c h a p t e r

2

The Strategic Role of Production Processes in Manufacturing and Services

Virtually every organization depends on the production (or operations) function to transform inputs such as raw materials, labor, capital, technology, and energy into usable outputs, which are bundles of goods and services. How effectively the organization manages this transformation often determines the success of the company in the competitive marketplace. This chapter explores different kinds of production processes in both manufacturing and service organizations.

To understand the role of the production process, it is first necessary to become familiar with basic process characteristics and to identify fundamental differences among types of processes. Then we can address the strategic relationship between the *product* (a good or a service) and the *process* by which it is produced.

It is important to understand the unique properties of services that make them different from manufacturing operations. There are also many similarities between manufacturing and service processes, and we can often improve the management of service operations by adopting manufacturing process ideas and technology. For similar reasons, it is useful to be able to distinguish among different types of services. This can be accomplished by examining classifications of service operations.

2-1 THE PRODUCTION PROCESS

Consider a small service organization, The Yuppie Car Wash Company.

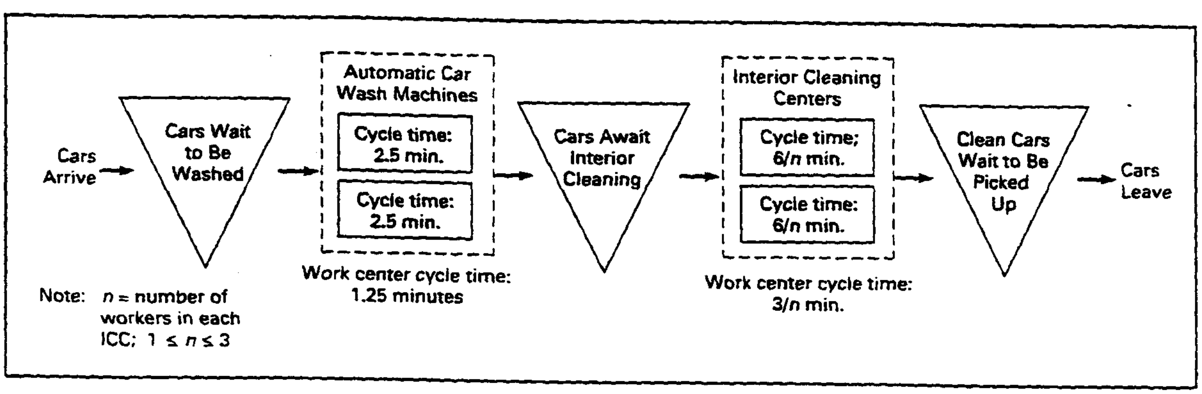
Jane Dow (known by her friends as "the Dow") recently opened a new car wash in an affluent suburb of a major metropolitan area. Dow decided to cater to the high-priced segment of the car-wash market and to try as much as possible to service expensive cars that are highly pampered by their *owners. The Yuppie Car Wash, as Dow chose to name her enterprise, uses a two-stage wash and cleaning process. In the first stage, cars are washed using state-of-the-art automatic car-wash machines with brushes that are "baby-bumper smooth." The second-stage of the process involves the cleaning of the interior of the cars.*

Yuppie has two automatic car-wash machines, each of which costs $150,000. To be cleaned, a car need only go through one of the machines. Both machines are identical and can process cars in parallel. These machines are fed from a single common waiting line. They are imported from Italy and use extremely fine brushes that are guaranteed not to scratch even the most delicate paint finishes. Each machine requires 130 seconds to wash a car. It also takes an additional 20 seconds for one car to exit the machine while another car simultaneously enters it. This standard is set sufficiently high so that there is comfortable spacing between the two cars.

The second stage of Yuppie's process, which concentrates on cleaning the car's interior, is labor intensive and is performed in one of two interior cleaning centers (ICC). Each ICC is staffed by at most three employees. In each ICC the cleaning process for a car requires a total of 6 labor-minutes; that is, this job can be performed by one person in 6 minutes, by two persons in 3 minutes, and so on. (This standard includes the time required to move the car into and out of the ICC.) Dow has found that four or more persons tend to get in each other's way and do not save a proportional amount of time.

Yuppie's production process is illustrated in Figure 2-1 using what is commonly referred to as a *process-flow diagram* (see, for example, Marshall 1974 or Bohn et al. 1986). The diagram illustrates the general flow of product or service from input to final output. In addition to showing the different stages of the production process (shown as rectangles), the diagram includes the various kinds of *inventory* designed into the process (shown as inverted triangles). The inventory of cars that have driven up to Yuppie and are awaiting service is directly comparable to the inventory of raw materials typically encountered immediately prior to the initial stages of a manufacturing process. This analogy extends to the *work-in-process* (*WIP*) inventory of cars that have been washed and will soon enter one of the two ICCs. This is much like the WIP inventory found between work centers in a manufacturing process. Finally, there is the *finished-goods inventory* of cars that have been cleaned and parked, and await being picked up by their owners.

Figure 2-1 Yuppie Car Wash: Process-Flow Diagram



There are two stages to Yuppie's process, so we refer to it as a *multistage* production process. The first stage, which is performed by a relatively expensive machine and requires very little direct labor, is *capital intensive,* whereas the second stage is *labor intensive.* Whenever a process involves multiple stages, it must be designed and managed to take into account the relationship between product flows in each of the various stages. For example, the time required for each car—that is, the *cycle time* of a car in each automatic car-wash machine—is equal to 130 + 20 = 150 seconds, or 2.5 minutes. Thus, the *capacity* of each automatic car-wash machine is $1/2.5 = 0.4$ car per minute, or equivalently, 24 cars per hour. Since there are two automatic car-wash machines, the capacity of the first stage of Yuppie's process is 2(24) = 48 cars per hour. In this manner we see that capacity provides a measure of potential *rate of production.*

Similarly, we see that the cycle time per car in each ICC is $6/n$ minutes, where n is the number of people assigned to work in the ICC. Thus, if Dow schedules two workers in each ICC, the capacity of each ICC is one car every 3 minutes, or 20 cars per hour; since there are two ICCs, the resulting capacity of the interior cleaning process is 2(20) = 40 cars per hour. In this case the capacity of the two ICCs is less than that of the first stage; thus, the ICCs are the *limiting* (or *bottleneck*) *resource.* Therefore, the capacity of the total process is 40 cars per hour, the capacity of the bottleneck process.

By increasing the number of workers assigned to each ICC, Dow can increased the capacity of the second stage of the process. This gives her the capability to manage the bottlenecks. For example, if three workers are assigned to each ICC, the capacity of the second stage increases to 60 cars per hour. Now the first stage is the bottleneck process, and the capacity of the system is 48 cars per hour.

Even if Dow schedules enough workers in each ICC to achieve a theoretically perfect balance between the two stages of the process, it is important to realize that at times either work-in-process inventory will occur between the two stages or the ICCs may be waiting (or *starved*) for work even though one or both automatic car-wash machines may be running. This is due to the variability in processing times. Because it is automatic, there will be relatively little variability in automatic car-wash service time. There will, however, be greater variability in ICC service time because of the inherent nature of the interior cleaning process, which is a function of the type and size of the car (sports car versus full size), type of interior, the state of the interior (has it been one week or one year since the last cleaning?) and the efficiency of the particular crew assigned to the ICC (how experienced are they? how rigidly are their jobs defined by management? will they be as fast on Saturday at 7:00 A.M. as they will be in the early afternoon?) Dow can reduce the average level of work-in-process inventory by scheduling the capacity of the ICCs to be greater than 48 cars per hour. However, if she plans the capacity to be too large, she then incurs the tangible and intangible costs of idle workers. These intangible costs include the carryover of inefficient work ethic, as well as the potential cost of irritating customers who are waiting seemingly long periods of time for their cars to enter the first stage of the process while seeing workers standing around doing nothing!

In the process-flow diagram for the Yuppie Car Wash Company, we see three different types of *queues* (that is, waiting lines) corresponding to the various types of inventory occurring in this system. The effective management of queues is an essential part of the study of production systems. This applies to planning for queues, which addresses issues such as the physical location of the queue and the capacity of the queue. It also applies to controlling the queue, for which we must determine in what order goods will be produced or customers will be served, and manage the flow of information about products (or customers) in the queue.

Although the process flow for Yuppie Car Wash is straightforward, it enabled us to consider important aspects of the process and to understand better the way in which the various components of the process combine to produce the service. The systematic application of "combine, simplify, and eliminate" to process-flow analysis of large-scale operations has vast potential to increase overall process effectiveness and efficiency.

It is the management of the production process that is the topic of this book, and throughout the chapters that follow we will learn considerably more about this challenging task. For now, let us continue to focus on the basic types of production processes.

REVIEW PROBLEMS

1. a. Even though different types of inventory are pictured separately in the process-flow diagram for the Yuppie Car Wash Company, it is common for different types of inventory (and hence, queues) to occupy the same physical waiting area. Looking at Yuppie's process-flow diagram as shown in Figure 2-1, which waiting areas should be kept separate and which might be combined? Explain your answer.
   b. Planning the size of each waiting area is also a significant issue concerning the design of production processes. Briefly discuss factors affecting the size of Yuppie's waiting areas, and provide some indication of their size relative to one another.
   c. What sequencing rule (also referred to as the *queue discipline*) should Yuppie use to set the order in which cars will be processed?

2. The points that were addressed in the preceding question were discussed primarily within the context of a service organization. Briefly discuss similarities and differences between these points as they pertain to both manufacturing and service operations.

Solutions

1. a. Yuppie may wish to combine the parking area for arriving (dirty) cars and finished (clean) cars. In fact, displaying "before" and "after" may be good advertising. In addition, the cost of two separate parking lots may be prohibitive.

   On the other hand, it may not be desirable to combine cars awaiting interior cleaning with either of the other two queues. The time required to drive a car from the automatic car-wash machines to the main parking lot and then drive it back to the ICCs may lengthen considerably the time required to service the car. Also, some confusion about the quality of interior cleaning may arise from customers seeing partially clean cars parked in the main lot.

   b. Assuming that the incoming and clean cars are parked in the same lot, Yuppie should plan this lot to be large enough to handle its periods of peak business. There is, of course, a trade-off in regard to this decision,

since Yuppie will not want to run out of parking space for arriving customers, but more space is costly.

We would expect the WIP waiting area to be relatively small. It should, however, be large enough to accommodate differences in service times in the automatic car-wash machines and the ICCs. It would be undesirable to have cars *blocked* from leaving the automatic car-wash machines as a result of a lack of space.

c. Since customers will presumably wait for their cars to be cleaned, Yuppie will probably follow the first-come, first-served priority sequencing rule. This rule is common among service operations of this type.

2. The points mentioned in the solution to review problem 1 need to be addressed in both manufacturing and service operations. Because customers are generally not present in the manufacturing process, we typically enjoy greater flexibility in resolving these issues. The location of waiting areas, for instance, can be selected to make the production process more efficient, allowing for physical constraints arising from the nature of the product. (For example, when processing food, cooked food must be kept away from raw ingredients.) On the other hand, in a service operation, we must plan for and continually manage the process with an awareness of the customers' presence. The customers' experience while waiting may directly affect their perception of the quality of service.

Determining the relative size of waiting areas is an important decision concerning both types of operations. As the size increases, we are generally faced with the challenge of managing and controlling the inventory. When this "inventory" consists of people, we need to plan carefully such issues as how customers are treated while waiting, how long customers wait, and how customers are kept informed of their status in line. The effective management of this task encompasses many behavioral issues.

Finally, manufacturing operations usually offer much greater latitude in sequencing jobs, provided the finished good is produced in a reasonable amount of time. For instance, if a sophisticated piece of machinery has been set up with intricate tooling to produce a particular type of part, the manager may choose to select all goods in the queue that require that particular part and advance them through that stage of the process. An entire theory of scheduling has evolved over the past several decades, and we will address some of these ideas in Chapters 11 and 13.

2-2 WAYS TO COMPETE

As a consumer of goods and services, think about the differences in products (that is, goods and services) that result in your selection of one product over another. Often we purchase simply on the basis of *low cost,* especially for products that we use in high volume and that vary relatively little across suppliers. Alternatively, we sometimes require a *customized* product that is tailored to fit our unique needs. This occurs when we seek the services of a highly-trained professional, such as a physician or management consultant, or a special custom-made product, such as contact lenses. Beyond seeking a customized product, we sometimes look for an *innovative* good or service.

Consider, for example, the architect who is very good at putting together a home or office building that is customized to meet our particular needs, and contrast this against the architect who develops an entirely new design concept that not only meets our needs, but offers an innovative approach to building design. Also, there are certain goods and services that we select on the basis of their *quality,* and we may be willing to pay a premium for them. This applies, for example, to top-notch services or extremely reliable consumer products. Finally, we select goods and services on the basis of other factors as well. For example, we often base purchasing decisions on *time*-related attributes, ranging anywhere from the time required to develop or produce a product to the time required to deliver a service (see Blackburn 1991).

Competing on the basis of low cost, customization, innovation, quality, and time have direct implications on the design and management of the process that delivers the product. We can design the process to produce a high-volume, low-cost good or service. Alternatively, we can design the system to be *flexible,* so that it is capable of handling a high degree of customization and, if desired, innovation, as well as of adjusting to changing levels of demand. Many fast-food restaurants offer a limited menu and compete primarily on the basis of cost, whereas expensive gourmet restaurants may offer a broader range of menu choices and thereby compete on flexibility. (Both may be high quality, but in different senses.)

It is useful to differentiate among processes on the basis of their strategically planned degree of standardization or customization (see Sari 1981). The firm that produces to finished-goods inventory and supplies its customers from this inventory operates in a *make-to-stock* environment. Since goods are produced to inventory, there is usually little or no customization. Alternatively, organizations that produce to customer order, thus allowing for customization, operate in a *make-to-order* environment. There are varying degrees of customization within this strategy. When component parts and subassemblies of a product are produced and stored in inventory, and assembly of the final product is delayed until a customer order is placed, the process is referred to as *assemble-to-order*. By operating within an assemble-to-order strategy, the customer is afforded some degree of customization. When the item is produced to meet the customer order, and production begins in the early stages of the physical construction of the product, the strategy is one of *make-to-order*. Finally, if customization is required in the design stages of the good or service, the environment is one of *engineer-to-order*.

The notion of competing on quality is also extremely important. "Quality" in its common usage takes into account a variety of attributes. As we will see in Chapter 6, it is useful to explore the definition of quality so that we know exactly what it encompasses. For example, quality is often defined as "fitness for use" or "conformance to requirements." It is common in everyday usage, however, to include the "grade" of a product or a service within the assessment of its quality. In this regard, the high-priced, U.S. made car is commonly viewed as a "high quality" car while the standard model, bottom of the line Japanese car is often viewed as a "lower quality" car. The comparison of these two products is actually being made on the basis of grade rather than quality. As we well know, it is quite possible (and often the case) that someone might pay twice as much for the American made car, only to have it require repair considerably more often and last a shorter time than the "cheaper" car. Quality also includes notions of reliability, dependability, and responsiveness. For this reason, it is useful to keep separate the concepts of grade and quality.

Types of Production Processes

We now examine different types of production processes. First we consider two fundamentally different types of processes, known as *job shops* and *flow shops*. The various types of processes are further refined and then situated along a continuum. Each process type enables the organization to compete in a different manner. The choice of process can be effectively employed within the company's strategic plan for competing in the marketplace.

A job shop is a production process that is designed for low-volume production of highly customized products or services. Since job shops are geared for low-volume, customized production, they are typically labor intensive, and moreover, require a relatively highly skilled work force. Also, job shops utilize a production layout that is more process oriented. *Process layouts* are arranged on the basis of the various processes and tasks that are typical of the general good or service that the process is responsible for delivering. For example, in a machine shop, which is a classic job shop, the workplace is often arranged according to the type of machine; that is, drill presses are located in one area, and milling machines are arranged together in another part of the facility.

Each job within the job shop follows its unique path (or *route*) through the facility. This random routing of jobs is a function of the degree of customization, low volume, and the high skill level required to produce the product. The challenges of managing a job shop relate directly to the skill level of the workers and the scheduling of product through the shop, together with the vast amount of information that is required to produce highly varying items to desired specifications and to keep track of each item in the system.

A flow shop is a production system that is designed for high-volume production of a standardized product. The automobile assembly line is the classic example of a flow shop. Because of the standard nature of the good or service, the skill level required of the workers need not be high, and there is often opportunity for specialization of labor, as well as automation of part or all of the process. Thus, flow shops often exhibit more of a capital-intensive nature.

Since the demands for customization that are placed on the process are low, it is common for products in a flow shop to follow a *serial* or straight-line routing through the shop. Hence, the layout of the process is essentially determined by the manner in which the product is constructed; that is, flow shops employ a *product layout*. Managers of flow shops are concerned with problems arising from a relatively low skilled work force performing narrowly defined jobs, as well as with the effective utilization of expensive equipment that is not readily adaptable to changes in the environment.

In addition to "job shop" and "flow shop," there are other terms that can be used to identify production processes. For example, a *project* is a one-time, usually large task that is made up of a set of activities that must be performed subject to precedence requirements. The construction of a building or the development and introduction of a new product are common examples of projects. Since projects are highly customized and unique, we can view their corresponding process as an extreme case of a job shop. (Projects are addressed in Chapter 4, where we discuss techniques that have been developed for managing and controlling the many tasks that constitute the project.)

The *batch process* lies between the job shop and the flow shop. As suggested by the name, products move through the production facility and are produced at each work center in *batches* (or *lots*), which can range in size from a handful to several thousand. The batch process allows for some degree of customization, but considerably less than in a pure job shop.

As noted earlier, the assembly line is an example of a flow shop. The extreme version of a flow shop is a *continuous-flow* process. Continuous-flow processes are extremely capital intensive and are encountered, for example, in the petroleum and chemical industries. In this setting the process is set up to run for a relatively long period of time and once set into motion requires little direct labor and allows for little change in the specified production.

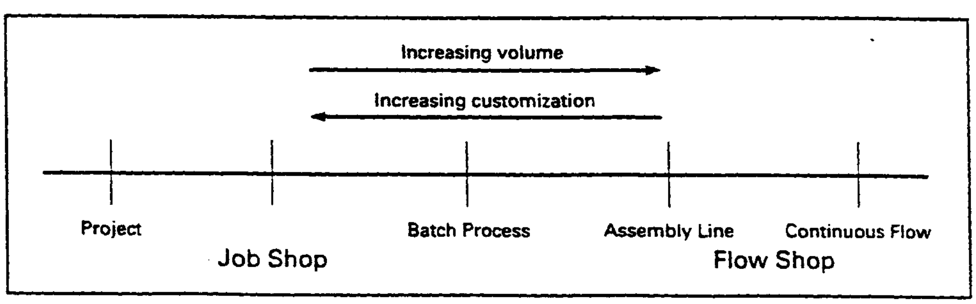
These different processes can be placed along a continuum ranging from low volume, high customization to high volume, low customization (see Figure 2-2).

In today's globally competitive environment, it is essential that upper-level management view the selection of process as a strategic decision. It is not enough simply to be able to distinguish among the various types of processes. Rather, as Hayes and Wheelwright (1984) point out, the selection of a particular process type must be made in conjunction with the nature of the product (good or service) produced by the firm. In addition, this strategic decision must be viewed as being *dynamic;* that is, it changes over time in response to factors in the environment.

Within the study of marketing, the concept of the *product life cycle* is extremely helpful in planning strategy for a product or service over time (Levitt 1965; Kotler 1988). The "product" to which the life cycle concept applies can range anywhere from an entire industry to a specific product brand, although the nature of the life cycle usually differs between these extremes. It is often useful to apply the concept to an intermediate level, such as a product class (Day 1986). For example, instead of looking at the entire automobile industry or a particular brand of car, we may wish to apply the concept to sports cars.

The behavior of a typical product life cycle is illustrated in Figure 2-3. Observe that the product begins in the introduction (or *incubation*) stage, characterized by a high rate of product innovation and change, together with a low sales volume. As acceptance of the product increases, the demand for the product increases rapidly, and the product is said to be in the *growth* stage. As this stage continues, the rate of product innovation begins to slow as the product features become more standardized. The product then reaches the *mature* stage in which a few changes are made to the basic design of the product as demand peaks. As the cycle progresses, some products enter the *decline* phase, in which demand begins to decrease.

Figure 2-2 Types of Production Processes



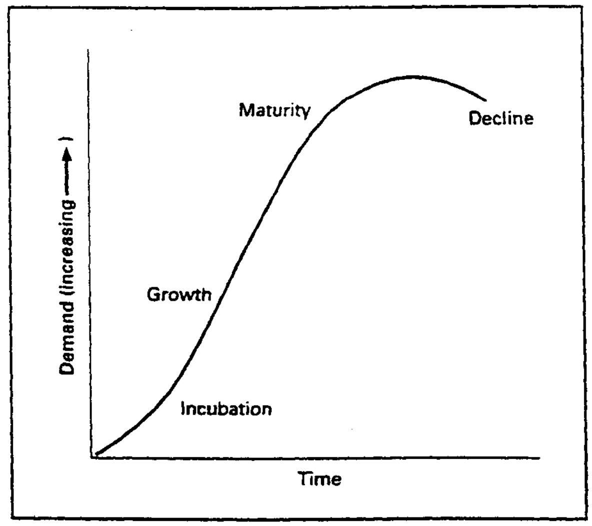
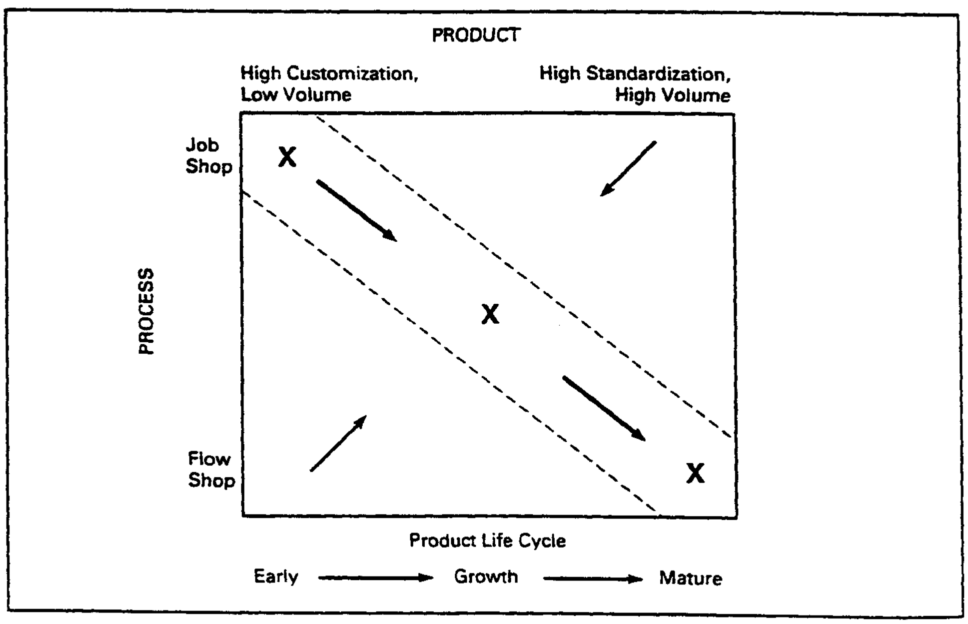


Figure 2-3 Product Life Cycle

Hayes and Wheelwright (1984) observe that from a strategic perspective the choice of process must be viewed in conjunction with the product life cycle. Their product–process matrix is depicted in Figure 2-4. In this matrix the product life cycle is measured along the top of the matrix, and process type is indicated along the left side. The levels of demand and degree of customization serve as a useful measure of the position of the product in its life cycle. In this manner, low volume and high customization typify products in the early stage, whereas high volume and low customization characterize products in the mature stage. Notice that process types range from job shop (toward the top of the matrix) to flow shop.

Figure 2-4 Product–Process Matrix.

(Adapted from R. Hayes and S. Wheelwright, *Restoring Our Competitive Edge: Competing through Manufacturing*, New York: John Wiley & Sons, 1984. With permission.)



In their strategic analysis, Hayes and Wheelwright observe that by positioning itself along the main diagonal, a company is able to match the nature of the product with the most effective process type. That is, job shops are best suited for low volume, highly customized production, whereas flow shops are better able to handle high-volume mass production. Moreover, as the product evolves along its life cycle, a corresponding strategic change in process should occur; that is, movement should occur down the main diagonal.

Manufacturing and corporate strategy will be discussed in greater detail later (Chapter 17). We mention product–process strategy here so that we can begin to think about how the operations management decision concerning which type of process to implement can be viewed within the framework of the organization's competitive strategy. It is necessary to recognize some additional ramifications of the product–process relationship. Not all companies must situate themselves along the main diagonal. Some companies have deliberately chosen to position themselves off the main diagonal to achieve a specific competitive advantage in the marketplace. For example, Volvo chooses to produce its automobile, a very mature product, using a process that is more like a job shop than a typical assembly line (Gyllenhammar 1977; Kapstein and Hoerr 1989). The company must realize exactly what it is doing and be able to justify it on a strategically determined competitive basis.

What drives this decision—the product or the process? The answer to this question must ultimately be decided by top-level management in the strategic plan for the firm. It is important, however, that the choice of product and process be consistent. As the company considers expansion into new products, it must look carefully into whether existing process capability adequately matches the new products. Also, as the company becomes more diverse in its product offerings, it must choose carefully where each product will be produced throughout its production facilities (see, for example, Hayes and Wheelwright 1984 or Skinner 1974).

REVIEW PROBLEMS

1. Consider the Yuppie Car Wash example presented earlier in this chapter. On what basis does Yuppie compete?

2. Provide examples of make-to-stock, assemble-to-order, make-to-order, and engineer-to-order in both manufacturing and service organizations.

3. The *lead time* of a product is the length of time required from the moment when an order is placed until the time the item is delivered to the customer. Which would have shorter lead times, make-to-stock, make-to-order, or assemble-to-order? Explain why.

Solutions

1. Yuppie competes on the basis of grade of service, quality of service, and speed of service. Customers will go to Yuppie expecting appropriate treatment of expensive cars (and temperamental owners). Quality of service will be measured by achieving and maintaining a consistent level of (high-grade) cleaning, as well as dependability of the service.

2. Among manufacturing organizations, producers of consumer products (such as packaged food and clothing) are typically make-to-stock producers. The automobile industry provides an example of both make-to-stock and assemble-to-order. In the first instance, companies produce cars with prespecified options and ship them to car dealers. Alternatively, prior to building the car, consumers can specify the combination of options they would like included in the car. The consumer generally selects from among existing options, which are produced and stocked to inventory independently of, and prior to, the customer's order.

   An example of a make-to-order manufacturing company is a small furniture manufacturer for which customers select furniture from a catalog; production of the furniture from the raw materials begins after the order is placed. The aerospace contractor that designs and builds equipment to be used in the space program is an example of engineer-to-order.

   McDonald's restaurants have designed their service operations to follow a make-to-stock strategy, whereas Burger King has traditionally been more assemble-to-order. McDonald's serves customers from stores of finished-goods inventory, whereas Burger King stores the cooked hamburger patty and then assembles the completed burger to customer specifications (no onions, extra pickle, and so on). Traditional, sit-down gourmet restaurants with waiter service are usually make-to-order. The management consulting firm that develops an innovative solution approach to a complex business problem facing one of its clients is an engineer-to-order service.

3. Make-to-stock has shorter lead times. One merely has to retrieve items from finished-goods inventory to satisfy customer demand. In make-to-order operations, the lead time encompasses the time required to fabricate and assemble the item through all stages of production. It may also include lead times for purchasing component parts from outside suppliers. Assemble-to-order production is between these two extremes. It offers some degree of customization with smaller lead times than make-to-order.

2-3 SERVICE OPERATIONS

Services have become the predominant component of the U.S. economy, accounting for over 70% of the gross national product. As indicated in Chapter 1, productivity growth in the service sector has been much lower than in manufacturing for many years. It is therefore no surprise that there is a growing interest concerning the effective management of the production function in service organizations.

Service organizations and their operations have some characteristics that differentiate them from manufacturing organizations (Fitzsimmons and Sullivan 1982). Perhaps the key characteristic is that the customer of a service organization is a participant in, as well as a direct recipient of, the service. The process must be designed and managed to reflect the customer's presence in the system. For example, jobs should be designed with a sensitivity toward the manner in which workers and customers interact. Facilities often need to be located near the customer to facilitate customer access and convenience. Also, the customer's presence contributes to the uncertainty and variability in the delivery of the operation.

Another distinctive characteristic of services is that a service typically cannot be inventoried. For many services, production and consumption occur simultaneously, and it is not possible to produce in advance for later consumption. This has a direct effect on managing the capacity of the process. Manufacturing firms, in anticipation of a period of peak demand, can produce to inventory in advance of the peak demand. This affords them the opportunity to level production over the year. Services, however, often must plan capacity to meet peak demand. The Yuppie Car Wash, for example, must design its process to be able to accommodate peak demand, which will probably occur on Friday evenings and Saturdays. During periods of low demand, the excess capacity will remain idle. This property places heavy emphasis on the importance of managing capacity in conjunction with managing demand. Since demand management is typically the responsibility of the marketing function, service organizations frequently require careful coordination and critical cooperation between marketing and operations.

Services are often labor intensive. While this is not true of all services, labor intensiveness requires that we pay particular attention to the work force and the manner in which they interact with the customer. Quality control becomes crucial and also a little more difficult as we attempt to control the interaction of the worker and the customer. Levitt (1972) claims that "discretion is the enemy of order, standardization, and quality."

Service operations frequently employ various techniques to limit discretion on the part of both customers and workers. By offering a limited menu or by not allowing substitutions in the menu, a restaurant seeks to reduce customer discretion. As Levitt notes, McDonald's restaurants limit worker discretion in the preparation and serving of french fries by using a standard input of precut, partially cooked frozen potatoes, a specially designed fryer, which is strategically situated in the layout of the operation, and a special-purpose wide-mouth scoop that is designed to deliver a standard-size serving.

Finally, services are often intangible in nature. For instance, it is not unusual for two or more persons to perceive the outcome of the same service on the same day quite differently. (Have you ever discussed one of your classes with your classmates and found, much to your surprise, that you hold dramatically different, sometimes conflicting views on the overall quality of that same class?) This makes it extremely difficult to measure the output and quality of the service. The classic case of a telephone operator illustrates this point nicely. Often telephone companies attempt to measure the effectiveness of an operator by monitoring the number of phone calls that can be handled on a per-hour basis. This may adversely affect the perception of operator-service quality for someone who requires assistance, since the operator might choose to terminate a long inquiry prematurely.

This intangibility of a service also leads to a unique relationship between the product and the process. That is, the process and, in particular, the customer's role in the process actually become part of the service that is delivered. Classroom teaching, especially the case method, provides an excellent example. The learning on the part of the student is not only a function of the information that is conveyed by the teacher, but also depends on the students' participation and role in the process.

The customer's assessment and attitude toward perceived risk also enter into the intangible nature of services. Heskett (1986) notes that research suggests "that customers associate risk more highly with the purchase of services than with goods." Customers are sometimes willing to pay a premium for services to overcome this increased perception of risk. By utilizing a carefully designed service process, companies can seek to manage risk perception.

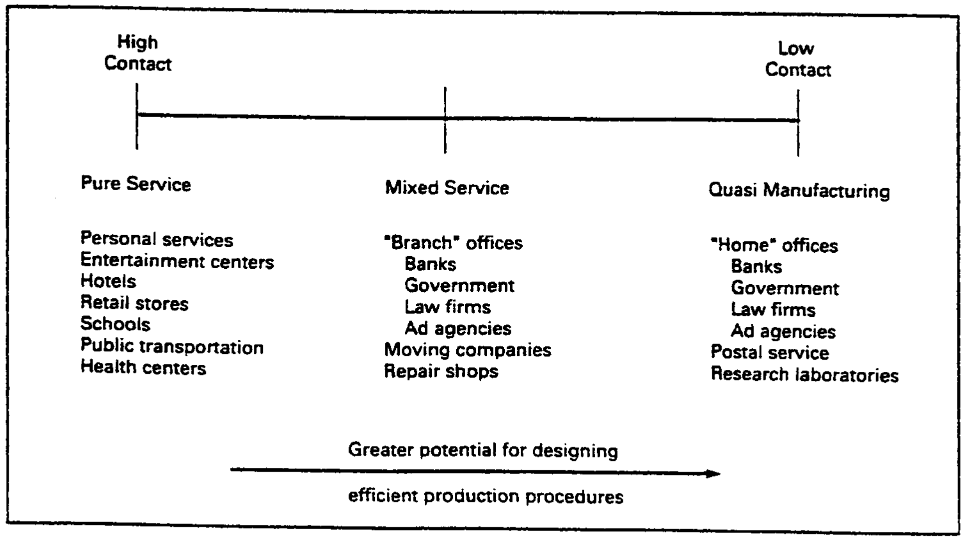
To enable us to study the effective design and operation of the production process in a service organization, we must be able to distinguish between different types of service organizations. Several classifications of service operations have been proposed for this purpose. Chase and Aquilano (1989) differentiate between service operations by using a one-dimensional taxonomy based on the degree of *customer contact* in the creation of the service. In this context, customer contact is "the physical presence of the customer in the system," and creation of the service means "the work process that is entailed in providing the service itself."

Using this concept of customer contact, services are classified along a continuum that ranges from low contact to high contact, as shown in Figure 2-5. Appropriately, low-contact services are referred to as *quasi-manufacturing* services, since they exhibit many of the characteristics of manufacturing operations. High-contact services are called *pure services*. For ease in classification, companies falling between the two extremes are referred to as *mixed services*. Looking at Figure 2-5, we see that different parts of the same organization can fall into different categories. For example, the home office of a bank can experience very little customer contact, while the branch office has a greater degree of customer contact. Activities such as loan application processing and account-servicing paperwork that occur in a bank have a lower degree of customer contact than those occurring in a pure service, such as a hairstyling shop for example.

Low-contact service operations have a greater potential to apply productivity-enhancing principles developed for manufacturing operations. Efficiency-improving concepts have been studied in relation to manufacturing systems since the onset of the industrial revolution, and low-contact services are well positioned to take advantage of this existing technology. Although it follows that high-contact services do not enjoy the same potential, there is often a *technical core* of the operation which can indeed benefit from the adoption of

Figure 2-5 **Classification of Services Based on Extent of Customer Contact.**

(From R.B. Chase and N.J. Aquilano. *Production and Operations Management: A Life Cycle Approach*. Fifth Edition. Homewood. IL.: Irwin. 1989. p. 99. With permission.)



manufacturing technology (Thompson 1967; Chase 1981; and Chase and Aquilano 1989).

In almost every organization, there are functions that do not require the presence of the customer. There are usually corresponding sets of workers who are responsible for performing these activities. Often these functions are highly technical in nature. For example, in a company that develops customized accounting-information-system software for corporate clients, there is typically a field team that is responsible for working directly with the client while the system is being designed and implemented. There is also a technical group that develops the computer programs that make up the software. This group's activities are quite different from those performed by field-team members; entirely different skills are needed.

Figure 2-6 illustrates the concept of the technical core within the operations function. In manufacturing operations and in low-contact service operations, the technical core is distinct, and it also constitutes most of the production function. In this environment the technical core is easily sealed off from unnecessary customer contact without interfering with the nature of the operation. In a high-contact service organization, however, it becomes more difficult to seal off the operation of the core from the customer. Hence, in this setting the technical core is less easily identifiable and constitutes a smaller portion of the total production process. Nevertheless, a technical core usually exists, and it is advantageous to identify it and manage it efficiently.

It is necessary to examine each activity within a service operation and ensure that relevant technical-core activities are indeed performed within the core. Once the technical core is established, the firm should take advantage of the productivity-enhancing potential in the core. At the same time, we must realize that noncore activities, by their nature, involve customer contact. Thus, it is necessary to concentrate on improving the interpersonal skills and establishing the desired behavior of high-contact workers (Chase and Aquilano 1989).

We should be careful not to push the efficiency-enhancing potential of the technical core to the extreme by recommending that service organizations continually seek to enlarge their technical core. This can have an adverse effect on the strategically planned competitive nature of the service. (This idea is discussed further in review question 2.) In addition, even though the technical core can operate in the absence of the customer, it must remain sensitive to the needs of the customer, and it must add value for the customer (Chapter 17).

Because of the high degree of customer contact in pure services (or in the high-contact side of other services), they pose an intrinsically challenging operations management environment. In a high-contact service, the operations function is faced with the decision of planning adequate capacity to meet day-to-day and even hour-to-hour variations in demand. Since the level of customer

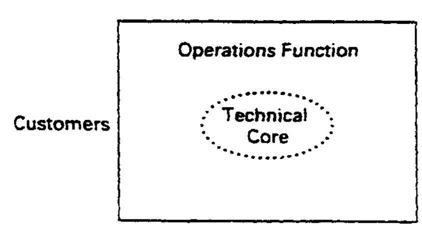


Figure 2-6 The Technical Core

contact is high and the demand behavior of customers is often hard to forecast, it is difficult to match capacity and demand.

As we noted earlier, the nature of each customer's request, and to some extent the personality of the customer (or server), can contribute considerably to the variability in demand. This adds to the total amount of uncertainty. (Have you ever stood in line at a bank while the person in front of you argues with the teller?)

Furthermore, because the customer is present in the system, the operations function must be sensitive to the customer's needs and possible demands. This means that the workers in high-contact jobs require public relations skills. Many high-quality service organizations devote considerable effort to enhancing employee–customer encounters. It is common, for example, for workers to wear uniforms and follow standard operating procedure, which often includes a standard greeting and closing ("Good morning. Welcome to . . . May I take your order? . . . Thank you.").

In high-contact systems we must be sensitive to the fact that customers will probably be required to wait for service. Many clever ways have been devised to manage the customer waiting process. For example, when visiting a medical clinic, a long wait frequently occurs between the time when a patient enters the clinic and the time when he or she finally sees the physician. In the interim, however, if the patient is directed to an office where vital signs are checked by a nurse and then returns to the waiting area (or perhaps "proceeds" to a different waiting area), the perceived total waiting time is reduced.

Disney World has some excellent queue-management methods. For many of the attractions, signs are posted along the waiting area telling visitors of the expected wait from that point. Also, the queue configurations are adroitly managed by a series of rails and (adjustable) ropes. As the line advances, it typically moves from the outside to the inside of the exhibit. Thus, upon entering the building, the change in environment signals that significant progress has been made in advancing toward the front of the line. In actuality, there may be a considerable wait inside. Finally, the waiting areas themselves are lined with interesting or humorous paintings or signs.

Service organizations offer unique challenges to the operations manager. Other classifications of service operations have been suggested (see, for example, Schmenner 1986). We will use the classification given in Figure 2-5 throughout this text, since it provides a convenient way to relate services and manufacturing. In the chapters that follow, whenever manufacturing ideas are presented, it is important to also think of them as they apply to the technical core of a service. We will also consider issues that arise in the high-contact side of the operations function.

REVIEW PROBLEMS

1. Provide specific examples of high-, medium-, and low-contact service operations. For each, discuss high-contact activities, as well as technical-core activities.

2. It was mentioned previously that although service operations should seek to identify and seal off the technical core, it is not necessarily wise to expand its size even though it offers productivity-enhancing benefits. Explain why this is the case.

3. Provide other examples of ways in which service operations control worker discretion in the delivery of the service.

Solutions

1. An exclusive retail clothing store provides an example of a high-contact service. As customers enter the store, they are greeted by a salesperson who is responsible for assisting the customer in locating and selecting the desired clothing. Finally, the customer may have to be fitted for the clothing by the tailor, or in the case of minor alterations, by the salesperson.

    In this setting the technical core consists of activities in the tailor's shop (other than fitting customers) and activities involved in ordering, receiving, and stocking new items of clothing. Activities occurring in the general office also form part of the core (although some workers may have to call customers to communicate account information or handle special inquiries). Activities of the clothing buyers may be viewed as part of the core from the point of view of the customer, but buyers interact with clothing designers and wholesalers.

    A small office dealing in the preparation of relatively straightforward individual tax returns is an example of a medium-contact service. In this setting clients meet with front-office workers who provide general information concerning the service, talk with the client about the nature of the return, screen clients by forwarding complex returns to an accountant's office, and inform clients of the necessary information required to complete the return. The technical core consists of those activities required in the processing and preparation of returns, which include making the appropriate number of copies and handling the necessary correspondence. Some of these technical-core activities are now supported, and in some cases replaced, by automation in the form of personal computers and specialized software.

    A mail-order house is an example of a low-contact service. Customers phone or mail in orders, which are received by a staff of customer-service employees who are trained to communicate with the customer, gather information of the correct type, and place it in the correct form for processing. This group also handles customer complaints. The technical-core activities are warehouse receiving, stocking, order retrieval, order sequencing, packaging and shipping, and materials handling.

2. The design of the service operation, including the relative size of the technical core, is largely determined by the nature of the service and by the specific dimensions along which the organization wishes to compete. If an organization desires to compete on its warm, friendly, customized service but places more aspects of its service delivery into the core, the resulting effect could easily conflict with the desired competitive strategy.

3. Educational institutions have developed a number of ways to control worker (that is, teacher) discretion in the delivery of the service (teaching). This is frequently accomplished by establishing a required curriculum, requiring teachers to follow a standard syllabus, and using common exams.

    Examples occur in the health services as well. The discretion of nurses and physician's assistants is limited by using standard operating procedures and strict specification of illnesses that can be treated without the direct involvement of a physician. Physician discretion is also limited through the use of established treatment procedures, common certification, control of prescription drugs, and hospital procedures.

2-4 SUMMARY

The operations function in an organization is responsible for converting the inputs of raw materials, labor, technology, capital, and energy into the desired output, which is a specified bundle of goods and services. This chapter has sought to increase our familiarity with the production process. In addition to studying basic types of production processes, we have seen that one of the keys to achieving a competitive position in the marketplace is the management of the organization in a manner that simultaneously takes into consideration the nature of the product (that is, the good or service) and the process that is used to make or deliver it.

We began our discussion by looking at the example of the Yuppie Car Wash Company. This discussion introduced many of the concepts relevant to multistage production processes. It also enables us to realize how operations management decisions can affect the way in which the process runs, as well as the ability of the process to either facilitate or hinder achievement of the strategic competitive goals established by top management. Firms can compete on the basis of low cost, high quality, customization, innovation, or time. Although it may appear obvious, the importance of the production process in achieving these goals was perhaps one of the most significant (and, in many instances, painful) lessons learned by United States manufacturing companies in the 1980s.

Job shops and flow shops represent two extreme stereotypes of production environments. Along the continuum ranging from job shops to flow shops, there are other well-known types of production processes, which include projects, batch processes, and continuous-flow processes. We have also seen that it is useful to distinguish between make-to-stock and make-to-order production environments and that there are different degrees of make-to-order. The product–process matrix of Hayes and Wheelwright provides a convenient way to compare process capability with product demands. It also provides a basis upon which a company can consider whether it is pursuing a coherent competitive strategy.

The chapter concludes with a discussion of services. Although the study of operations management traditionally has been dominated by manufacturing, the significant presence of the service sector in the economies of developed nations has brought about a critical need to explore and realize the productivity-enhancing potential in service operations. We began our study of services by identifying characteristics that make them different from manufacturing operations. We also discussed a one-dimensional classification of services based on the concept of degree of customer contact. By observing the nature of the technical core as it changes from low contact (quasi-manufacturing services) to high contact (pure services), we are better able to understand the similarities and differences between manufacturing and service operations. This understanding will prove to be invaluable in our study of operations management in the chapters that follow.

From *Operations Management: Production of Goods and Services,* Third Edition John O. McClain, L. Joseph Thomas, and Joseph B. Mazzola. Reprinted with permission.

CASELET

HALL RUNNERS*

Robert Hall was a marathon runner. Earlier in his running career, Bob had some problems with his feet because of the running. Dr. Baines, an orthopedist, diagnosed Bob's problem as one requiring special running shoes. While in graduate school, Bob started making running shoes for himself, and later for a few friends. These shoes were designed by Bob in consultation with Dr. Baines. During the first few years, Bob made the shoes in the garage of his parents' home using their sewing machine. For other processing equipment, he invented methods and processes to get the job done cheaply.

Bob's method of manufacture was to purchase what he could and make whatever he could not purchase. At the beginning he purchased all his material in flat sheets or in rolls and cut out the patterns with scissors. He made some wooden shoe lasts (forms) on which he constructed the shoe after he had all the necessary parts. He converted an old clothes dryer into a drying oven (by removing the drum drive) to dry the glues and solvents that held most of the shoe together.

Bob had started this business just before the "jogging craze" began sweeping the country. He was now selling some of his shoes through independent shoe stores in three large cities within 200 miles of his home. With the help of Dr. Baines, he developed three master patterns for the majority (85%) of the shoes that he now makes. The remaining shoes continue to be made for specific customers in consultation with Dr. Baines.

Bob currently rents a 2000 square foot facility, which houses his operation. The current manufacturing operation differs little from that which Bob started in his parents' garage, except for larger production runs and some heavier-duty equipment (including two industrial sewing machines). The layout of the shop is shown in Figure 2-7. In addition to himself, Bob's shop now employs one full-time worker, who is an experienced garment maker, and five part-time workers, who received on-the-job training. All the basic "Hall Runners" are made in the same style except for the tread design. As was noted previously, there are three of these: one for street, one for cross-country, and one for track. The only other variation is in size. To facilitate scheduling, shoes are produced in lots consisting of the same size and style shoe. Bob has also noted that more and more people are wearing running shoes as casual attire or as everyday shoes. This trend may warrant developing different styles and colors. Bob feels that the market potential is great for quality running shoes, and he intends to enlarge his production capacity.

Required

This case contains many aspects of the product-process operations concepts discussed in this chapter. Discuss briefly all such concepts that are applicable to Robert Hall's operation. Be as thorough as possible, and be sure to include in your discussion concepts such as process characteristics, relevant product characteristics, and product-process interaction and evolution.

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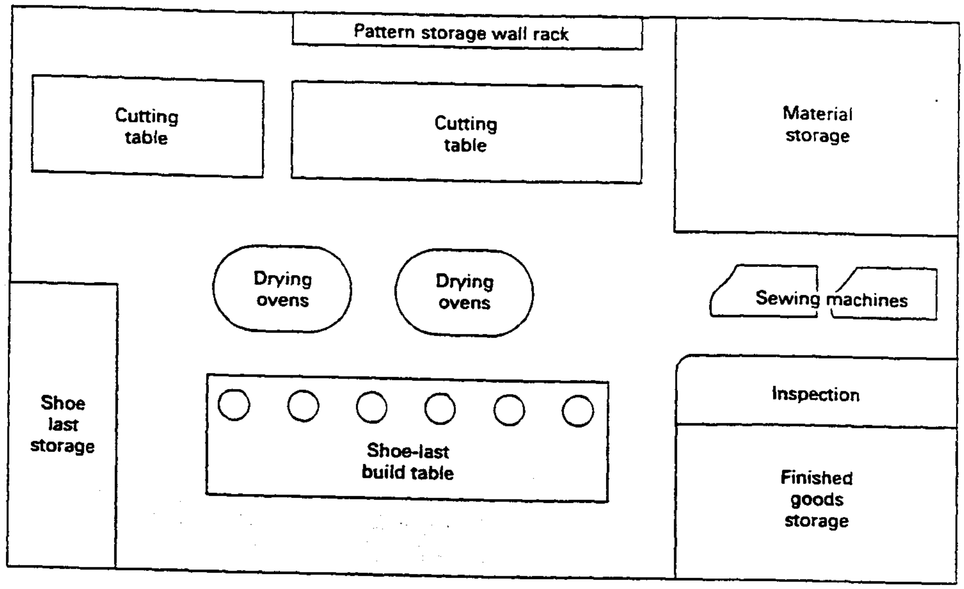

Figure 2-7 Shop Layout for Hall's Running Shoes

PROBLEMS

1. Answer each of the following questions concerning multistage production processes.
   a. What is a multistage production process?
   b. What is meant by the capacity of the process?
   c. What does it mean for one of the stages to be a bottleneck?

*2. a. Is it possible for there to be more than one bottleneck in a process? Explain.
   b. For a given process, must the bottleneck(s) always remain at the same stage(s) of the process or can it (they) "move around"? Explain.

*3. In the Yuppie Car Wash Company example of Section 2-1, we saw that if Yuppie uses two workers in each of the ICCs, the resulting capacity of the total process is 40 cars per hour.
   a. If Yuppie assigns one worker to each ICC, what is the capacity of the ICCs, and what is the resulting capacity of the entire process? Identify the bottleneck work center(s).
   b. Answer the questions in part a assuming that Yuppie assigns three workers to each ICC.

4. Consider a production process consisting of three workstations (Stations 1, 2, and 3). All goods enter the process immediately prior to Station 1, where they await processing at Station 1. All goods flow sequentially through each of the stations in the same order (Station

*Problems with an asterisk have answers in the back of the book.

1 to Station 2 to Station 3). Upon leaving Station 3, finished goods are stored in inventory until they are eventually sold to customers.

The workstations operate independently of one another. Stations 1 and 3 are each machine controlled. Station 1 has a cycle time of 0.5 minute per good, and Station 3 has a cycle time of 20 seconds per good. Station 2 is labor intensive, and its capacity depends on whether there are two, four, or six workers assigned to it. (Workers must work in pairs because of the nature of the work performed at the station.) The capacity of Station 2 is 100 goods per hour if it is staffed by two workers, and its capacity increases by 50 goods per hour for each additional pair of workers. There are work-in-process storage bins between consecutive workstations. The cycle times at each workstation include the average time required to move the good into and out of the storage bins.

a. Draw the process-flow diagram for this operation.

b. Determine the hourly capacity of this process assuming that (i) two, (ii) four, and (iii) six workers are assigned to Station 2.

c. Determining the bottleneck workstation(s) for each assumption in part b.

5. Consider the production process defined in problem 4. Suppose now that the company purchases another machine of the type that is used in Station 1. This machine would be used in parallel with the machine currently in Station 1 and would effectively double the capacity of that work center. The machines would be fed by a common queue. Answer parts a, b, and c of problem 4 for the modified process.

6. List and define the different types of inventory discussed in this chapter.

*7. Consider a two-stage production process in which ten different parts are fabricated from raw materials in the first stage (using only one machining center) and are then assembled, in the second stage, into the finished product. Four of the ten parts come in different (but interchangeable) styles and colors. Also, each of the ten parts is made in the first stage from a unique raw material, and only one part can be made at a time. A finished assembly contains one of each of the ten parts.

a. Would you expect to see work-in-process inventory between the two stages of this process? Why?

b. Assuming that the company operates in a make-to-stock environment, draw the process-flow diagram for this manufacturing process.

c. Assuming that the company operates in an assemble-to-order environment, draw the process-flow diagram and explain the differences between this diagram and the one occurring in part b.

d. Assume that the company operates in a make-to-order environment. Draw the product-flow diagram and discuss differences between it and the ones arising in parts b and c.

8. Describe a few ways in which a company may compete. How does this relate to the operations function? Provide examples to support your answer.

9. One way in which a firm may choose to compete is on the basis of "quality." Sometimes the quality of a good or service is confused with its "grade." What is meant by the grade of a product (good or service)? Provide examples that illustrate a high-grade product that may be of low quality and a low-grade product that may be of high quality.
10. a. What is the difference between a make-to-stock and a make-to-order production environment?
    b. Explain differences in competitive advantage offered by these two environments.
    c. Identify the various types of make-to-order processes, and explain the differences between them.
11. a. Define the term "job shop," and discuss the general characteristics of a job shop.
    b. Define the term "flow shop," and discuss the general characteristics of a flow shop.
    c. What is a project?
    d. What is a batch process?
    e. What is a continuous-flow process?
12. Summarize the basic ideas contained in the Hayes and Wheelwright product–process matrix. Be sure to discuss the strategic implications of this concept.
13. In what ways do services differ from manufacturing organizations?
14. What does Levitt mean when he asserts that "discretion is the enemy of order, standardization, and quality" in service organizations? Provide examples to support your response.
15. Discuss the classification of service operations based on customer contact. In your response, be sure to include and define each of the following terms:
    a. customer contact
    b. creation of the service
    c. pure services
    d. quasi-manufacturing services
    e. mixed services
16. What is the technical core of a service operation? How does the nature of the technical core change as the operation ranges from a quasi-manufacturing to a pure service?
17. a. Why is it helpful to be able to distinguish between different types of services using a taxonomy such as the classification based on the degree of customer contact?
    b. What are the implications regarding the design, planning, and control of service operations that result from understanding the concept of the technical core, as well as the nature of the service based on the degree of customer contact?
18. Think of your favorite (or least favorite) food service. In general terms, what type of production process does it employ? On what basis does it compete? Can you think of any characteristics of its production process or general operations that support or run counter to this competitive strategy?

*19. In the calculation of the cycle time for the two ICCs in the Yuppie Car Wash Company example of Section 2-1, it was assumed that an equal number of workers would be assigned to each ICC. In reality, Jane Dow is free to assign to each ICC, independently of the number assigned to the other ICC, any number of workers (including none) up to the maximum of three workers allowed per ICC.

For each allowable combination of workers in the ICCs, answer the following questions. (Assume that cars waiting to enter the ICC are serviced first come, first served and that each car is serviced by the ICC that first becomes available.)

a. Compute the cycle time and capacity of the ICCs (i.e., the subsystem defined by both ICCs).
b. Determine the capacity of the entire process.
c. Identify the process bottleneck(s).

20. The discussion of the Yuppie Car Wash Company in Section 2-1 purposely focused on the flow of cars through the process and did not take into account what happens to the customer. This is reflected in the process-flow diagram shown in Figure 2-1. Consider now what happens to the customer at the Yuppie Car Wash.

Upon arriving at Yuppie, customers park their cars in the large parking lot in front of the car wash and proceed into a separate building adjacent to the car wash. The building is nicely furnished in contemporary design, with an attractive combination of natural wood paneled walls, ceramic tile, and plush carpeted floors, with light music in the background. Customers wait in line in front of the reception desk. At the reception desk, the customer provides basic information on the type of car and any special washing or cleaning instructions. (For example, upon request, Yuppie will use a special-formula Bavarian-made soap for extremely delicate paints; of course, Yuppie charges extra for this.) The customer then hands the ignition key to the employee and proceeds to a large waiting room. Reception-desk employees wear standard uniforms that are primarily dark colored.

The waiting room is amply equipped with comfortable furniture, a minilibrary of investment magazines, and two large-screen TVs, with one tuned to a cable news station and the other tuned to a financial information network. A large window runs along the wall of the waiting area facing the car wash so that customers can watch the progress of their cars through the process and also monitor the careful handling of cars by Yuppies' employees.

When servicing of the car is complete, an employee returns the keys to the customer checkout desk. The customer checkout desk is located at the opposite end of the waiting area from the location of the reception desk, and the room is designed so that a large wall obstructs direct vision between the reception and checkout desks. Customer checkout representatives are required to wear standard uniforms that are predominantly white in color. The customer is paged over the public address system in the standard manner: "Mr. (or Ms.) Smith, your car has been serviced; please proceed to the customer checkout area." The customer then approaches the checkout area and, if necessary, joins a single line that is formed in a winding pattern by a series of velvet-covered ropes. After paying the customer checkout representative, the customer receives his or her key back and then proceeds to the large parking lot, picks up his or her car, and drives away.

Given this additional information, answer each of the following questions:

a. Expand the process-flow diagram in Figure 2-1 so that it also takes into account the customer flow throughout the system. To distinguish between car and customer flow, use solid lines to represent the flow of cars and dashed lines to indicate the flow of customers.
b. Process-flow diagrams are also useful in indicating the flow of information in the process. Augment your answer to part a by now including the flow of information in the system. Use dotted lines to indicate information flows.
c. This example illustrates many of the points mentioned in the chapter concerning the planning, design, and control of service operations. Discuss instances of this pertaining to each of the following:
   (i) limiting customer discretion
   (ii) the design of waiting areas
   (iii) the technical core
   (iv) the customer's presence in the system
   (v) intangibility
d. Suggest minor changes to the process flow that could reduce the total amount of time a customer spends in the system.

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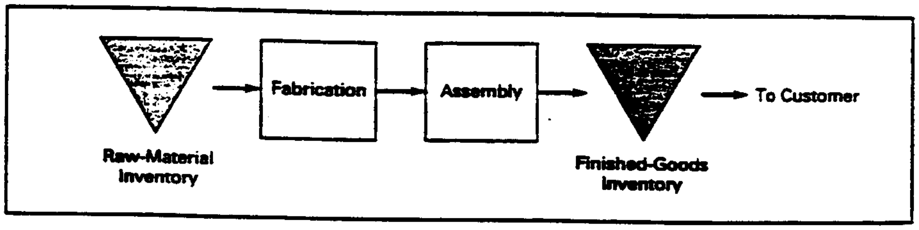
Solutions to Starred Problems

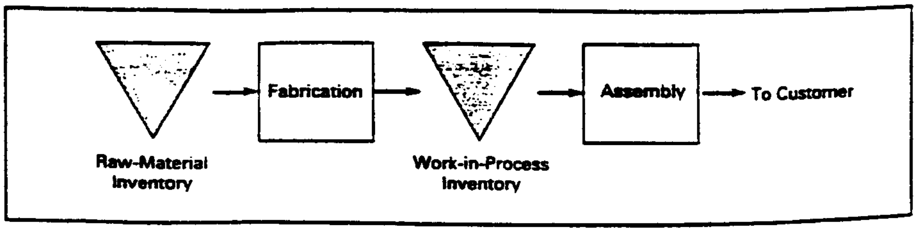
CHAPTER 2

2. a. Multiple-bottleneck processes occur when two or more work centers are limiting resources.
   b. The location of bottlenecks can indeed shift in the process. If different types of products are made, changes in the production mix can cause a shift in the bottlenecks. Also, bottlenecks can change as the capacities of work centers are changed by adjusting the number of workers or machines.
3. Recall that automatic car-wash-machine capacity is 48 cars/hour.
   a. 1 worker/ICC: ICC capacity is 60(1/6)(2) = 20 cars/hour; process capacity is min {48, 20} = 20 cars/hour. Bottleneck: ICCs.
   b. 3 workers/ICC: ICC capacity is 60(3/6)(2) = 60 cars/hour; process capacity is min {48, 60} = 48 cars/hour. Bottleneck: ACW machines.
7. a. Ordinarily we would expect to see some work-in-process inventory, since the work centers operate independently, and some parts might have to await processing of remaining parts before assembly can begin. As we will see in the rest of this question, the nature of the production process will determine the size of this work-in-process inventory.
   b. Make-to-stock process:



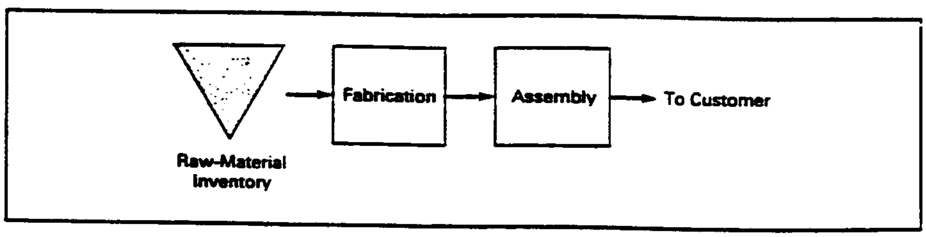
Characteristics: Large (planned) finished-goods inventory. Some planned raw-material inventory. Although work-in-process inventory will occur between fabrication and assembly, it is not depicted separately, since it is not a key planned feature of the make-to-stock process.

c. Assemble-to-order process:



There is a large planned work-in-process inventory of fabricated parts so that products can be assembled to customer order.

d. Make-to-order process:



No planned work-in-process or finished-goods inventory. Raw-material inventory shown here can reduce product lead time.

19.

Number of Workers	ICC Cycle Time (min)	ICC Capacity (cars/hr)	Process Capacity (cars/hr)	Bottleneck
1	6	10	10	ICC
2[a]	3	20	20	ICC
3	2	30	30	ICC
4	3/2	40	40	ICC
5	6/5	50	48	ACW[b]
6	1	60	48	ACW

[a]Includes all combinations of workers in ICC1 and ICC2 that add up to 2: i.e., (2, 0), (1, 1), (0, 2).
[b]Automatic car-wash machine.