual purchasing—a model in which stock levels are reviewed each time stock is issued (or at least weekly) and orders are placed whenever stock falls below a minimum level
- Draw-downs from framework contracts

Annual purchasing

With annual purchasing (which is actually a form of scheduled purchasing), procurement is carried out once each year for all items. Order quantities are normally calculated by a large-scale quantification process (see Chapter 20).

After quantification is done, a tender or competitive negotiation (see Chapters 18 and 21) is used to purchase

Figure 23-4 Impact of reorder interval on average inventory



the entire annual amount (or as much as can be afforded). Contracts with suppliers may provide that deliveries be spaced throughout the year if problems exist with local storage space, storage conditions, or security. In virtually all supply systems using annual purchasing, mechanisms exist to make supplementary purchases during the year. Countries use annual purchasing for the following main reasons—

- Financial regulations and realities may dictate the choice.
- A single procurement can be easier to manage than more frequent purchasing, depending on staff capacities and availability of information.
- Pharmaceutical purchase prices per unit are usually lower when large-volume purchases are made. This consideration can be important when inflation or local currency devaluation is significant and progressive. In such cases, committing the funds at discounted prices and prevailing exchange rates is preferable.
- Tradition and inertia may promote continuance of annual purchasing just because it has always been done that way.
- Greater purchase volumes result in lower prices and can be accompanied by staggered deliveries to facilitate storage and distribution management, as well as a more even cash flow arrangement.

Several disadvantages stem from using annual purchasing as the sole purchasing model for the supply system—

- Actual consumption is often different from the annual forecast or the actual demand, leading to shortages and surpluses; expensive emergency orders are required to cope with shortages, and surplus stock may spoil or expire.
- Average stock levels and inventory-holding costs are higher with this model (see Figure 23-4).
- Local suppliers that win annual tender contracts may find coping with huge, single deliveries difficult.
- More storage space is required, unless deliveries from suppliers can be spaced throughout the year.

- The necessary funds to pay for the single annual purchase may be difficult to obtain, particularly if hard currency is required.
- Workload in the procurement office and main receiving points is uneven.

In general, annual purchasing is best suited to new programs, which have no existing system for inventory management. Annual purchasing may be mandatory in countries where local sources of supply are limited and lead times from foreign suppliers average several months. Annual purchasing may also be preferred when donors support pharmaceutical purchases. Even in systems that use mainly scheduled or perpetual purchasing, some items may be best purchased annually.

Scheduled purchasing

In this periodic review model, specific ordering windows are determined, and regular orders can be placed only at the scheduled intervals—for example, once each month, each quarter, or every six months. Orders are placed at the scheduled order date for quantities large enough to cover average needs until the next order is scheduled plus stock needed during the lead time for that order (plus replenishment of safety stock, if needed).

One variation on this model is staggered review, in which the procurement office reviews one group of medicines (or medicines from one group of suppliers) at one interval, another group at the next interval, and so forth. In this manner, the workload in the procurement office and the financial requirements for pharmaceutical purchasing are spread out during the year, while still limiting the number of orders placed to each supplier (which can be an important issue in supply contracts).

The ordering frequency can also be varied according to ABC category, so that more expensive, faster-moving items are ordered more frequently and other items less frequently (this system is discussed below).

Scheduled purchasing with a review period of six months can operate in much the same way as annual purchasing, but shorter intervals require one of the options for calculating order quantities described in Section 23.9. Normally, an emergency ordering system is used when stock runs low between scheduled orders or when a supplier's shipment is delayed.

In scheduled purchasing, supply contracts can be negotiated anew at each interval, or longer contracts can be negotiated at the beginning of the year, with the provision that orders will be placed as needed at the specified ordering intervals (the estimated-quantity contract; see Chapter 21).

In most supply systems, a new order is customarily placed only after the previous one is received. However, some pro-

grams use tandem ordering, with overlapping orders and different expected times of arrival, if estimated lead times are reliable.

Scheduled purchasing has several benefits—

- An estimated-quantity rather than fixed-quantity contract can be supported.
- A scheduled system may be preferable to local suppliers because it allows them to spread their demand over the year.
- Inventory-holding costs are less than with annual purchasing (see Figure 23-4).
- Less space is needed in warehouses than with annual purchasing.
- Items with variable demand can be purchased more frequently in smaller lots, reducing overstocking and costly emergency orders.
- The procurement unit can respond more rapidly to program needs and make better use of a limited pharmaceutical budget.
- In many countries, funds and foreign exchange are easier to obtain for making smaller, more frequent purchases.
- The procurement and port-clearing workload is fairly evenly spread over the year.
- Because many products need reordering at scheduled points, procurement costs are better controlled, especially in instances where the procurement process is lengthy and cumbersome.
- It supports pooled procurement systems, where orders from all partners are joined and placed as a single order. See Country Study 23-1.

One potential difficulty is that when orders are placed late in the fiscal year, the purchasing cycle will not be complete before the end of the year. This schedule may result in a conflict with regulations regarding spending time limits. Shortages caused by poor forecasting or changes in demand are less likely with this model than with annual purchasing, but they can still occur with scheduled review periods three to six months apart.

If progressive inflation and devaluation are problems, an escalator clause may be required in annual estimated-quantity contracts; if a separate contract is negotiated at each ordering interval, prices are likely to increase throughout the year. In such cases, the best strategy may be to procure as many essential items as possible, along with any items likely to increase in price, in the first part of the year.

Scheduled purchasing works most effectively when consumption patterns are relatively stable, at least for the duration of the period between orders. If needs fluctuate widely from month to month, perpetual purchasing would be preferable, assuming that it is logistically feasible.

Country Study 23-1 Scheduled purchasing in the eastern Caribbean

Scheduled purchasing is used in the Pharmaceutical Procurement Service (PPS) pooled procurement program. PPS is an agency serving the nine member countries of the Organisation of Eastern Caribbean States (OECS). The OECS/PPS operates a centralized, restricted international tendering system in which all approved suppliers are prescreened by a vendors' registration questionnaire. Prequalification is necessary to assess the quality standards, technical competence, and financial viability of competing suppliers. The supply contracts are awarded every eighteen months based on estimates of needs submitted by the nine member countries and compiled by the OECS/PPS. The pooled procurement list represents large-volume class A and B items for which demand is consistently high in the participating countries.

The countries use a scheduled purchasing system in which orders are placed every February, July, and October; some countries order from all suppliers at each

interval, and others use a staggered method. The reorder quantity is calculated using the consumption-based forecasting formula.

In this scheme, each country has a revolving drug fund at the Eastern Caribbean Central Bank; the country can order pharmaceuticals only up to the value of their allocated national budget during any order interval. Emergency purchases are made when shortages occur because of delayed shipments, or when unusual demand depletes stock before another order is due to be placed with a contract supplier. If the primary contract supplier defaults, an order is placed immediately with an alternative supplier.

The contract suppliers that are located in the region allow for more frequent orders in some cases, are frequently used as secondary contract suppliers, and are used as the primary source for emergency purchases.

Source: F. Burnett, personal communication.

Scheduled purchasing is probably the best choice as an alternative to annual procurement in countries that do not have immediate access to suppliers. The major requirements for managing scheduled purchasing are an inventory information system that can produce reliable information on consumption, stock levels, and outstanding orders, and the management and financial capacity to place all necessary orders according to the schedule.

Perpetual purchasing

In this model, a perpetual inventory record is maintained for each item. The inventory position (stock on hand and on order) is reviewed on a regular basis (usually with every transaction, but at least weekly); whenever the stock position falls below a designated reorder point, an order is initiated. As will be discussed later, the order quantity may be predetermined or variable.

Safety stocks and average inventories are much lower with this model than with either scheduled or annual purchasing, but some safety stock is still needed. The chief advantage of perpetual purchasing over scheduled and annual purchasing is the ability to rapidly respond to sudden changes in consumption, because the inventory position is reviewed continuously and orders are placed frequently.

In some systems that use perpetual purchasing, orders are batched—that is, an order is not placed with a supplier

until several different items are needed from that supplier. If batching is used, safety stocks must be adequate to cover periods when a needed item is on hold for batching.

Perpetual purchasing is used by most hospitals and health systems in industrialized countries, where lead times for virtually all items are one or two days. In the United States, perpetual purchasing normally takes place in a prime vendor distribution system, whereby a commercial distributor supplies all contract items on short notice (see Chapter 8). This system avoids the batching issue, because all or virtually all items are ordered from the same supplier. However, in many developing countries, government regulations and difficulty in employing suitable primary distributors may make this method challenging.

If applied appropriately, perpetual purchasing produces an even workload for procurement, warehousing, and port clearing. Depending on the supply system's budgeting and financial policies, perpetual purchasing with frequent small orders may be useful in spreading cash requirements throughout the year.

Despite the many benefits of a perpetual system, it is not suitable for all public-sector pharmaceutical supply systems. Several potential constraints exist. If lead times are not relatively short (one month or less), perpetual purchasing will be difficult to use without maintaining large safety stocks (thereby defeating its purpose). If the supply system cannot maintain current and accurate stock records, the perpetual

purchasing model will fail because by the time transactions are posted, vital items may be out of stock. If formal approval from the ministry of health or ministry of finance must be obtained for each purchase and for foreign exchange permits, the time needed for approval may make perpetual purchasing awkward.

The more frequent purchases in perpetual purchasing will drive up incremental purchasing costs and perhaps total purchasing costs, but any increase in incremental purchasing costs may be offset by decreased inventory-holding costs. Perpetual purchasing may be comparatively harder to fit into public health objectives and budgetary limits, because all the small purchases must be tracked for compliance with guidelines.

Potential applications for perpetual purchasing exist in many pharmaceutical supply systems even if the entire purchasing system cannot be converted to this method. For example, perpetual purchasing might be considered for fast-moving items that can be ordered at competitive prices from local sources. A perpetual system might be used by lower-level stores and facilities that order from a larger warehouse; this could be done whether or not the main warehouse uses perpetual purchasing, so long as the ordering cycles can be coordinated.

The main requirements for perpetual purchasing are—

- Stock records that are current and accurate
- A computer with suitable software to manage an inventory of more than a few items (see Chapter 50)
- Good access to and communication with suppliers and user units, with lead times of one month or less
- Ready access to funds, unless suppliers are prepared to wait for payment
- An estimated-quantity contract that allows ad hoc orders, or a purchasing environment where formal contracts are not used

Drawing down from framework contracts

A framework contract establishes the essential terms and conditions of the procurement agreement, such as time frame, product specifications, prices, quantities, and conditions of supplier performance. During the framework contract term, the supplier holds the stock until it receives orders for specific purchases. Each order is itself a separate contract that follows the broad framework terms with specific terms added, such as delivery date.

Combinations of annual, scheduled, and perpetual purchasing

Although establishing one inventory control model for all pharmaceuticals may be simplest from a management perspective, it may not be the most cost-effective solution.

A thorough review of options may reveal that some medicines are best purchased annually—for example, imported medicines in a country where local currency devaluation is a major problem, or low-priced, infrequently used medicines. Other medicines might be most effectively purchased through scheduled purchasing—for example, relatively slow-moving but regularly used items. High-volume medicines and very expensive medicines may be most effectively purchased with a perpetual model, if logistically feasible.

ABC analysis can be used to examine the effect of variations in order frequency on average inventory value for class A, B, and C items. Table 23-1 shows the relationships among the average order interval, the average inventory level, and the service level for class A, B, and C medicines in a large public-sector pharmaceutical supply system. This projection is based on an average lead time of nine months. Note the difference in average inventory value needed to maintain a 95 percent service level with the various permutations of order frequency for class A, B, and C items.

Although the lowest average inventory cost is obtained in the example by increasing the frequency of ordering for all classes, this strategy may increase the procurement workload and the costs of purchasing significantly, particularly if formal tenders are required. Changing the tender frequency for class A items to twice, rather than once, a year and changing the order quantity from twelve months' to six months' usage reduce the average inventory value by almost half, while still maintaining the desired service level; this change should not increase the cost of purchasing to unacceptable levels (although a total cost analysis should be performed to check the potential effect).

Dear (1990) describes a reordering system that builds on ABC analysis, called ABC/FS. In this system, the A, B, and C items are further broken down into three categories—fast turnover (F), slow movement (S), and no movement in the past year (class C items that might be reclassified as D for dead).

Using a mixed model of annual, scheduled, and perpetual purchasing, the purchasing office in this system concentrates on the fast-moving and expensive stock items, which have the most effect on inventory costs. Vital (V) and nonessential (N) classification can be combined with ABC/FS, with interesting implications for inventory management. For example, a class A, slow-moving item that is also a vital medicine (ASV) might be accorded a higher safety stock than a class A, fast-moving, nonessential item (AFN). An AFN item might be ordered only for specific patients as needed, or a class C, slow-moving, nonessential item (CSN) might be considered for nonstock status and ordered only as needed. Clearly, combinations of annual, scheduled, and perpetual purchasing can be used in many different ways if the supply system can manage such flexibility.

Table 23-1 Value of average inventory by service level and procurement pattern

Procurement pattern and ABC category—order interval	Value of inventory (USD thousands)				
	99%	98%	Service level 95%	90%	85%
Pattern A A products—12 months B products—12 months C products—12 months	10,801	9,730	8,204	7,394	7,394
Pattern B A products—6 months B products—12 months C products—12 months	8,766	7,750	6,902	5,217	4,606
Pattern C A products—6 months B products—6 months C products—12 months	8,365	7,360	5,927	4,788	4,056
Pattern D A products—6 months B products—6 months C products—6 months	8,103	7,104	5,661	4,507	3,697
Pattern E A products—4 months B products—6 months C products—12 months	7,820	6,862	5,476	4,392	3,738
Pattern F A products—4 months B products—4 months C products—4 months	7,380	6,471	5,086	3,982	3,275

Source: Adapted from Quick 1982.

23.7 Factors to consider in calculating reorder quantity

When the basic inventory control model has been established, the final question is how much should be ordered at each order interval. This section examines the factors that must be taken into account; Section 23.8 shows how the factors are integrated into a reordering formula.

Factors in the reorder formula

Depending on the reorder formula used, any or all of the following factors may be essential variables.

Average consumption. Sometimes called *demand*, the average consumption expected in the next purchasing cycle is the key variable that determines how much stock should be ordered. Future consumption is the great unknown of inventory management, so it is given special attention in this section. However, the other factors are equally important. Even if consumption is accurately predicted, stockouts will occur if the lead time is badly underestimated or if another factor is overlooked or miscalculated.

Lead time. Lead time is the time between initiation of a purchase order and receipt at the warehouse from the

selected supplier. If a distinct trend exists in that supplier's performance, the average should be weighted toward recent performance with a moving average. However, if the pattern fluctuates—for example, two months, six months, two months, six months—it is best to apply lead-time analysis (Chapter 40) or calculate the standard deviation as discussed in Section 23.9.

Safety stock. Safety stock is the stock that should always be on hand to prevent stockouts. When lead times and consumption are predictable and stable, the reorder level does not necessarily need to include safety stock; however, when consumption patterns and lead times are highly variable, additional safety stock will be needed, as discussed in Section 23.5.

Reorder level. The reorder level is the quantity of remaining stock that should trigger a reorder of the item. In the minimum-maximum ordering system, this level is called the *minimum stock level*. The standard way to set the reorder level in a basic purchasing formula is to multiply the average lead time by the average quantity consumed during the lead time. This stock level may or may not be the same as the safety stock level, as discussed above, and in fact, may include a separate quantity of stock as a safety stock.

Maximum stock level. In most reordering formulas, this level is the target stock level, which is the stock

needed to satisfy demand until the next order after the current one is received.

Stock position. Stock position is the sum of stock on hand (working and safety stock) and stock on order, minus any stock back-ordered to clients. Overstocks may occur if several months' worth of stock are on hand or on order when a new order is placed. Stockouts may result if significant quantities from an upcoming order are on back-order to lower-level facilities and this amount is not factored into the reorder quantity.

Procurement period. The procurement period covers the time until the next regular order will be placed. In a scheduled system, the period might be in multiples of one month; in a perpetual system, it could be counted in days or weeks for the purposes of forecasting. Note that the quantity ordered plus the safety stock must cover the time until the next order is received, which is the procurement period plus the lead time.

It should be noted that in all previous cases, stock levels are dependent on accurately estimating medicine demand. If estimates are not based on accurate stock-keeping records, then stock-level computations will also be inaccurate, and health institutions will run the risk of mismanaging procurements, resulting in stockouts or overstocks.

Projecting demand

Ordering rationally requires forecasting future needs, the least predictable variable in a reordering formula. Four different methods can be used for forecasting demand—

1. *Projective*: forecasts using past consumption to predict demand (in pharmaceutical supply systems, the method most likely to produce reasonably accurate forecasts)
2. *Causal*: forecasts based on external factors such as market conditions, epidemics, changes in health system size and structure
3. *Judgmental*: forecasts based on subjective estimates of purchasing staff and advice from other staff (the least demanding method, and often the least accurate, if used alone)
4. *Morbidity*: forecasts based on the incidence of disease and the use of standard treatment guidelines

Generally, a reordering formula should be based primarily on projective forecasting, derived from average monthly consumption. The other methods can be used as appropriate to adjust actual purchase quantities. Unfortunately, although past demand is the best source of data for projection, a stable pattern or trend may not exist. In a series of observations of monthly consumption for a twelve-month period (called a time series), several components may be part of the observed demand pattern—

Base rate: demand that may be fairly stable from month to month

Trend: a steady pattern of increasing or decreasing demand, for example, increased usage caused by gradually increasing patient attendances

Seasonality: relatively predictable changes, such as increase in demand for malaria drugs during the rainy season

Cyclic demand: demand that ebbs and flows, for example, with a country's economic cycle

Random noise: unexplained variations in demand; for example, in one month, 100 bottles of amoxicilline suspension were consumed, with a pattern of thirty, ten, eighty, and twenty bottles in succeeding months, with no obvious reason for the variation

Adjustment is relatively easy for a definite trend toward higher (or lower) use or seasonality (if it is predictable). Cyclic use patterns can also be dealt with if they are apparent. The real problem is random noise, and in many consumption series at the item level, random noise seems to be the dominant component.

Fairly complex mathematical models have been developed for smoothing forecasts—exponential smoothing, seasonal indexes, and other methods. Some of these models are discussed later in the chapter. Most incorporate factors such as trend and seasonality while attempting to cope with random noise. However, the more complex models have limited value in most pharmaceutical supply situations; the following methods of tracking average consumption (to forecast demand) are suitable for most pharmaceutical supply systems—

- *Simple average consumption*: the average monthly consumption over the past twelve months (or less, such as six months, if no seasonal changes exist in consumption)
- *Seasonal average consumption*: the average consumption in the last comparable season or epidemic cycle for specific medicines
- *Moving average consumption*: the average monthly consumption in the most recent months—for example, the past two or three months

The key variables in these methods are which months and how many months (or weeks or days) are included in the review period for which consumption is averaged. Note that consumption in the three methods is stated in monthly terms, but it could be daily or weekly for a perpetual system, or yearly for annual purchasing.

Whichever review period is used, if the item was out of stock for part of the period, the consumption must be adjusted to what it would have been if no stockouts had occurred. One good method for making such adjustments is described in Chapter 20, Section 20.4.

When consumption patterns during the year are fairly stable or unpredictable variations (random noise) exist, simple average consumption provides adequate results, adjusting safety stock levels to cope with variations in consumption.

When big differences exist in seasonal demand, use of simple average consumption may produce stockouts in peak demand seasons (and simultaneously set stock levels too high in nonpeak seasons). Therefore, the seasonal average is used to adjust reorder and stock levels for each season. The review period is set to the number of periods in a season. For example, if the malaria season lasts four months, look at consumption patterns for sulfadoxine-pyrimethamine in the four-month malaria season last year rather than the past twelve months to predict needs for this year's season.

Moving averages are suitable for use when a definite trend exists in consumption, up or down, in recent months and reasons exist to expect the trend to continue. Both moving averages and seasonal averages fit well with scheduled purchasing, but they can be applied (with caution) to perpetual purchasing as well.

Integrating experience and other factors

No matter how precise the reordering formula is, external factors may force an adjustment of the quantity suggested by a reordering formula. In most supply systems, the reordering formula suggests quantities, but the purchasing manager makes the final decision. If the reordering formulas are appropriate, relatively few formula recommendations should be overruled by the manager (certainly fewer than 10 percent). However, if the manager knows about an external factor, such as those cited below, or believes that the formula is producing nonsense (perhaps because reordering factors have not been properly entered), experience and local judgment should be the deciding factors.

The key is for responsible officials to understand and accept the reordering formula, so that managers are not looking for reasons to override suggested quantities. One way to ensure this acceptance is to involve operations-level managers in developing and approving the reorder formula that will be used. Examples of factors that might affect reorder quality follow.

Budget status. Most supply systems operate under a specified budget ceiling. Budget management has two basic approaches. In one, the supply system develops a purchasing budget for each item, specifying the quantity budgeted for the year. Then the orders during the year are tracked against this line-item budget. In order to increase the total annual quantity for any item, the quantity for another item must be reduced (or more funds must be located). In the other budget management approach, all procurement funds are lumped together, and orders are placed for whatever items

are perceived to be needed until funds are gone. With either budgeting approach, managers need to monitor the items and quantities on each purchase order and cumulative purchases to make sure that the budget is not overspent.

Access to funds. Even if funds are theoretically budgeted, they may not be available at the time to place an order; if funds are insufficient to purchase all the items suggested by the standard reordering formula, adjustments need to be made (see Chapters 20 and 40).

Pack size and minimum order. The order quantity often needs to be adjusted so that even pack sizes are ordered. For example, if the formula suggests ordering 900 capsules, it might be possible to order nine bottles of 100 capsules. However, if the contract price is based on bottles of 1,000, the order would be placed for one bottle of 1,000. Similarly, if the formula suggests ten bottles of 100 capsules but the supplier's contract specifies a minimum order of twelve bottles, then twelve bottles must be ordered (such minimums should be avoided in supply contracts, if possible).

Expected changes in use. If a change is anticipated within the next purchasing cycle in the number of health facilities or in the formulary or essential medicines list, allowances need to be made in reordering schemes, particularly in annual and scheduled purchasing models.

Expected price increase. If managers know that prices will rise significantly for a medicine or group of medicines before the next ordering cycle, they may decide that ordering unusually high quantities will be cost-effective if consumption patterns indicate that the higher quantities will be used before expiry (or loss or deterioration).

Rising delivery costs. If shipping costs are a major factor in total pharmaceutical costs and they are expected to increase significantly, the approach is similar to the one used for rising prices. The medicines affected should be ordered in higher quantities, with the same precaution concerning capacity to use the entire quantity.

Quantity discounts. Some suppliers routinely offer quantity discounts—for example, 10 percent off with a certain total monetary order, or one item free if twelve are ordered. In such cases, particularly for fast-moving items that will definitely be used, the reordering system should be flexible enough to take advantage of the discounts, within funding limits. Again, the main limitation is the capacity to use the item before expiration or loss.

Excess stock of slow-moving products. If senior managers discover an excessive average inventory level, the temptation is to order a cutback in all purchasing. But this policy will only lead to shortages of fast-moving items, with no reduction for most of the problem stock. Strategies to promote the use of slower-moving items by substitution for other medicines (as appropriate), close review of reorder levels and quantities, and careful monitoring of the ordering procedures, without a purchasing freeze, are better alternatives.

Losses to theft and wastage. If losses are significant, they need to be considered in the order quantity (see Chapter 20).

Storage space. In the case of certain bulky products, order quantities may need to be reduced to accommodate storage space limitations.

Short-dated products. Certain pharmaceutical products come with a very limited shelf life. In such cases, order quantities should be limited in relation to the expected monthly consumption rate to prevent risk of medicine expiry.

23.8 Standard reordering formulas

The previous section discussed factors that need to be incorporated into the reordering formula. This section looks at two approaches to the question of how much to order—

1. Minimum and maximum stock levels
2. Consumption-based reordering formulas

Minimum and maximum stock-level formula

This formula is often used in scheduled purchasing with set order intervals. Using this approach, one defines a theoretical maximum stock for each item to provide sufficient, but not excessive, stock to last from one order to the next, as well as a minimum stock level or reorder level that determines at what point an order should be placed. Safety stock may be included in the minimum stock level, or an additional quantity may be assigned to protect against variations in demand and supplier performance.

Some supply system managers set the minimum and maximum stock levels arbitrarily for all items, but better inventory control is obtained with a flexible calculation for each item, based on standard reorder parameters—

- Average monthly consumption, adjusted for stockouts (C_A)
- Supplier lead time (LT)
- Procurement period—time until the next order will be placed (PP)
- Safety stock—additional stock to cope with variability in consumption and lead time (SS)
- Stock on hand in inventory (S_I)
- Stock now on order from a supplier but not yet received (S_O)
- Quantity of stock back-ordered to lower levels (S_B)

The basic formula for setting the minimum stock level is the average consumption multiplied by the lead time, plus any additional safety stock. Times are usually expressed in months, and stock quantities, in basic units (see the glossary at the end of Chapter 18). Options for setting safety

stock levels were discussed in Section 23.5; any safety stock needed in addition to the minimum stock level might be defined arbitrarily or by calculating the difference between average and maximum consumption. The equation for calculating the minimum stock (S_{MIN}) is—

$$\text{Minimum stock} = (LT \times C_A) + SS$$

The maximum (target) stock level (S_{MAX}) can be calculated as the minimum stock plus the procurement period multiplied by the average consumption; the equation is—

$$(S_{MAX}) = (S_{MIN}) + (PP \times C_A)$$

An example of minimum-maximum level calculations is a case in which the lead time for tetracycline capsules is two months, the average monthly consumption (adjusted for stockouts) is 1,000 capsules, and the additional safety stock allocated is 2,000 capsules. For a procurement period of six months, the following minimum and maximum quantities would be set—

$$\begin{aligned} S_{MIN} &= (2 \times 1,000) + 2,000 = 4,000 \text{ capsules} \\ S_{MAX} &= 4,000 + (6 \times 1,000) = 10,000 \text{ capsules} \end{aligned}$$

When the stock level is found to be at or below the minimum level, the order quantity (Q_O) is calculated as the maximum stock plus stock back-ordered to clients, minus the sum of stock on hand and stock on order. The formula is—

$$Q_O = (S_{MAX} + S_B) - (S_I + S_O)$$

In the example above, suppose 3,000 tetracycline capsules are in stock and another 2,000 are on order. Because the tetracycline has been in stock, there are no back orders to health facilities. The quantity to order would be calculated as—

$$Q_O = 10,000 - (3,000 + 2,000) + 0 = 5,000$$

Some variation of this system is used in many different countries. As long as the minimum and maximum quantities reflect current lead times, consumption patterns, safety stock needs, and order intervals, this system works as well as any other basic reorder formula. The key is regular updating of the minimum and maximum levels. Otherwise the original minimum and maximum levels will become obsolete, because average consumption and lead times usually change with time for many items. Then the formula will produce shortages of items that are moving faster than when the levels were set and overstocks of the items that are moving slower than before.

These problems are most likely to occur when the levels were set for each item by hand in one massive effort, with

no formal plan for reviewing and updating the quantities. If several thousand items are used, at least one full-time worker is needed to keep the minimum and maximum quantities updated using a manual review system. Any supply system that uses this reorder formula to manage a large inventory would be well advised to obtain computer software that does the minimum-maximum quantity updating automatically, according to a formula similar to those above. In addition, by using an ABC analysis of all items, managers can prioritize the setting and reviewing of minimum and maximum quantities for items by class A, B, and C.

A supply system using the minimum-maximum method needs supplementary orders to cover situations in which the stock for an item has not sunk to the minimum when regular orders are placed but does so in the middle of the interval between orders, or when the order is not placed as soon as the reorder level is reached. In those situations, the stock will not last until the next regular order has been placed and received, unless safety stocks have been set very high.

One way to deal with emergency orders in a minimum-maximum system is called *modified optional replenishment*. With that system, there is a reorder level, which is the same as the standard definition for minimum level, as well as a second minimum stock level, which might be called the *emergency warning level*. If the stock position is above the reorder level at the reorder date, no order is placed. If the stock level falls to the emergency warning level between scheduled orders, an emergency order is placed.

Although the terminology can vary, this sort of emergency warning level can be useful in any supply system. Of course, emergency purchases must be closely monitored by managers. Some temptation may exist to disregard the regular system and rely mostly on emergency orders (which can be ruinously expensive).

Consumption-based reordering formula

This formula bypasses the step of setting (or calculating) minimum-maximum levels and instead calculates the proposed reorder quantity directly. The formula recommended here is basically the same as the formula for consumption-based quantification in Chapter 20 (except for back orders, which are normally not an issue in large-scale forecasting). The suggested next order quantity is calculated for each item based on the average consumption, lead time, desired safety stock level, stock position, and period to be covered by the purchase. The safety stock level in this formula serves a function equivalent to the minimum stock level in the previous formula, in that it is the level that warns of possible stockouts if an order is not placed. However, with this formula, an order quantity can be calculated at any time without waiting to reach the safety stock level.

Note that the variables are the same as those used in the maximum-minimum method; in fact, the proposed reorder

quantity should be the same with both formulas, assuming the same variable values. This formula facilitates management of scheduled purchasing, because the formula always suggests an order quantity whenever stock is not enough to cover the next procurement period, without regard to any predetermined reorder level. Another advantage with this formula is that when emergency orders are needed in a scheduled purchasing system, the same formula is used to compute emergency order quantity as would be used for a regular order.

This consumption-based reordering formula is suitable for perpetual purchasing, assuming that computer software is available that recalculates suggested order quantity on command, ideally after each transaction. Country Study 23-1 shows how scheduled purchasing is managed with this formula in the Organisation of Eastern Caribbean States.

The variables in the recommended formula are—

- Average monthly consumption, adjusted for stockouts (C_A)
- Supplier lead time (LT)
- Procurement period—time until the next order will be placed (PP)
- Safety stock (SS)
- Stock in inventory (S_I)
- Quantity of stock now on order from a supplier but not yet received (S_O)
- Quantity of stock back-ordered to lower levels (S_B)

In this formula, the minimum safety stock (which can be modified as discussed in Section 23.5) should be the lead time multiplied by the average consumption during the lead time: $C_A \times LT$.

The complete formula to calculate the quantity to order (Q_O) for each item (without considering intrasystem back orders) is the adjusted average consumption, multiplied by the sum of lead time and procurement period, plus safety stock, minus the sum of stock on hand and stock on order. The symbolic formula is—

$$Q_O = C_A \times (LT + PP) + SS - (S_I + S_O)$$

If the supply system uses back orders internally, and quantities are outstanding to operating units that must be filled when an order is received, the formula would add back orders (S_B) to the projected demand requirements in the formula (as was the case for the minimum-maximum formula), yielding—

$$Q_O = C_A \times (LT + PP) + SS + S_B - (S_I + S_O)$$

For example, suppose (because of an epidemic of cholera) no tetracycline capsules are in stock, and 2,000 are back-ordered to lower-level facilities at the time scheduled

for reordering. One order is outstanding to the supplier for 3,000 capsules. The lead time for this supplier is two months, the average monthly consumption is 1,000 capsules, the safety stock is calculated as 2,000 capsules, and the procurement period is six months. The quantity to order is calculated as—

$$Q_o = 1,000 \times (2 + 6) + 2,000 + 2,000 - (0 + 3,000) = 9,000$$

23.9 Mathematical models for reordering

The goal of inventory management is a system that responds to what patients actually need, not one based on the results of modeling. The most advanced commercial supply systems are moving toward using technology to track what customers buy, then reporting the information throughout an integrated supply chain to the manufacturer. However, until those technologies become the norm for pharmaceutical supply, many authoritative sources agree that simple models to determine product orders, such as those presented in Section 23.8, are preferable to more complex models in most situations. Objections to complex models include (1) that the refinements gained in controlling stock even in the best cases are not substantial in comparison to minimum-maximum and consumption-based formulas; (2) that in most cases, the information fed into the equations is only an estimate, leading to results that are not precise despite the air of precision lent by sophisticated calculations; and (3) that in many cases, staff members do not understand the more complex models, do not trust the results, and make their own subjective determinations of order quantities and desired stock levels.

Mathematical models have been developed to address most aspects of inventory management. The most widely known of these models is the economic order quantity (EOQ), but others are worth mentioning, such as the economic order interval (EOI) and some of the mathematical approaches for smoothing forecasts of demand and lead time and for estimating safety stock requirements. EOQ and EOI are illustrated in some detail here, followed by brief discussions of some of the other models.

Economic order quantity

The EOQ concept has been around for more than fifty years and is widely applied in commercial firms that use a perpetual purchasing model. The basic idea is that an ideal order quantity exists for any item, which strikes an optimum balance between inventory-holding costs and incremental ordering costs (see Box 23-3 and Chapter 40).

With its precise outputs, EOQ seems very sophisticated. EOQ might appear to be exactly what is needed in all pharmaceutical supply systems, or at least those that use per-

petual purchasing. In fact, the need to order by package means that some deviation from the true EOQ will occur for many items. Another limitation is that the EOQ formula assumes that lead times and consumption rates are predictable, orders are received instantaneously, and stockouts are not permitted. Because that is obviously not true, additional calculations are required to establish the appropriate safety stock level, which introduces uncertainty even if the basic EOQ calculation is exact.

Some have contended that EOQ is really “the square root of two times a guess, times a scientific guess, divided by a precise guess, times management’s guess.” Nevertheless, the EOQ is still a reasonable choice for estimating order quantities in a perpetual purchasing system in which access to suppliers and funds is such that orders can be placed at any time. The quantities calculated using the model should, however, be treated as guidelines and not absolutes.

When other reordering formulas are used to manage inventory, calculating the EOQ periodically for high-use, high-value items (class A) may be useful for comparing the theoretical ideal order quantity with current practice.

Economic order interval

A concept related to EOQ is EOI—the theoretical ideal interval for spacing orders placed for the EOQ. As is the case with EOQ, the EOI changes, depending on the values of the individual variables; with a much higher acquisition cost, the EOI decreases (more orders per year), and so forth. Also, like EOQ, the EOI formula produces recommendations that must be rounded.

Although EOI has its main application in systems that use EOQ to set the order quantity, EOI can be used in pharmaceutical supply systems to check the theoretical ideal ordering intervals for scheduled purchasing and then to group items that would best be ordered monthly, quarterly, semiannually, and so forth. The EOI is also illustrated in Box 23-3.

Exponential smoothing

Exponential smoothing is a common technique for coping with variation in consumption or lead-time patterns. In this technique, a smoothing constant (called *alpha*) is used to adjust the observed average consumption or lead-time values.

One application of exponential smoothing calculates the projected demand (D) by factoring in the average consumption from the three-month lead time (C_L), the consumption from the past month (C_A), and the smoothing factor alpha (α), which for these purposes is usually set between 0.1 and 0.2. The equation is—

$$D = C_L + [\alpha \times (C_A - C_L)]$$

Box 23-3 Economic order quantity and order interval

EOQ

Although many variations exist, the most basic formula for the EOQ is—

$$\text{EOQ} = \sqrt{(2 \times U \times O) \div (H \times C)}$$

where—

U = annual use, in units

O = incremental ordering cost

H = average holding cost (percentage of average inventory value)

C = projected net acquisition cost

Considering an example of dextrose bags for IV injection, assume a projected annual use of 25,000 bags at an average acquisition price of USD 2 per bag. Also assume that the estimated incremental ordering cost is USD 70 per order placed, and the average inventory-holding cost is 40 percent. The calculation proceeds as follows—

Step 1: $2 \times 25,000 \times 70 = 3,500,000$ ($2 \times U \times O$)

Step 2: $2 \times 0.4 = 0.8$ ($H \times C$)

Step 3: $3,500,000 \div 0.8 = 4,375,000$
($[2 \times U \times O] \div [H \times C]$)

Step 4: Square root = 2,091.65

Thus, according to the EOQ model, dextrose bags should be ordered in quantities of 2,091.65 bags. Before going further, the reader should consider what happens when the individual variables go up or down. For example, if the item's acquisition cost is USD .20 (with all other vari-

ables the same), the EOQ would be 6,614.38 bags; if the price is USD 20, the EOQ would be 661.44 bags. If only consumption changes, annual use of 5,000 bags produces an EOQ of 935.41 bags, and annual use of 50,000 bags yields an EOQ of 2,958.04 bags. When incremental costs of purchasing go up, the EOQ goes up (to decrease the ordering frequency); as the holding cost percentage goes up, the EOQ goes down, to increase order frequency and decrease stock levels.

EOI

The formula for calculating the EOI uses the same variables as the EOQ but combines them as follows—

$$\text{EOI} = \sqrt{(2 \times O) \div (U \times H \times C)}$$

where—

U = annual use in units

C = projected net acquisition cost

O = ordering cost

H = holding cost

The EOI produces its result as fractions of a year (assuming that consumption is based on a year). For the EOQ example above, the EOI for orders of 2,091.65 bags would be 0.084 years, which converts to 1.004 months, 4.35 weeks, or 30.5 days. The calculation is—

Step 1: $(2 \times 70) \div (25,000 \times 0.4 \times 2)$

Step 2: $140 \div 20,000 = .007$

Step 3: $\sqrt{.007} = 0.08366$ years

If, for example, an item had averaged 150 units consumed per month over the last three months but 200 were used in the last month, the smoothed average using an alpha value of 0.1 would be—

$$D = 150 + [0.1 \times (200 - 150)] = 155$$

Clearly the difference between the simple average and the smoothed average would be greater with larger consumption values and with a higher alpha factor.

This equation is not complex in itself, but choosing the value for the alpha factor is tricky (most authorities recommend trial runs using various values, then observing results and trying again). The higher the alpha, the more “adaptable” the forecast is to recent trends; however, the higher the alpha factor, the lower the reliability when a large random noise factor is present in the consumption pattern.

Standard deviation of consumption and lead time

The standard deviation of consumption and of lead time can be used in mathematical models to adjust forecasts when variation (random noise) in the consumption or lead-time pattern is considerable. Standard deviation is basically an estimate of how much an individual value is likely to vary from the average of all values in a series (see Rowntree 2003 for methods for calculating standard deviation).

The following equation illustrates how the standard deviation of lead-time consumption (SD_{LTC}) is calculated, for use in setting safety stocks—

$$SD_{LTC} = \sqrt{(LT \times SD_C^2) + (C_A^2 \times SD_{LT}^2)}$$

where—

C_A = average monthly consumption

LT = average lead time

SD_C = standard deviation of consumption

SD_{LT} = standard deviation of lead time

For example, if consumption of an item averages 1,000 units per month with a standard deviation of 100, and the lead time averages three months with a standard deviation of 0.75 months, the average consumption during the lead time period is 3,000 units, and the standard deviation of that lead time consumption is calculated as—

$$\sqrt{[3 \times (100 \times 100)] + [(1,000 \times 1,000) \times (0.75 \times 0.75)]} = 769.74$$

Most values in any series of observations show a normal distribution pattern around the mean (average) value. (For example, in a population of men who average 6 feet in height, about half the men will be taller and about half will be shorter rather than exactly 6 feet.) Normal distributions characteristically demonstrate that the standard deviation times about two will encompass 95 percent of the values clustered above and below the average (see Rowntree 2003). Thus, in the example here, 95 percent of the time, the monthly consumption will fall within two times the standard deviation of monthly consumption.

This calculation could be used with any reordering formula to assign safety stock in order to theoretically achieve

a 95 percent service level. For the example given above, 2×770 equals 1,540 units needed as safety stock, in addition to average lead-time consumption. In a minimum-maximum formula, the minimum level would be 3,000 units ($C_A \times LT$), and the added safety stock would be 1,540 units. In a consumption-based formula, the total safety stock would be 4,540 units. ■

References and further readings

★ = Key readings.

- ★ Burt, D. N., S. Petcavage, and R. Pinkerton. 2009. *World Class Supply Management*. 8th ed. New York: McGraw-Hill.
- ★ Dear, A. 1990. *Inventory Management De-mystified*. Dordrecht, The Netherlands: Kluwer Academic Publishers.
- Downes, J., and J. Goodman. 2010. *Dictionary of Finance and Investment Terms*. 8th ed. Hauppauge, N.Y.: Barron's Educational Series.
- Quick, J. 1982. Applying Management Science in Developing Countries: ABC Analysis to Plan Public Drug Procurement. *Socio-Economic Planning Sciences* 16(1):39–50.
- ★ Rowntree, D. 2003. *Statistics Without Tears: A Primer for Non-mathematicians*. Upper Saddle River, N.J.: Pearson Allyn & Bacon Publishers.
- Warren, C., J. Reeve, and J. E. Duchac. 2008. Inventories. In *Accounting*. 23rd ed. Cincinnati, Ohio: South-Western College Publishing.
- ★ Waters, C. D. J. 2003. *Inventory Control and Management*. 2nd ed. Chichester, England: John Wiley & Sons.

ASSESSMENT GUIDE

Performance indicators

As discussed in Chapters 36 and 48, indicators have been developed expressly for use in public-sector pharmaceutical supply systems. Some of them should be considered as tools to measure inventory management performance, although no standards exist yet for the acceptable range of performance. These indicators include—

- Average percentage of inventory variation in the stock record-keeping system, at a sample of warehouses and facilities
- Percentage of stock records that correspond with physical counts, at a sample of warehouses and facilities
- Percentage of a specified set of indicator medicines that are in stock at a sample of warehouses and facilities
- Average percentage of time out of stock for the set of indicator medicines
- Average lead time from suppliers and from warehouses to facilities

Context for inventory management

- Are all supply system operations related to finished goods, or does the system also manufacture pharmaceuticals?
- At what levels of the system are pharmaceutical orders placed, either to suppliers or to other levels of the system?

Selection of items for stock status

- How do managers and operations personnel determine which items should be held in stock and which (if any) should be ordered only as needed?

Costs associated with inventory and purchasing operations

- How is inventory valued, and what procedures are used to physically count stock and reconcile records?
- How many months' worth of stock is on hand at central storage facilities? At regional and district facilities? At hospital pharmacies, health centers, dispensaries, and other clinical facilities?
- What information is available on inventory values, operating costs of warehouses, operating costs of the purchasing department, and costs associated with shortages? If such information is available, how is it used?
- Are techniques such as ABC value analysis, VEN analysis, and total variable cost analysis used in for-

mulating inventory management strategies? If so, in what areas?

Stock records and routine reports

- What inventory needs exist at each level of the health care system? How accurate and how current are the records? Do they supply the information needed for procurement and distribution decisions?
- If a computerized information system is in use, is it a general purpose inventory management package or a special-purpose package developed for managing public-sector pharmaceutical supply systems? Does it automatically calculate minimum and maximum quantities or consumption-based order quantities?
- What standard reports are produced on inventory status, procurement operations, and consumption patterns? How is the information used?

Safety stocks and service levels

- How are safety stock levels calculated at each level of the system?
- What adjustments in safety stocks are made for variations in consumption and lead-time patterns?
- What percentage service levels are normally achieved by warehouses supplying lower levels of the system? What percentage service levels are provided by major suppliers to the system?

Purchasing model

- How frequently are pharmaceutical orders placed at each level that places orders? Is the same model used for all items?
- What percentage of orders are routine and what percentage are emergency orders?
- Do any special factors dictate the choice of inventory management strategies, such as government financial and administrative regulations, staff, existing management information systems, supplier access, or contract procedures?

Reorder formulas

- What reordering formulas are used to determine purchase quantities? Is the same formula used at all levels and all facilities?
- What source data are used in the formulas?
- How much weight is given to the manager's experience and judgment? What other factors are considered?