CHAPTER 13

Inventory Management in Services

LEARNING OBJECTIVES *The material in this chapter prepares students to:*

- Know how service inventory issues differ from manufacturing inventory issues.
- Conceptually understand how limited capacity and substitution effects change traditional inventory decisions.
- Find numerical solutions to simple inventory problems.
- Additional material on the Student CD prepares students to find numerical solutions to more complex inventory problems.[1]

Inventory in services? A hallmark of many service firms is their lack of inventory. With simultaneous production and consumption in many services, inventory is not stored. As discussed in Chapter 1, the core of the definition of services is intangibility. For many of the service firms that typical consumers visit every day, however, the facilitating goods that supplement the service can be inventoried and the amount and type of inventory represents a vital strategic decision. Many service sector firms, in fact, use inventory methods as a source of competitive advantage.

Inventory decisions are vital for four broad types of services:

1. Retail (e.g., grocers, auto parts, consumer electronics, department stores)
2. Wholesale
3. Field service (e.g., computer repair, copier repair)
4. Military (e.g., number/type of goods to be put in a tank, submarine, or soldier's pack)

For each of these general service sectors, inventory is a major cost. More than just the cost, inventory entails a basic strategic trade-off: In the retail, field service, and military sectors, space is limited, making it especially valuable. Given any specific store size, more inventory of one item means that the item takes up more shelf space, which in turn means less shelf space available for other items. The strategic choice, then, comes down to a lot of inventory of a few items *or* a little inventory of a lot of items.

1. The subject of services inventory poses both qualitative and quantitative problems. This chapter has quantitative content, but the focus is on a qualitative understanding of the issues. More quantitative material is available on the Student CD.

Beyond a general strategic direction, properly managing inventory is vital. "Recent studies indicate that 20% of customers leave video rental stores without the movie they would like to rent, 10% of items in grocery and convenience stores are out of stock, and 35% of women fail to buy apparel that they are shopping for because of stockouts of their size" (Narayanan, 2003, p.1). Inventory stockouts mean lost revenue, so properly managing inventory can substantially change profitability.

Services Versus Manufacturing Inventory

This chapter presents the inventory problems specific to services. Inventory chapters are common in typical operations management textbooks, but much of that material focuses on manufacturing inventory problems, whose characteristics are fundamentally different from service sector problems. These differing characteristics include: setup/ordering costs, number of products, limited shelf space, lost sales versus back orders, product substitution, demand variance, and information accuracy.

Setup/Ordering Costs

A typical textbook manufacturing inventory problem entails large, costly setups. For example, the setup for changing the outer width of steel pipe manufactured by the Siderca plant of Techint Group costs $1 million so the width is not changed often. Because of these large expenses, a significant amount of manufacturing inventory work involves "rationalizing" large setup costs by determining how long one product should be produced before switching to another. The trade-offs between setup costs and other inventory costs are the main concern of such common inventory techniques as the Economic Order Quantity (EOQ), Wagner-Whitin algorithm, and various lot-sizing methods found in most textbooks.

Although these techniques are somewhat applicable in services, in most service inventory environments setup/ordering costs for all products combined can be substantial, but the added cost of ordering any one product can be trivial. For example, in the inventory-intense grocery business, the combined warehousing and distribution function is listed in company annual reports as 20% to 30% of cost of goods sold, but the added cost of a store manager deciding to order or not to order a given product is essentially zero.

A look at the typical services inventory system shows why. Often, a manager or clerk scans a computerized printout once every ordering period and notes any changes to the orders recommended by the computer. This revised list is often sent by computer to a distribution center, where order pickers roam warehouses, pick cases of product, and load them on a truck. When the truck arrives at a retail store, product is moved to store shelves. Altogether, it is an expensive process. The decision to order or not order any given product, however, barely nudges those costs. A few seconds of managerial time is required to place the order, the warehouse order picker picks just one more product on their list, the truck rolls regardless, and the store stocker takes at most a few more minutes to stock another product.

Consequently, here we will be concerned only with inventory techniques that are applicable to situations without ordering or setup costs.

Number of Products

A manufacturing firm may sell a few hundred, or even a few thousand products. (*Note*: Individual products are generally called stockkeeping units, or SKUs, in these businesses, and they will be referred to as SKUs in this text.) Even this amount is dwarfed by the number of SKUs sold by such services as supermarkets (an average of 40,000 SKUs in a store), auto parts stores (up to 60,000 SKUs), bookstores

(200,000 SKUs) or department stores (approximately 400,000 SKUs), many of which are ordered weekly or several times per week. What this scale of operation means is that, although manufacturers may have the luxury of pondering over production decisions, the managerial time spent on the ordering decision of any one SKU by a service firm must be short.

Limited Shelf Space

Shelf space presents a key consideration in many services, which is the primary reason why this chapter appears in this section of the textbook. Retail stores—even Wal-Mart Supercenters—are too small to carry all the different items that might sell, and are certainly far too small to carry all the items product manufacturers would like them to carry. A key decision is how to allocate that limited space among products.

Lost Sales Versus Back Orders

Manufacturers often cannot immediately ship items, because they are not in inventory. It is common for manufacturers to quote a lead time or place a requested item on back order and then fill the order weeks later. Although back orders may also occur in some service firms, a more common result is a lost sale. Imagine a supermarket clerk telling you to come back in two weeks for those lasagna noodles you want to serve tonight. Even though this distinction may not seem large in analyzing what to do, it actually complicates theory greatly and makes stocking out a much more expensive proposition.

Product Substitution

In many service inventory situations retailers carry nearly identical products from many manufacturers, so service inventory models need to consider the effects of customer's substitution behavior when faced with product stockouts. In other words, the stocking levels of products should not be considered in isolation of each other; groups of substitutable products have to be considered as a whole.

Demand Variance

The unpredictability of demand is often greater in services, especially for SKUs in a given store with a small average number of units sold. For example, more than 50% of dry goods SKUs in supermarkets sell fewer than one unit per week on average. However, on a given day an interested customer may clean out the entire stock. This high variance makes inventory decisions tougher to figure out and makes an inventory model—versus back-of-the-envelope guesses—more important. Consider the extremes: If precisely 50 units are sold every day, the decision on how much to stock is simple—stock 50. But if some days nothing is sold, other days a few, and occasionally 100, then a mathematical inventory model is useful.

Information Accuracy

Throughout the economy, millions of dollars are spent by manufacturers and service firms alike on information systems to track inventory. Service firms, however, must deal with an aspect that most manufacturers do not: customers! It would be reasonable to think that a grocery store would keep track of inventory through the computer by noting sales through the scanners at the checkout register. Unfortunately, grocers still must track inventory by physically walking the aisles to see how much is on the shelf. When customers or employees steal goods, they inconveniently don't scan them. Also, when someone picks up a jar of salsa in aisle 9 and changes his mind and deposits it in aisle 12, or breaks the jar in aisle 14, one less salsa sits on the shelf, but not in the computer system. Customer misshelving is perhaps worst in retail bookstores, where a book taken out of, say, the "history" section is reshelved by the customer in the "political science" section. The problem is magnified for these retailers because books do not look out of place in the wrong section, unlike a bottle of ketchup next to a gallon of milk in a grocery store, so it will not automatically be corrected by employees. For the purposes of a bookstore inventory system, the customer might as well have just burned the book—it won't be found by employees or other customers again until the annual physical inventory.

These problems receive serious attention in many businesses. Many U.S. retailers attach 3-inch-long plastic antishoplifting devices to dresses and suits. At Lojas Renner, the largest department store chain in Brazil, those tags are even attached to socks! As one otherwise highly successful Wal-Mart store manager said concerning the annual physical inventory, "[I]f inventory came out really bad, I was afraid they would ask for my keys" (Helliker, 1995).

The Need for Inventory Science

The conditions noted in the previous section make the services inventory problem different from the manufacturing inventory problem, so the inventory formulas normally found in textbooks dedicated to manufacturing problems are not especially helpful. The question is, "so what?" It may not seem like a major concern, since, clearly, grocers and department store managers used their own intuition and "gut feel" when ordering inventory throughout the history of commerce.

However, services need inventory models because the "common sense" inventory replenishment rules learned through years of practical experience are no longer good enough, and the computer power is now available to lend some science to the issue. The combination of time-based logistics practices, technological innovations, and changes in manufacturer product strategies radically altered the business environment for services, which impacts inventory decisions. According to Southland Corporation (1997 annual report), in a description of its new inventory information system, claims that "[r]etailing is evolving from an art to a science." The revival of Southland Corporation's 7-Eleven stores from near bankruptcy to a thriving enterprise, growing at more than a store per day, resulted primarily from advances in logistics and inventory management. See the accompanying Service Operations Management Practices: IBM Service Logistics' "Optimizer" for the value these methods can bring to another significant services inventory problem.

A basic thrust of time-based competition is to compress the amount of time required in the product delivery cycle. Time-based competitive practices began in the manufacturing sector, but they are used in services as well. Such practices are called *efficient consumer response* in the grocery industry and *quick response* in the apparel and general merchandise industries. These movements provide the central organizing principles for logistics planning in many firms in these industries.

These back-room advances significantly affect the practice of front-room inventory replenishment. Replenishment decisions can now be made far more frequently, reducing the need for inventory.

Technological innovations play a large role in the institution of time-based practices and the reduced need for retail inventory. Bar coding, scanner technology, and electronic data interchange all combine to reduce the uncertainty of inventory position, make the inventory ordering process less costly, and reduce the order fulfillment cycle time.

SERVICE OPERATIONS MANAGEMENT PRACTICES

IBM Service Logistics' "Optimizer"

IBM faces a very challenging service inventory problem. IBM office equipment is everywhere, and it is indispensable. When an IBM mainframe computer goes down, customers cannot be served, product orders cannot be entered, Web sites crash, and payroll will not run, just to name a few problems. Consequently, fast service is job 1. Fast service doesn't mean, "We'll overnight the part to you and get you running tomorrow." It means, "We'll have you back up and running in two hours."

How does that happen? It happens by placing the right amount of inventory in the right places. IBM services more than 1,000 products, and those products use a collective 200,000 different parts, and most of the 1,000 products have several common parts. For fast service, IBM operates two central warehouses, 21 field distribution centers, 64 parts stations, and 15,000 "outside locations," which often means an inventory of parts is maintained at the customers' locations. Clearly, IBM cannot stock all the possibly needed parts at every location, because the cost would be immense. Furthermore, "common sense" and "good judgment" are not enough when the problem is this large and complex.

A combined team from IBM, Stanford University, and the University of Pennsylvania developed inventory heuristics to maintain current service levels and cut $500 million of inventory out of the system. During implementation, IBM strategically chose to increase service levels, which still allowed them to cut $250 million in inventory.

Source: Cohen et al. (1990).

On another front, manufacturer strategies make service inventory decisions more complex and more important. Retail shelf space remains limited while the number of products increased sharply in recent years. For example, in the grocery industry the average supermarket can stock approximately 40,000 SKUs, but manufacturers list a few hundred thousand SKUs for consideration.

Generally, service inventory policy addresses three decision areas:

- *Assortment:* Deciding which products should be stocked
- *Allocation:* How much shelf space to give each product in the assortment
- *Replenishment:* When and how much to reorder

Assortment and allocation are usually decisions made by marketing. Assortment decisions are made by company buyers based on what products the buyers think will sell, and allocation decisions are often made on the relative sales between products in a category: If Heinz sells twice as much as Hunt's, then Heinz gets twice the shelf space within the ketchup category.

In the next several pages we describe some mathematical ways of addressing services inventory problems.

The "Newsvendor" Model: Uncertain Sales, No Ordering Costs, and Lost Sales

We start with the simplest of inventory models for uncertain sales: The "newsvendor" model. This model tells us how much inventory to order if the number of customers purchasing product any day is uncertain, no ordering costs are involved, and if no more product is available, then customers simply don't buy anything. The classic teaching example is selling newspapers.

EXAMPLE 13.1: *The Newsstand*

Although you were top academic achiever in your class, you studied so hard you had no time for interviewing and found yourself jobless at graduation. Knowing a good opportunity when it presents itself, the newspaper vendor at 5th and Broadway sold you his newsstand. His parting advice was, "Always buy 150 papers every day, that way you'll never disappoint your customers," which you followed for the first 20 days.

The cost of a newspaper to you is $0.30, and they are sold for $0.50. Excess papers have no value and unsatisfied customers harbor no ill will if you are out of newspapers; you just do not make the sale that day.

Sure enough, you never ran out of papers by buying 150 every day, but the business was hardly profitable. The amount sold each day can be found in Table 13.1. (Data for all tables in this textbook can be found on the accompanying CD.) Over the course of 20 days, you paid for 150 papers × 20 days × $0.30/paper = $900 and received 90 papers × 20 days × $0.50/paper = $900 from customers, earning no net profit overall.

What can you do to make more from this opportunity? Some notation will help in solving this problem:

C_o = the cost of overage, or ordering another unit that isn't sold, which here is $0.30 (if any value remains, usually called *salvage* value, that value is subtracted from C_o)

C_s = the cost of stocking out, or not getting the profit from selling a unit, which here is $0.50 − $0.30 = $0.20

y = inventory order

d = units demanded

$E(\bullet)$ = an expected value

$P(d \leq y)$ = probability demand d is less than or equal to y

One way to think through solving this problem is through a method called *marginal analysis*; that is, thinking about the marginal impact of incrementally increasing y, the inventory position, until the expected revenue from inventory is less than the expected cost. Starting from the lowest logical number, if 53 papers are stocked, then 53 will be sold every day with probability = 1.00, and no papers will be left over, so the profits for the 20 days in Table 13.1 will be 53 × 20 × $0.20 = $212 (see Table 13.2).

That stocking level, however, leaves a lot of customers unhappy. If 62 papers, the next logical number, are stocked, then 95% of the time those marginal, 62 − 53 = 9, papers will be bought, and 5% of the time, when demand is only 53, they will be thrown out. So those marginal papers contribute [0.95($0.20) − 0.05($0.30)]

TABLE 13.1: *Newsstand Example*

Demand	P (demand ≥ amount in first column)
53	1.00
62	.95
71	.90
71	.90
78	.80
81	.75
82	.70
85	.65
86	.60
88	.55
90	.50
92	.45
95	.40
95	.40
96	.30
97	.25
98	.20
118	.15
125	10
137	.05

Average demand = 90
Standard deviation = 20

× 9 papers × 20 days = \$31.50, and bring the total profit for stocking 62 to \$212 + \$31.50 = \$243.50 (see Table 13.2). We keep increasing the number of papers until the marginal contribution turns negative. We can take a short cut in this process by analyzing this problem algebraically. We increase *y* as long as:

$$E(\text{revenue of next unit of inventory}) \geq E(\text{cost of next unit of inventory})$$

which is the same as

$$\begin{gathered}(\text{Profit from selling a unit}) \times (\text{Probability that the unit will sell}) \geq \\ (\text{Cost of leftover inventory}) \times (\text{Probability that the unit will not sell})\end{gathered}$$

In the mathematical terms used previously,

$$C_o \times P(d < y) \leq C_s \times P(d \geq y)$$

which can be converted to

$$C_o \times [1 - P(d \geq y)] \leq C_s \times P(d \geq y)$$

or equivalently,

$$C_o - C_o \times P(d \geq y) \leq C_s \times P(d \geq y)$$

Adding $C_o \times P(d \leq y)$ to both sides and dividing both sides by $(C_o + C_s)$ leaves the basic newsvendor formula: Find the largest inventory number for which

$$C_o/(C_s + C_o) \leq P(d \geq y) \tag{13.1}$$

In this problem, equation (13.1) yields \$0.30/\$0.50 = $0.60 \leq P(d \geq y)$, and in Table 13.1 demand is greater than or equal to 86 with a probability of 0.60. Table

Access your Student CD now for Table 13.2 as an Excel spreadsheet.

TABLE 13.2: *Marginal Analysis of the Newsstand*

Amount Ordered	53	62	71	78	82	85	86	88	90	95	98	125
Demand for Papers	Daily profit											
53	$10.60	$7.90	$5.20	$3.10	$1.90	$1.00	$0.70	$0.10	−$0.50	−$2.00	−$2.90	−$11.00
62	$10.60	$12.40	$9.70	$7.60	$6.40	$5.50	$5.20	$4.60	$4.00	$2.50	$1.60	−$6.50
71	$10.60	$12.40	$14.20	$12.10	$10.90	$10.00	$9.70	$9.10	$8.50	$7.00	$6.10	−$2.00
71	$10.60	$12.40	$14.20	$12.10	$10.90	$10.00	$9.70	$9.10	$8.50	$7.00	$6.10	−$2.00
78	$10.60	$12.40	$14.20	$15.60	$14.40	$13.50	$13.20	$12.60	$12.00	$10.50	$9.60	$1.50
81	$10.60	$12.40	$14.20	$15.60	$15.90	$15.00	$14.70	$14.10	$13.50	$12.00	$11.10	$3.00
82	$10.60	$12.40	$14.20	$15.60	$16.40	$15.50	$15.20	$14.60	$14.00	$12.50	$11.60	$3.50
85	$10.60	$12.40	$14.20	$15.60	$16.40	$17.00	$16.70	$16.10	$15.50	$14.00	$13.10	$5.00
86	$10.60	$12.40	$14.20	$15.60	$16.40	$17.00	$17.20	$16.60	$16.00	$14.50	$13.60	$5.50
88	$10.60	$12.40	$14.20	$15.60	$16.40	$17.00	$17.20	$17.60	$17.00	$15.50	$14.60	$6.50
90	$10.60	$12.40	$14.20	$15.60	$16.40	$17.00	$17.20	$17.60	$18.00	$16.50	$15.60	$7.50
92	$10.60	$12.40	$14.20	$15.60	$16.40	$17.00	$17.20	$17.60	$18.00	$17.50	$16.60	$8.50
95	$10.60	$12.40	$14.20	$15.60	$16.40	$17.00	$17.20	$17.60	$18.00	$19.00	$18.10	$10.00
95	$10.60	$12.40	$14.20	$15.60	$16.40	$17.00	$17.20	$17.60	$18.00	$19.00	$18.10	$10.00
96	$10.60	$12.40	$14.20	$15.60	$16.40	$17.00	$17.20	$17.60	$18.00	$19.00	$18.60	$10.50
97	$10.60	$12.40	$14.20	$15.60	$16.40	$17.00	$17.20	$17.60	$18.00	$19.00	$19.10	$11.00
98	$10.60	$12.40	$14.20	$15.60	$16.40	$17.00	$17.20	$17.60	$18.00	$19.00	$19.60	$11.50
118	$10.60	$12.40	$14.20	$15.60	$16.40	$17.00	$17.20	$17.60	$18.00	$19.00	$19.60	$21.50
125	$10.60	$12.40	$14.20	$15.60	$16.40	$17.00	$17.20	$17.60	$18.00	$19.00	$19.60	$25.00
137	$10.60	$12.40	$14.20	$15.60	$16.40	$17.00	$17.20	$17.60	$18.00	$19.00	$19.60	$25.00
Total Profit for 20 Days	$212.00	$243.50	$270.50	$284.50	$290.00	$291.50	$291.50	$290.50	$288.50	$279.50	$269.00	$144.00

13.2 shows that an order quantity of 86 is the most profitable amount, earning $291.50.

A few aspects of this problem are worthy of additional attention. First is the similarity of this math to the overbooking problem discussed in Chapter 12: Understand one of these situations, and you will understand the calculations behind the other.

Notice how the overall profitability differs little with orders anywhere between 82 and 88 in Table 13.2. This property is particularly important for this type of inventory problem. About the optimal solution you will notice is a "bowl" effect, where profits are close to optimal if the order quantity is close. This bowl effect is important because C_o and C_s are often estimates, rather than precise cost figures. Consequently, even if those estimates are off a bit, a solution close to optimal will still result. This bowl shape for the cost curve provides a major advantage in using a mathematical model. If one were to guess, based on intuition, one could easily make a significant mistake and end up far from optimality. These mathematical models, even without precise cost estimates, will generate a close-to-optimal solution. The bowl shape is so shallow that in this problem an order quantity of 85 provides the same profit as 86: Either solution is correct.

Finally, in the example given, the calculated answer of 0.60 corresponded directly to a number in Table 13.1. If the number does not correspond exactly, the optimal answer is the inventory position where the probability is "greater than" the result of the calculation. As an example, consider the situation if papers sold for $100, but cost $99—generally not considered a good profit margin. Common sense dictates that one would stock only what one is absolutely certain of selling, which would be 53 papers here. The ratio $C_o/(C_s + C_o) = 0.99$, and the lowest probability greater than or equal to 0.99 would be 1.00, representing an inventory position of 53.

This general formula can be used with general probability distributions as well as with actual data. For example, if data are normally distributed, one can use the z-score as taught in statistics classes. For example, the data in Table 13.1 appear to be normally distributed with a mean of 90 and standard deviation of 20. Looking for a probability of 0.60 corresponds to a *z*-score of approximately 0.25 in standard normal tables. So the typical *z*-score calculation of

$$\text{Order quantity} = \text{Mean} \pm z(\text{standard deviation})$$

would be $90 - 0.25(20) = 85$. (*Note:* In most examples of z-score arithmetic, when one is looking for less than 50% under the distribution, then one is *adding z* times the standard deviation to the mean. Here, we are looking for more than 50%, so it is appropriate to subtract. The business reason is that the costs of having too much inventory are greater than the profits gained, so one would stock *less* than the average demand.)

Product Substitution and Demand Variance

The gross profit margins of many service sector inventory items are considerably larger than the preceding newspaper example. For example, the difference between selling price and purchase price of an average dry grocery item in a grocery store is approximately 40% of the selling price. Further, the cost of overage between order cycles continues to decrease for many items due to improved logistics. It is fairly common in service inventory systems to take delivery of a given product several times per week. Consequently, for any individual inventory decision, the cost of over-ordering nonperishable goods is just the cost of holding that item on the shelf until the next order cycle, which comes up in a few days.

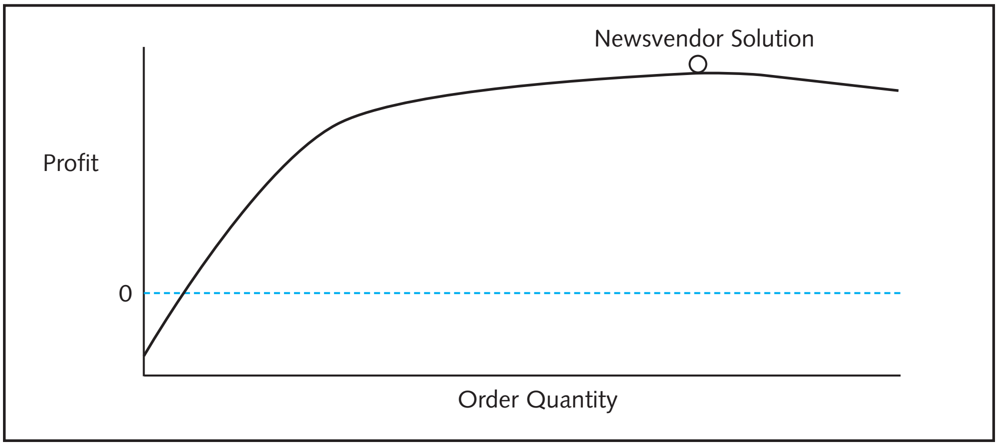
Consider a mythical product with the preceding characteristics that sells for $10. The cost of a stockout results in C_s = $4 in lost profit as well as some additional cost for disappointing the customer. This "disappointment" cost is real. Customers who routinely see favorite products out of stock will take future business to a competitor. However, it is difficult to put a solid number on disappointment for each individual stockout. For this example, let us say customer disappointment costs an additional $2, so C_s = $6. Let us say that deliveries are made weekly and that the annual cost attributed to holding an item is considered to be 25% of the item cost. Therefore, the cost of overage, $C_o = \$10 \times 0.25/52 = \$0.05$.

For this typical retail item, then, $C_o/(C_s + C_o) = 0.008$, which means that one should stock to ensure only a 0.8% chance of demand exceeding the stock on the shelf. To put it another way, the newsvendor model suggests stocking in this example so that customers are served 99.2% of the time. These extreme stocking levels near 100% are not unusual in clothing stores and for dry goods at supermarkets (see the Service Operations Management Practices: Think Mom Buys Too Much?). Asymmetric penalties for missing the optimal target reinforce this high service level; that is, the cost penalty for carrying too much inventory over the optimal target number is relatively light compared to the financial penalty for holding too little. Just as Table 13.2 provided information concerning costs around the optimal order quantity for example 13.1, Figure 13.1 provides a typical profit curve for ordering a service inventory item. Stocking too few items that customers want to buy often results in angry customers and negative profits. After the newsvendor solution is achieved, the profits decline only slightly with the amount ordered, because the holding costs are relatively small.

Consequently, if one were only concerned with satisfying the demand for a single product in a store not subject to capacity restrictions, Figure 13.1 would depict the results of potential choices. However, other considerations enter in. First, we consider product substitution.

When consumers are faced with a stockout of their preferred product, a substantial percentage simply buy a competing brand. Although this tendency may be of great concern to product manufacturers, product substitution makes the stockout somewhat "revenue neutral" from the perspective of service sector inventory. The level of substitution differs drastically depending on the product category and ranges from 40% to virtually 100%, according to research. Physically, what this situation

FIGURE 13.1: *Profit Curve for Typical Service Inventory Form*



SERVICE OPERATIONS MANAGEMENT PRACTICES

Think Mom Buys Too Much? Look Who She's Buying From!

Ever look in the kitchen pantry and see enough cans of tuna to feed the world's hungry for a year? A study of a representative store at one of the leading U.S. grocers in terms of both sales and profits found something similar. Although deliveries from the main warehouse to the store took place five times a week, the average amount of inventory in the store section studied was enough to last a month. For one product in particular, the supermarket shelf held enough to last for six months.

How does this inventory overload happen? Several reasons: Unreliable sales data from creaky information systems that don't tie together can keep the person who makes the order from really knowing the situation; the need to purchase case-packs of 12 at a time, even though only two units sell per month, creates extra inventory everywhere; a reward system that punishes employees who let stockouts occur, but ignores employees who create excess inventory.

The entire industry knows it has an inventory problem. The industry-wide movement of Efficient Consumer Response (ECR, as it's known in the grocery biz) is based on tackling it. To the grocery chain that can solve its inventory problems will go some big rewards: Dominating market share and vastly increased profits.

Source: Ketzenberg et al. (2000).

means is that service firms are not negatively affected by occasional stockouts of certain products. For inventory policy, the substitution factor changes the calculation of the stockout cost in equation (13.1). For example, if consumer substitution were 90%, the real value of C_s would be 0.10($6) = $0.60, rather than $6, and the service level would be set at 92.4%, rather than 99.9%.

The difference between a 92.4% service level and a 99.9% service level may not sound like much, but it represents a significant difference in the amount of inventory ordered because of the high variance of service sector demand. As an example, typical demand for a service sector inventory item can be described by the negative binomial distribution, with a variance higher than its mean. Although it is not vital that you understand the intricacies of the negative binomial distribution, the shape of the distribution is important and is replicated graphically in Figure 13.2 and tabulated in Table 13.3, for a product with a mean demand of 2 and variance of 10.

Access your Student CD now for Excel worksheets of Table 13.3, Figure 13.2, and Figure 13.3.

For this example problem—and for most service inventory problems—we are concerned with a tail of the distribution, or service levels over 90%. Because that particular area is difficult to see on Figure 13.2, it is shown in greater detail in Figure 13.3. Without considering substitution, one should order enough inventory to reach the 99.9% of demand, or 22 units. Including substitution, one should order up to the 92.4% of demand, or 7 units. Including the substitution effect in this case cuts the amount of stock to buy from 22 to 7 units, a nearly 70% reduction.

FIGURE 13.2: *Negative Binomial Distribution (mean = 2, variance = 10)*

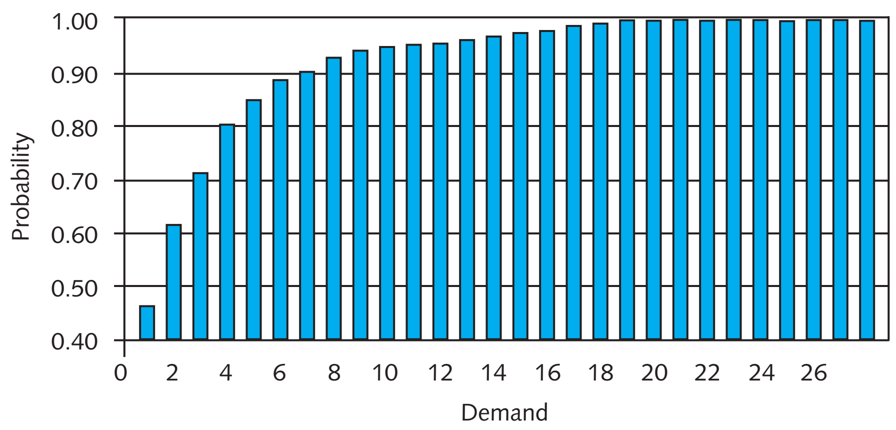
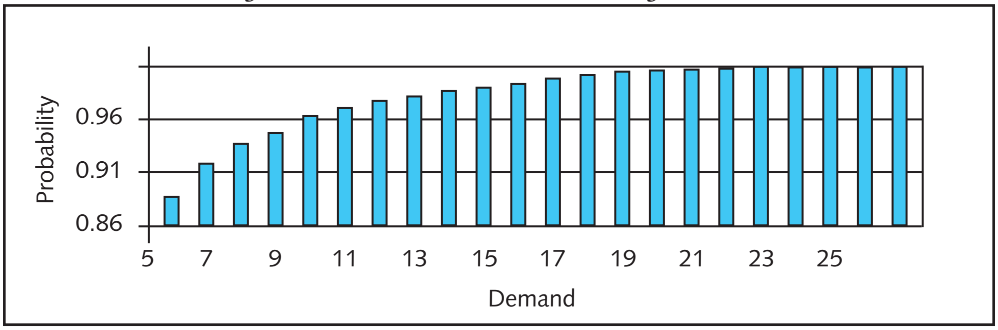


TABLE 13.3: *Probability Distribution (mean = 2, variance = 10)*

Amount	Probability Demand = Amount	Probability Demand ≤ Amount
0	0.447	0.447
1	0.179	0.626
2	0.107	0.733
3	0.072	0.805
4	0.050	0.855
5	0.036	0.891
6	0.026	0.918
7	0.020	0.937
8	0.015	0.852
9	0.011	0.963
10	0.008	0.972
11	0.006	0.978
12	0.005	0.983
13	0.004	0.987
14	0.003	0.990
15	0.002	0.992
16	0.002	0.994
17	0.001	0.995
18	0.001	0.996
19	0.0008	0.997
20	0.0006	0.998
21	0.0005	0.998
22	0.0004	0.999

Without considering substitution: order 22
Considering substitution: order 7

FIGURE 13.3: *Negative Binomial Distribution with High Service Levels*



Multiple Products and Shelf Space Limitations: A Qualitative Discussion

*Access your Student CD now for a **quantitative** discussion on multiple products and shelf space limitations.*

The numerical examples 13.2 and 13.3 on the Student CD provide some solid numbers to the inventory problems in the service sector. One purpose of showing detailed, quantitative calculations is to lead to a more strategic discussion. As noted in the introduction to this chapter, service inventory problems are difficult due to such factors as the enormous number of SKUs, high demand variance, and other factors. Because of these difficulties, services historically took a less than scientific view of inventory management.

The most prevalent method of ordering inventory in services could be called the "weeks of demand" method. That is, a manager has a gut feel that, say, three average weeks worth of demand should be on the shelf. So, if demand in the past five weeks has been 100, 150, 50, 75, 125, this method indicates that $3 \times 100 = 300$ units should be available. While this method has an intuitive appeal and is easily implemented, it can be substantially outperformed by other methods. In other words, "opportunity knocks" for changing the way services treat inventory.

One way to get a better inventory policy is to consider the demand variance of different items. Suppose Item A demand looks like this: 500, 0, 250, 100, 400; and Item B demand is more like this: 250, 250, 250, 250, 250. Clearly, one policy of "three weeks of demand" is not appropriate for both products. The higher variance of Item A means that it should have an overall higher inventory level than Item B.

Another consideration should be the relative product profitability. Suppose Items C and D both cost $10, but Item C sells for $100 and Item D sells for $10. It would be wise to have a higher service level on Item C that Item D. That is, get the best "bang for the buck" in inventory decisions. A similar problem occurs in repair businesses like computer and copier repair. Companies usually send out a technician with a van full of equipment to fix a computer or copier, but a van is only so large and can't possibly hold all the spare parts that may be needed. A customer is equally disappointed if a repair is not made because an expensive part or a cheap part is not on hand. Consequently, the parts to load in the van are the cheap ones. While this sounds trivial for a single van, firms like IBM and Xerox have a thousand or more mobile repair units servicing the United States alone.

Access your Student CD now for these tables and examples in the quantitative discussion of multiple products and shelf space limitations.

The qualitative solutions for these problems presented here are a bit vague when it comes to the detail needed for implementation. The basic lesson is that there are substantial gains to be made by managing product inventories individually, considering such differences as demand variance and product profitability. Specific methods for doing this are on the Student CD.

Practical Methods to Reduce Stockouts, Shrinkage, and Inventory Inaccuracy

Revenue Sharing

A major cause of stockouts at the retail level is the low and uncertain margin that retailers get for selling a product compared to the high price they must pay for the product from the manufacturer. Years ago, a movie video would cost a video rental store perhaps $60 to purchase, then the store could rent it out as many times as possible. The number of rentals is guesswork, but that $60 was clearly money out the door. Quoting the CEO of Movie Gallery, the third largest video rental chain, "Out-of-stocks were the single biggest problem in our industry. Between 20% and 25% of the people coming in to rent a video would leave without their intended title. Some of those found another movie to rent, but some proportion of them went away disgruntled. Under revenue sharing, only about 5% of video rental customers leave without their intended title" (Narayanan, 2003, p. 5).

"Revenue sharing" refers to charging a lower up-front price to the retailer, but sharing in the retailer's revenue. For the movie rental industry, this change meant the price for getting videos from Hollywood dropped from about $60 to about $8, but their rental revenue dropped from about $5/rental to $2.50/rental. The net effect of revenue sharing was that stores stocked more copies of each movie, and more customers got what they wanted. In the terms of the newsvendor model described earlier in the chapter, the cost of overage is reduced severely, while the cost of stocking out is reduced relatively mildly. Consequently, the optimal amount to order increases.

Markdown Money

Another type of incentive to give to retailers is "markdown money," which is sometimes called "price protection." Once it is determined that a product is not selling well, retailers often severely mark down the price on the remaining items to get some return for their dollars. Marking down the price below their own cost still makes sense—it's better to lose 80% of your money than 100%. Markdown money helps alleviate the downside of ordering too much product. The manufacturer agrees to pay a percentage of the markdown amount for the units that have their prices cut. With this downside protection, retailers are willing to order more product, and thereby take less of a chance of a stockout. Again, in terms of the newsvendor vocabulary, the cost of overage is reduced, so the optimal decision is to order more.

Phantom Stockouts

"Phantom stockouts" are situations where customers cannot locate the products they want, even though they are in a store. For the supermarket industry, the sales lost due to products that were in storage areas but not on the selling floor was estimated to be $560 – $960 million/year (Andersen Consulting, 1996). At Borders (bookstores), an average of 5,792 titles are in the store, but not in the selling area where a customer could find them (Ton and Raman, 2004). "One in six customers who approached a salesperson for help failed to find and purchase the title for which he or she was searching, not because the title was out-of-stock but rather because it was misplaced in a backroom, in other storage areas, or in the wrong aisle or location" (Ton and Raman, 1999).

Phantom stockouts hurt a business in several ways. Of course, the immediate sale is not made. Additionally, labor requirements are increased, as customers ask employees for help; forecasting accuracy and reordering policies are weakened, since the computer assumes product is sitting on the shelf and no one wants it. Customers walk away from the firm believing the employees are incompetent—the computer tells them the product is in the store but they can't find it.

Ton and Raman found that phantom stockouts were associated with having too much stuff. The more product variety was in a store, and the greater number of units of each product, the more phantom stockouts would occur. More to the point, just highlighting the problem and recognizing that it is a factor to be managed can help to reduce it. In the grocery industry it is common for manufacturers to hire full-time personnel to do retail audits. These personnel travel from store to store to make sure the manufacturer's product is actually on the shelf, rather than rotting in a back room.

Inventory Inaccuracy

The inventory records of many service firms are highly inaccurate. One particular "large, public retailer with highly modern operations including electronic point-of-sale scanning and automated replenishment systems in each of its nearly 1,000 stores and all of its warehouses" had discrepancies between what the computer thought it had and what it really had for 65% of all products (DeHoratius and Raman, 2003). Further, the average error was large—averaging being off by 5 units for SKUs that average only 15 units of inventory. Inventory inaccuracy isn't caused just by customers. For one new Borders store that customers had never entered, the inventory system had the wrong quantities for 29% of the SKUs (Raman, DeHoratius and Ton, 2001).

Inventory record inaccuracy has many costs. Increased labor cost is high among them. For example, computerized grocery store inventory records are so inaccurate that stores pay employees to wander the aisles and manually order products, rather than rely on their inventory system to tell them when to order. The other costs associated with inventory inaccuracy are the same as those associated with phantom stockouts, such as an inability to properly forecast demand. Further, many systems approaches such as Enterprise Resource Planning systems, Collaborative Forecasting and Replenishment systems, and Distribution Requirements Planning systems rely on accurate inventory information to work. If inventory records are not accurate, the recommendations and orders these systems place can be destructive.

DeHoratius and Raman (2004a) say that the most important aspect of inventory inaccuracy is to get managers to understand that it exists. In accordance with a Six-Sigma approach (Chapter 11), once it is visible it can be worked on. Some fixes are relatively easy, once known. For example, at H.E.Butt grocers, it was noticed that one store in particular sold enormous quantities of hard-boiled eggs—according to the computer. Consequently, more such eggs were ordered. When investigated, it was found that since hard-boiled eggs were priced at exactly 50 cents, when a cashier came upon an item he didn't know the inventory code for, he simply rang up an equivalent number of eggs to get close to the right price. So, a $4 mystery vegetable became eight eggs on the computer system. Once the problem was known, all it took was informing the cashiers they were causing problems elsewhere in order to get them to stop.

Shrinkage

Inventory shrinkage can be a significant problem for services. "Shrinkage" refers to lost, stolen, or damaged goods. The conundrum for service firms is that goods have to be available to see and touch for customers to make purchase decisions, but this also provides customers an opportunity to steal or damage products.

Most of the methods for reducing shrinkage are quite clear and will not be discussed here. Instead, the focus here is a cautionary tale of focusing too much on shrinkage.

The incentive for managers to reduce shrinkage at Bryn Mawr Stereo was powerful: Every dollar of shrinkage was a dollar that was taken out of their paychecks (DeHoratius and Raman, 2004b). With such an incentive, management took reducing shrinkage very seriously—too seriously. The focus on preventing theft and miscounts led to an atmosphere of "sales prevention." All small items that could be easily stolen were put behind lock and key. If insufficient employees were around to safeguard the store, the manager just closed the store down. Instead of helping and informing customers, managers personally counted shipments in the back room to make sure they were getting exactly what was on the invoice.

When a new incentive system was put into place, store performance changed dramatically. The new incentive system based manager pay on store profitability. Since the focus was no longer solely on shrinkage, the amount of shrinkage rose from a monthly average of $123 to $676. But the incentive system got managers out of the back room and helping customers, so sales jumped from $156,000 to $190,000 per month, and overall per store profit increased $5,000/month.

Summary

Yes, the service sector does have inventory—lots of it. It represents a major cost to service firms and, more importantly, a vital part of its strategic decisions.

Because of the high number of SKUs, product substitutability, high demand variances, the prevalence of lost sales rather than back orders, and the limited resource of space, service sector inventory problems are challenging and require solution methods different from many manufacturing inventory problems.

The good news is that inventory management can be a source of competitive advantage in the service sector. Consequently, both a quantitative study of inventory methods, as well as a good feel for what constitutes appropriate inventory policies are areas worthy of study.

Inventory models can harness the power of the computer to overcome the now less-effective common sense approach of yesteryear. Simple models, like the newsvendor model, allow retailers to offer the greatest possible customer satisfaction for the least cost. Product substitution tactics can also be employed to further lessen the impact of inventory stockouts.

Another exciting development in services inventory management is the use of modeling methods to address the cost and space limitation issues. Various methods can be used to make inventory management more rigorous, including weeks of sales, constant K, constant service, and marginal analysis. Qualitative judgment can then improve on the quantitative methods used just by applying the intuition gained by studying your results.

Review Questions

1. In what ways are service sector inventory problems different from typical manufacturing inventory problems?
2. How does consumer product substitution affect the amount of inventory a firm holds?
3. In practice, businesses often stock inventory in terms of the number of weeks of demand. For example, if average demand is 2 units per week, stock three weeks' worth, or 6 units. Discuss two problems with this policy.

Problems

13.1. Sales of hot dogs at the corner of Polk and Castro follow the following pattern: 30% of the days, 80 are sold; 40% of the days, 90 are sold; and the remaining days, 100 are sold. If 90 are stocked each day by the vendor, what demand fill rate is the vendor targeting?

13.2. For the information in problem 13.1, how much should be stocked to have a fill rate of 98%?

13.3. Due to long lead times, fashion goods must usually be purchased by retail stores long before the season begins, and "hot" items quite often cannot be ordered again during the season once their popularity becomes evident.

The new, trendy aluminum foil dress is creating a buzz. Getting a consensus of opinion as to potential sales, the predicted average sales are 5,000 dresses per store chainwide, but with a high variance. Assume potential sales are normally distributed with a standard deviation of 1,500. The dresses cost $40 and can be sold for $120. Unsold dresses can be sold at the end of the season to discount stores for $10. How many should be ordered?

13.4. Sales are brisk at the Christmas tree lot, but a tough decision must be made: It's two weeks until Christmas, and one final truckload of trees will arrive today. Currently, 100 trees remain on the lot. Sales for the 14 days until Christmas are normally distributed with a mean of 400, variance of 2,500. The average tree costs $30 and is sold for $70. Leftover trees have no value. How many should be purchased?

13.5. Dunkin' Donuts joined many other service providers by centralizing manufacturing. Doughnut making in a geographic area is now done centrally for many stores, and the doughnuts are trucked to stores in the early morning. Imagine the decision of the franchisee: Jelly-filled, sprinkle doughnuts cost $0.10 from the central facility, and sell for $0.60 each, and demand the past 10 days has been 50, 38, 27, 45, 62, 44, 44, 29, 31, 39. Day-old doughnuts are thrown out (hopefully). How many should be ordered?

13.6. Consider the stocking level of a single item: Waist 36, inseam 34, green plaid pattern #7, Johnny Miller actionwear slacks. Deliveries are weekly, and the store wishes to provide 98% service (fill rate). Shockingly, demand for this item is 8 per week, with a variance of 60, corresponding to the product Nega-Byno-Meal in the chapter example 13.2 on your Student CD. The pants cost the store $25 each. How much should be stocked, and how much will it cost, given each of the following strategies discussed in the chapter (weeks of sales, constant K, and marginal analysis)?

13.7. The rack of waist 36, inseam 34, Johnny Miller actionwear slacks can barely keep up with demand, and choices must be made. Consider just one other product in addition to the product in the previous problem: Green plaid pattern #8, which also costs $25 each, and also has demand of 8 per week, but the variance is 10. Only 25 total pairs of pants fit on the rack. How many of each should be chosen to provide the best service?

13.8. A distributor of Lincoln Electric motors typically carries inventory of 200 different motor types in its warehouse. Consider just three of these motors, one each corresponding to the distribution in example 13.3 on your Student CD (the negative binomial distribution). Each motor has a mean demand of 10, variance 20, but Motor 1 costs $20, Motor 2 costs $50, and Motor 3 costs $100. How much of each motor should be stocked to provide 90% service at the lowest cost?

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CASE STUDY

K's Grocery[1]

The inventory decisions at K's grocery are made to be simple. An employee with a hand-held electronic ordering device walks down the aisle and notes whether a product has a full amount of inventory on the shelf. If not, the amount needed to fill the shelf is punched into the ordering device and the employee moves on. As an example, consider the 64-ounce bottle of Wesson Vegetable Oil. The product has three "facings," where facings are the slots allocated to a product on a shelf—the number of product containers facing a customer. On any one facing, 4 units of the 64 ounce bottle can fit in the depth of the shelf, so the 3 facings can hold a total of $4 \times 3 = 12$ units of product. Thus, the ordering policy for an employee is to order up to 12 units. If there are 8 units on the shelf, she orders 4 more.

The price the grocer pays for the 64 ounce bottle of Wesson Vegetable Oil is $2.00 and she sells it for $2.80, an average dry goods mark-up for grocery stores. Ordering is done twice a week, late in the day on Thursday and Monday. Ordering takes such a small amount of time per product that it can be considered "costless." The product is delivered and on the shelf by the next morning. The historical demand in the last 10 weeks for the Friday-Monday time frame is: 5, 7, 10, 9, 6, 7, 8, 7, 6, 8. The historical demand in the last 10 weeks for the Tuesday-Thursday time frame is: 7, 4, 1, 6, 6, 4, 5, 7, 5, 6. If there is a stockout, there's a 70% chance that a customer will just buy a different brand of oil. The other 30% of the time the sale is lost. When a sale is lost, not only does the grocer not get the profit margin, but there's also a penalty for disappointing a customer—disappoint a customer enough with stockouts of his or her favorite brand, and that customer is lost for life. Though it is hard to know exactly what the real penalty cost is, assume it is 50 cents for every lost sale. The product doesn't go "bad," so the cost of overstocking is the cost of any investment for the firm, which is approximately 15%/year of the money paid for the item.

Questions:

1. In terms of inventory related costs only, what is the optimal inventory policy, if 100% of the stockouts are lost sales?
2. In terms of inventory related costs only, what is the optimal inventory policy, given the substitution effect listed?
3. The product currently has 3 facings. If equally profitable products are available, with the same demand, how many facings should the 64 ounce bottle get? How does that decision change as the substitution percentage increases?
4. What should K's grocery do?

1. Adapted from Ketzenberg, 2000.