



CHAPTER 9

Process Design and Layout Planning

LEARNING OBJECTIVES

After studying this chapter, you should be able to:

- 9.1a Argue for the strategic importance of process selection to an organization.
- 9.1b Identify factors that affect process choice.
- 9.2 List the unique features in the design of service processes.
- 9.3 Defend the reasons that it is important for companies to synchronize their internal processes with the external processes of their supply chain partners.
- 9.4 Describe the unique challenges involved in designing global processes.
- 9.5 Construct the different layout types, identifying their features in the design.
- 9.6 List strategies that companies can take to address the legal, ethical, and sustainability issues in process design and layout planning.

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OPERATIONS PROFILE:

Process Redesign at Mars: Moving Toward Sustainability and Social Responsibility

Mars, Incorporated (McLean, VA), one of the largest privately held organizations in the world, employs more than 70,000 people in more than 400 offices and factories in 73 countries. The firm's products range from candy to teas and coffee to pet food—all manufactured with the goal of social responsibility and sustainability. The company sponsors many sustainability initiatives:

- Sustainability workshops are held at Mars sites worldwide, and employees are encouraged to dedicate a week to generating ideas for new processes to save energy and water and to reduce waste. Since 2007, these efforts have helped the company cut its energy usage by 6%, water usage by 18%, and landfill waste by 51%.
- Mars has invested millions of dollars to improve the efficiency of equipment used to produce its Wrigley's gum and confectionary products. These improvements have helped streamline production and have significantly reduced the energy required to produce the products.
- Mars's goal is to acquire 100% of its cocoa, fish and seafood products, black tea, coffee beans, and palm oil from sustainable sources worldwide. The company works to acquire 100% of its materials from certified sources—that is, suppliers that have the highest ethical standards in growing food and supporting their workers.
- All of the company's product packaging has been redesigned to reduce its weight, ensure it's 100% recyclable, or make use of recycled materials.

Although many companies affirm their support of social responsibility and sustainable operations, Mars offers a model for other organizations to emulate.¹



Patrick Hertzog/Alamy/Getty Images

Because of their long-term impact on the organization, design of quality products and services, capacity planning, along with process design and layout planning, are among the most important and strategic decisions that operations managers have to make. These decisions also have implications for a wide range of subsequent tactical and operational activities, as well as the organization's supply chain. In the current competitive global economy, businesses are under intense pressure to reduce the time to market, lower the cost of their products and services, and meet the goals of sustainability. From the point of originating a new product or service idea to its introduction in the global marketplace, companies face myriad options for achieving this transition. One of the critical decisions operations managers have to make is to evaluate these various options in a systematic and robust manner and choose the best way to achieve this transition using existing resources. This chapter on process design and layout planning addresses this issue of transition—converting inputs into outputs in the most efficient manner.

9.1a Argue for the strategic importance of process selection to an organization.

9.1b Identify factors that affect process choice.

9.1 Designing, Selecting, and Redesigning Manufacturing Processes

Companies face many options in the way they produce their goods and services and in their choice of production methods. A **process** is a collection of interrelated tasks that converts specific inputs into specific outputs. A process design is the most cost-effective way to achieve this transformation to produce goods or services that satisfy customers' needs and achieve the firm's sustainability goals while accommodating the firm's technological and managerial constraints. Operations managers are responsible for evaluating processes in a systematic way as well as selecting among them (**process selection**), choosing the right technologies, and then analyzing the processes and redesigning them if necessary.

The particular process a company selects is influenced by its **process strategy**, which is the strategy a firm opts to take in producing goods and services determined by the availability and mixture of labor, equipment, and automation. The extent and the ease with which the firm can adjust its processes to changes in demand, technologies, product and service design requirements, and the availability of resources also affect a process strategy. In addition, a process strategy is influenced by the degree to which customers can affect a product's design specifications. First, however, let's look at some of the basic types of processes that companies use.

Process: a collection of interrelated tasks that converts specific inputs into specific outputs

Process selection: the decision of selecting the kind of process that can give a firm a competitive advantage in terms of speed to market, responsiveness to customers, and cost savings

Process strategy: the strategy a firm opts to take in producing goods and services determined by the availability and mixture of labor, equipment, and automation

Project process: a process that is selected when the product is unique and typically produced one at a time to the customer's specifications

Job-shop process: a process that is selected when the processing requirements are intermittent and different for each product because it is unique and produced in low volumes or sporadically

Basic Process Types

Depending on the product or service, companies have the option of choosing from five basic types of processes: project, job-shop, batch, repetitive, or continuous flow. Table 9.1 compares the five process types.

- A **project process** is used when the product is unique and typically produced one at a time to the customer's specifications. Examples include construction projects, new product development projects, or the production of a movie. This type of process works best when there is low demand for a product, nonroutine work, a large investment of resources, and stringent time and budget constraints for completion.
- A **job-shop process** is used when the processing requirements are intermittent and different for each product because it is unique and produced in low volumes or sporadically. For example, Orange County Choppers (Newburgh, NY), a manufacturer of custom-designed motorcycles, uses a job-shop process. In the service sector, a job-shop process is used in a doctor's office where various patients with different ailments are treated. Each treatment is unique based on the patient's specific needs.
- A **batch process** is used to produce a moderate variety of products in moderate volumes in groups or batches. In the case of paint manufacturing, a moderate variety of paints such as flat, semi-gloss, and storm-coat are produced in batches in different colors and in modest volumes. A service firm such as a credit card company uses a batch process to process bills. Instead of receiving a separate bill for each credit card transaction, the customer receives a bill each month for all of that month's credit card transactions.
- When a high volume of standardized products needs to be produced, a **repetitive process** should be used. Low unit costs, high efficiency, and high volume of production are the goal. Repetitive manufacturing processing systems include automobile assembly lines and the production of television sets and computers. In the service sector, automatic carwashes and fast-food restaurants use repetitive processes.
- When very large volumes of a highly standardized product are to be produced, a **continuous flow process** is appropriate. Continuous flow processes are used to

TABLE 9.1: Five Process Types

Process Type	Description	Advantages	Disadvantages
Project	Process for producing a single product, often unique, and the process is of limited duration	Unique product tailored to the customer's specifications	High risk of cost and schedule overruns and subsequent customer dissatisfaction
Job-Shop	Process for producing a low volume of customized products and services	High product variety, low capital investment, and high process flexibility	High variable cost per unit, low capacity utilization, low production volumes, the need for highly skilled labor, careful production planning, and complex control
Batch	Process for producing semi-standardized products and services	Moderate product variety and process flexibility, and moderate production volumes	Production planning and control moderately complex
Repetitive	Process for producing standardized products and services	Low variable cost per unit, high-capacity utilization, high production volume, need for skilled labor low, production planning and control less difficult	Limited product variety, high capital investment, and low process flexibility
Continuous Flow	Process for producing highly standardized products and services	Very high volumes of production, and very high-capacity utilization and efficiency	Highly rigid process with no flexibility; costly to redesign and associated with high costs when the process is interrupted or down

produce sugar, chemicals, oil, beer, and steel and to generate power—output that typically can't be counted individually. This type of processing system is highly automated, often operating 24 hours a day, and the entire plant is devoted to the production of a single, highly standardized product.

Figure 9.1 is a matrix of the five types of processes; it ranks each process according to its product and service variety and the volumes produced. Note that when there is the need for a high product and service variety with low volumes of demand, a project or job-shop process is best. Conversely, when little or no product variety is required but high volumes are needed, the choice should be a continuous flow process. Process choice also depends on the product's stage in its life cycle. During the introductory stage of a product life cycle, demand is low and sporadic, and the product design may change several times. Hence, the appropriate process for it at this stage is a job-shop process. As the product or service enters the growth stage, the demand for it increases and it requires fewer design changes. Thus, a batch process may be appropriate for this stage.

Shifting from one production process to another is often difficult and expensive. A company may have to scrap its existing processes and start anew. For example, suppose fast-food restaurant KFC (subsidiary of Yum! Brands, Louisville, KY) wants to add the Indian delicacy tandoori chicken to its menu. This new offering would require many operational changes. The operations manager would need to decide whether to purchase additional ingredients such as lemon juice, yogurt, and a variety of spices; process the chicken by marinating it in these ingredients for at least 8 hours to get the right flavor; buy new equipment to bake the chicken in a tandoor, a bell-shaped clay oven; redesign the layout for the process and space in the kitchen for the new equipment; train employees to produce the new product; and so forth. This seemingly small product addition can lead to large process challenges.

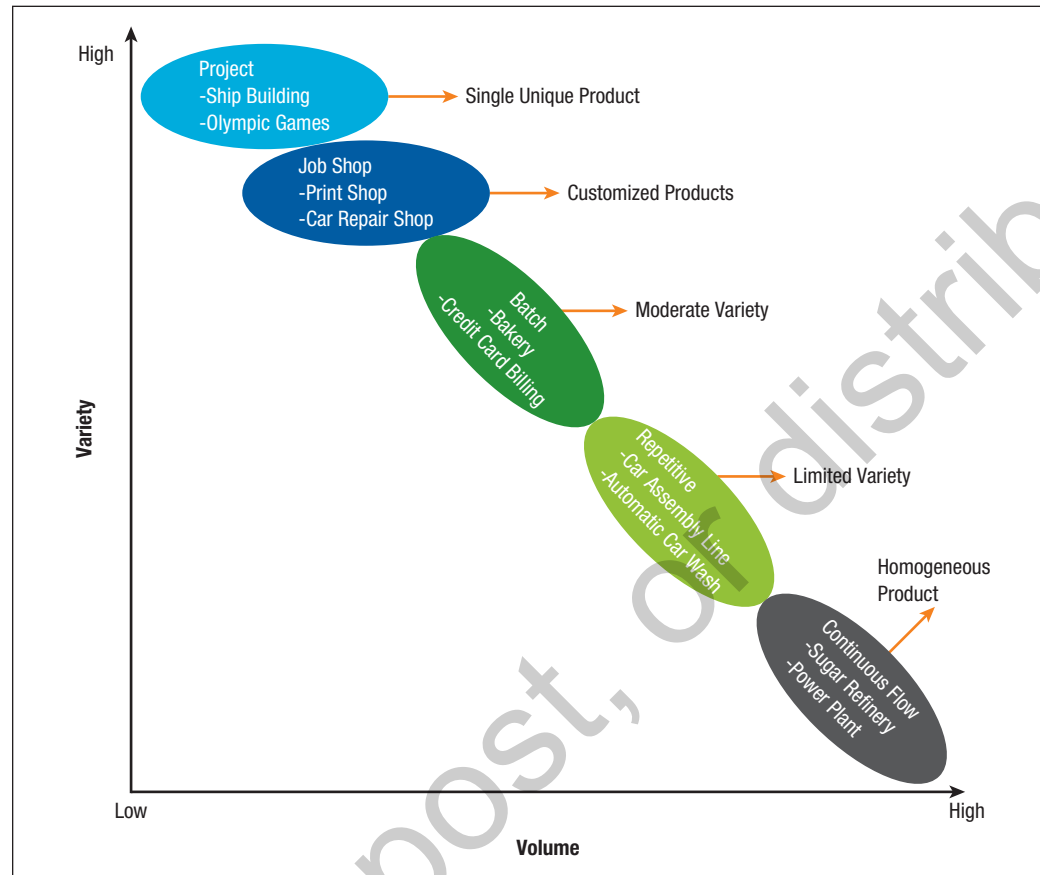
Batch process: a process that is selected to produce a moderate variety of products in moderate volumes in groups or batches

Repetitive process: a process that is selected when a high volume of standardized products needs to be produced

Why Process Design and Layout Planning Matters

Process design and layout planning are issues of strategic importance, enabling a company to produce and deliver goods or services in the most cost-effective way that satisfies customers' needs. They can also help the firm achieve its sustainability goals while accommodating technological and managerial constraints.

FIGURE 9.1: Product–Process Matrix: Process Choice as a Function of Product Variety and Volume



Mass Customization Processes

If a company's production process does not lie on the diagonal of options in Figure 9.1—that is, the process does not align with the volume and variety demanded of the product—then, generally speaking, the company made a bad process choice. Nevertheless, if the firm has designed an innovative process that combines the advantages of any two of the basic processes, then the company can gain a competitive advantage even though the newly designed process does not fall along the diagonal of options shown in the figure. Mass customization, which we introduced in Chapter 4, combines the advantages of job-shop and repetitive or continuous flow processes. A **mass customization process** allows a firm to produce customized products at the speed, volume, cost, and quality of a repetitive or continuous flow process. Dell Inc. (Round Rock, TX) uses a mass customization strategy to produce its computers to customer specifications but at mass production prices. There are several characteristics of mass customization. Let's look at them next.

Continuous flow process: a process that is selected when very large volumes of a highly standardized product are to be produced

Mass customization process: a process that allows a firm to produce customized products at the speed, volume, cost, and quality of repetitive or continuous flow process configurations

RAPID AND INNOVATIVE PRODUCT DESIGNING SYSTEMS

Achieving successful make-to-order product designs requires that companies use technologies such as computer-aided design (CAD) and rapid prototyping, which are design techniques we discussed in Chapter 5. CAD and rapid prototyping enable a company to come up with several versions of a product, sometimes in a matter of minutes. Using its website, customers of the Swiss-based shoe producer Bally (subsidiary of JAB Holding Company, Luxembourg) can specify design options, colors, and other details and then see the design of the shoes prior to ordering them.

FLEXIBILITY

Flexible processes are required for mass customization. To achieve this process flexibility, mass customization combines three production strategies: lean manufacturing, synchronous manufacturing,

and agile manufacturing. Lean manufacturing, which we have already discussed, allows a company to achieve efficient levels of high-volume, low-cost production. **Synchronous manufacturing** adds process flexibility by synchronizing customers' orders with the tasks performed at the various workstations. If the work done by the first workstation is on the first customer order, then the work done by the second workstation will also be on that first customer order, and so forth. This system allows the firm to produce a wide variety of products by using the job-shop process. Many products, including automobiles and lawn mowers, are produced this way. A mass customization strategy also uses agile manufacturing, which, as you may recall from Chapter 1, is the ability of an organization to respond quickly to market changes with a set of processes to produce high-quality products at a reasonable cost. For example, the Italian apparel manufacturer the Benetton Group (aka United Colors of Benetton, Treviso, Italy) delays the dyeing of its knitted garments until very late in the production process when it receives the most recent demand estimates for its garments. The strategy prevents Benetton from producing too many garments in colors customers do not want or too few garments in colors customers want.

RESPONSIVE SUPPLY CHAINS AND TIGHT INVENTORY CONTROL

Another key requirement for mass customization is to have an agile and responsive supply chain. The firm's supply chain partners have to realize that survival of the network depends on satisfying customers. Parts, materials, information, and decisions should flow through the company's supply chain network quickly and accurately. To keep tight control over inventory, the firm must know how much and what type of inventory exists in the pipeline so there are no unwanted or obsolete items in the supply chain. Many organizations have adopted enterprise resource planning (ERP) software, such as SAP (SAP SE, Walldorf, Germany) or Oracle (Oracle Corporation, Redwood City, CA), so they can receive constant updates on the status of their inventory in their supply chains.

Not every company can, or even should, produce products using a mass customization system. Yet, when implemented properly, it can give companies a competitive edge because they can meet customers' needs by offering them highly customized products in large volumes quickly and at reasonable prices. Table 9.2 lists some of the features, advantages, and disadvantages of mass customization.²

Process Selection Decisions

Selecting the right processes, or process selection, can give a firm a competitive advantage in terms of speed to market, responsiveness to customers, and cost savings. Nevertheless, process selection decisions can be expensive. Implementing them generally requires a substantial capital investment and significantly affects other downstream decisions such as the layout of facilities. In this section, we examine some of the strategic decisions operations managers have to make when selecting a production process.

ALIGNING PROCESS SELECTION DECISIONS WITH THE MARKET'S REQUIREMENTS

To avoid mismatches, operations managers need to understand how their firms' processes align with the needs of their markets. Consider, for example, the U.S. banking industry. After the

Synchronous manufacturing: a manufacturing strategy that adds process flexibility by synchronizing customers' orders with the tasks performed at the various workstations

TABLE 9.2: Features, Advantages, and Disadvantages of Mass Customization

Features	Advantages	Disadvantages
<ul style="list-style-type: none"> • Make or build-to-order • High- or low-volume production • Use of lean, agile, and synchronized manufacturing methods • Continuous flow work cells • Multiskilled and empowered employees 	<ul style="list-style-type: none"> • Customized products • Volume flexibility • Low cost • High quality • Highly flexible and responsive processes and equipment • Quick equipment changeover • Low inventories • Short lead and cycle times 	<ul style="list-style-type: none"> • High capital investment • Excess capacity • Requires unique operational capabilities • Can only be adopted by certain industries

SOURCE: Adapted from Rockford Consulting Group, Ltd. (2006). Mass customization. *RCG University*. Retrieved from <http://rockfordconsulting.com/mass-customization.htm>

financial-market meltdown of 2008, the federal government imposed new restrictions on bank operations. This changing set of market requirements increased regulatory pressure on banks (such as maintaining more liquidity and restricting loans to more credit-worthy borrowers), and it altered the way they competed and were able to satisfy their customers. Banks had to modify their lending practices and change the processes used to gather information to align these processes better with new market requirements.

Product profiling is a way to evaluate the alignment of the needs of a company's markets with its processes. Product profiling identifies the key product and service dimensions of a market to uncover misalignments that can occur over time.³ These dimensions include the product variety that customers want, the expected demand for the product, competitors' pricing and cost strategies, and the market's order-winning criteria. To see the benefit of product profiling, suppose that a company uses a job-shop process to produce a range of products to satisfy the order-winning criteria of quality and customization customers are demanding and that these products account for 35% of the company's sales revenue. Also assume the company is considering investing US\$40 million in its processes to target the market segment in which the order-winning criterion is price. Managers believe the firm could generate 20% of its total business sales to price-conscious consumers by doing so. To achieve this increase, the company would have to change the scheduling of its processes. This change in process scheduling could threaten its ability to meet the needs of its existing market segment—that is, customers who want quality, customized products, and who are willing to pay a premium for them. In a very short period of time, this investment, if made without careful analysis, could result in a manufacturing conflict. Had the company created a product profile prior to this process investment, it would have uncovered the mismatches between the existing and the new processes and the demands of the marketplace.

DETERMINING WHETHER TO USE IN-HOUSE PRODUCTION OR OUTSOURCING

Many parts and components go into manufacturing a product. Most companies do not have the capability to produce all of these parts and components. Therefore, a key decision companies have to make before selecting a process is to determine which parts and components will be produced in-house and which will be procured from an outside vendor. The decision of whether to manufacture a part or component in-house or to outsource it depends on the answers to the following questions.

1. *Do we have enough capacity to produce the component?*

A company may choose to manufacture a part or component or perform a service in-house rather than buy it from an outside vendor if it has enough idle or unused capacity. On the other hand, if the capacity available in-house is not sufficient to produce all of the components or to perform the service, then the company has to decide which parts or services should be outsourced and which should be done in-house. In general, if the demand for the product is highly variable or if it is a highly customized product or service, then the production of all parts or the service performed should be done in-house so the demand can be better managed. Producing the product or service in-house enables the company to have workers with the necessary skill levels available to produce products that meet customers' quality expectations. In contrast, outsourcing is a good alternative for highly standardized products that have a high and steady volume of demand.

2. *Do we have the core competencies to produce the component?*

If the company has the core competencies to produce quality products or services that give it a competitive advantage, then it should do so. The company can enhance the effectiveness of the product or service by focusing on what it does best. This decision is particularly true if the technology or competency is valuable and proprietary—that is, if the technology is only available to the company rather than widely available. Often, however, the components of a product are so highly specialized that they require special equipment or knowledge or a specific skill. In this case, an outside vendor or contractor can deliver a better product or service. For example, a company producing liquid natural gas (LNG) must transport it to other sites at extremely low temperatures (−260°F) in

Product profiling: a way to evaluate the alignment of the needs of a company's markets with its processes through identifying the key product and service dimensions of a market to uncover misalignments that can occur over time

extremely cold tanks. Many LNG producers contract with companies that specialize in manufacturing these tanks rather than make them themselves.

3. *Are our suppliers reliable?*

The decision to outsource depends to a large extent on the availability of suppliers that are reliable in the quality of the goods and services they provide and in their delivery. Delivery delays and poor quality shipments from suppliers can jeopardize a company's production process, and it is for this reason that some companies require their suppliers to meet quality and delivery standards, such as those specified by the International Organization for Standardization (ISO) 9000 standards (see Chapter 5).

4. *Does outsourcing entail significant risks?*

Buying goods and services from an outside vendor can be risky, particularly if the supplier is located in a foreign country. These risks include the loss of direct control over operations, the loss of proprietary information as a result of knowledge sharing, and the violation of intellectual property rights. Firms doing business in China have had problems with theft of intellectual property. Typically, the Chinese government requires Western firms to establish joint ventures with Chinese firms in the country. These joint ventures have led to numerous cases in which the Chinese partner appropriated the technologies and patents provided by the Western firm and then established its own company in China to compete with the Western partner, often with governmental support.⁴ In addition, the outsourcing company may lose goodwill and suffer damage to its reputation if the foreign supplier engages in unethical practices, such as the use of child labor. The human rights organization Amnesty International charged Apple Inc. (Cupertino, CA); Sony Corporation (Tokyo, Japan); and Samsung (Ridgefield Park, NJ) with child labor violations for purchasing cobalt ore from mines in the Democratic Republic of the Congo. Cobalt is a vital ingredient in lithium ion batteries, used to power many of these companies' devices. According to the reports, Congolese mines employ workers as young as 9 years old to fill the cobalt orders from these firms. Apple, Sony, and Samsung were charged with failing to conduct basic checks to ensure that minerals used in their products are not mined by children.⁵

5. *What are the costs of outsourcing?*

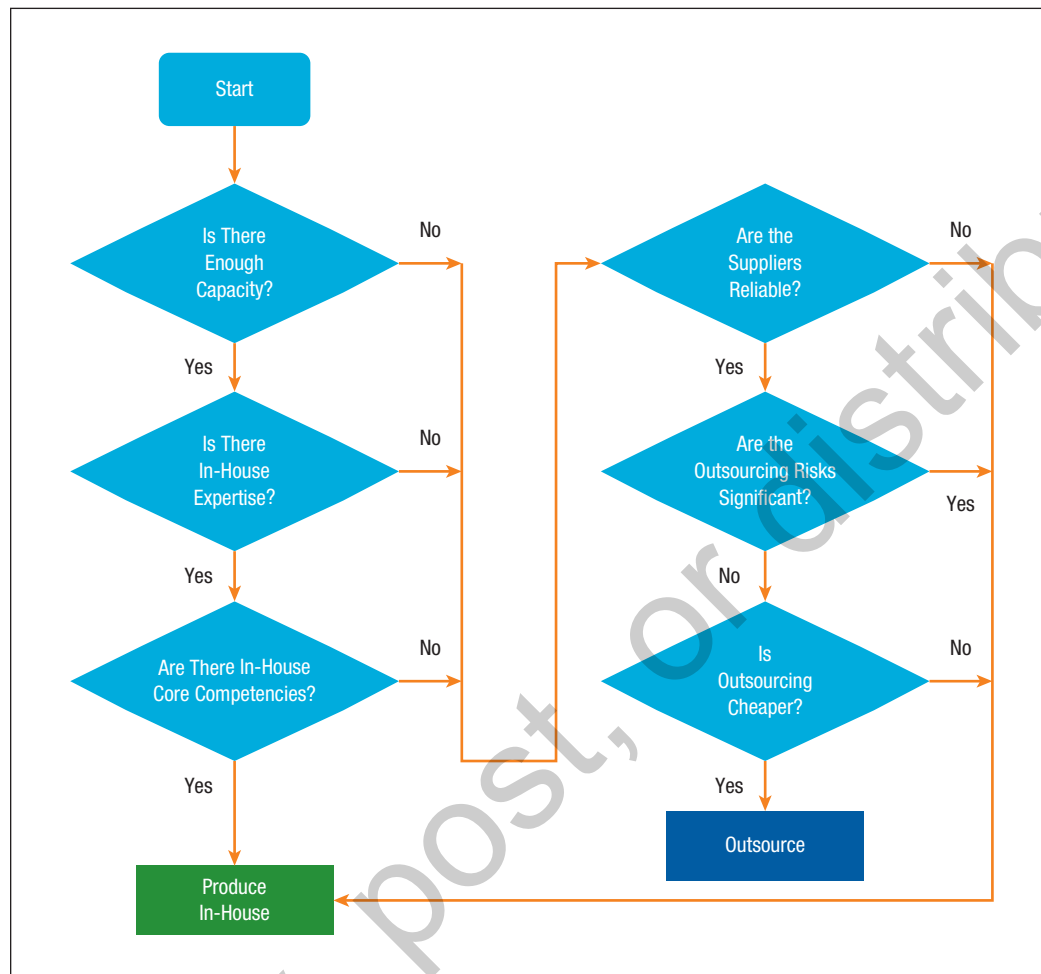
Although the cost of purchasing the item from an outside vendor includes the purchase price, transportation costs, taxes, tariffs, and so forth, the cost of in-house production includes labor, material, overhead, and inventory costs. In general, all other things being equal, outsourcing is a viable alternative if and only if the cost advantages of purchasing from an outside vendor are significant.

Figure 9.2 presents a decision framework that can be used to compare in-house production with outsourcing.

DETERMINING THE TECHNOLOGY AND EXTENT OF AUTOMATION NEEDED

Technological innovations can have a significant impact on how products and services are produced and delivered, their quality and costs, the firm's productivity, and whether the firm can achieve competitive advantage by adopting these innovations. Some examples of technological innovations include three-dimensional (3-D) printing; laser technology being used in surgical processes; digitized processes to collect and maintain patients' medical information; and the use of mobile data terminals (MDTs) in moving cabs, trains, and buses to improve communication among personnel and better manage transportation systems. The decision to integrate new technology in a production process should be made only after a thorough study of its advantages and disadvantages. Operations managers need to assess what the technology can and cannot do, the cost and time needed to implement the new technology, and its potential impact on the firm's existing human resource needs. For example, the firm may need to hire additional employees with different skills or train its current employees to use the technology.

The extent to which a firm's processes should be automated is closely related to technology. The most significant advantage of automation over human labor is the consistency of performance and quality. Unlike human labor, where there is high variability in performing the same

FIGURE 9.2: Decision Framework for In-House Production or Outsourcing

Fixed automation: the process of producing a product or component in a fixed sequence of operations

Flexible automation: the process of using high-cost, general-purpose machines to produce a variety of products in low volumes or in small batches

Numerically controlled (NC) machines: machines programmed with a specific set of instructions that tell the machines the details of the operations to be performed

Industrial robot: a versatile machine that can perform routine tasks such as cutting and boring, welding, assembly, and materials handling without any human intervention

Computer-aided manufacturing (CAM): an application of programmable automation in manufacturing processes that uses computer software and hardware to control machine tools and other related machinery

Computer-aided process planning (CAPP): a technological application that involves the use of computer technology to assist in planning the processes required to manufacture a part or product

tasks, machines perform these tasks repeatedly in the same amount of time and at the same general level of quality. Furthermore, unlike human resources used for labor, automated equipment does not suffer from fatigue or boredom, or go on strikes. Yet another advantage of automation is that it can reduce a firm's labor costs. Nonetheless, automation requires a firm's processes to be standardized, which makes it harder to produce a wide variety of products or customized products. Other disadvantages are the high initial cost of investing in automatic equipment, the high volumes of production needed to justify the investment, and the potential for decreased morale and productivity among workers who fear they may lose their jobs as a result of automation. Thus, the decision of whether to automate and by how much requires careful analysis.

Automation in manufacturing processes can be broadly classified into two types: fixed automation and flexible automation. **Fixed automation** is the process of producing a product or component in a fixed sequence of operations. This type of automation is appropriate for processes designed to produce large volumes of standardized products that have relatively long life cycles. For example, chemical companies and oil refineries use a fixed automated process. Fixed automation is highly efficient and produces products at a low variable cost. Yet, any major redesign of the product or the existing process will be very expensive. It could require purchasing new equipment or having to reconfigure the firm's factory.

Flexible automation evolved from *programmable automation*. High-cost, general-purpose machines are used to produce a variety of products in low volumes or in small batches. These machines are controlled by computer programs that provide instructions for the sequence of operations to be performed on each product. The ability to reprogram these machines to handle

varying degrees of product customization is the major advantage of this type of automation. Numerically controlled machines and industrial robots are examples of programmable automation. **Numerically controlled (NC) machines** are programmed with a specific set of instructions that tell the machines the details of the operations to be performed. The most common NC machines are milling machines, lathes, and grinders. NC machines are used to produce products such as industrial components. An **industrial robot** is a versatile machine that can perform routine tasks such as cutting and boring, welding, assembly, and materials handling without any human intervention. Most of the millions of industrial robots around the world are used to produce automobiles and metal and machinery products, electrical and electronic products, and rubber and plastic items.⁶ The advantage of using robots in manufacturing processes is that they can perform many of the difficult tasks such as heavy lifting, and dirty, repetitive, and dangerous jobs. Yet another application of programmable automation in manufacturing processes is **computer-aided manufacturing (CAM)**, which uses computer software and hardware to control machine tools and other related machinery. In modern computer NC systems, CAM, along with CAD (computer-aided design), is used to automate end-to-end component design and manufacture. CAM is used in various major industries such as silicone manufacturing, tanning, dairy, and beverage manufacturing. **Computer-aided process planning (CAPP)** is another technological application; it involves the use of computer technology to assist in planning the processes required to manufacture a part or product. CAPP provides a link between product design and manufacturing.

A more advanced application of flexible automation is a flexible manufacturing system. A **flexible manufacturing system (FMS)** is a processing method that can produce parts, allow changes to be made to products being manufactured, and handle varying levels of production.⁷ Many of The Ford Motor Company's (aka Ford's, Dearborn, MI) plants use FMS not only to improve efficiency but also to introduce new models of cars quickly. In a dynamic manufacturing environment, an FMS can increase a firm's manufacturing efficiency and reduce the downtime of its equipment. The biggest drawback of an FMS is the high initial cost of developing it because it requires firms to acquire sophisticated equipment and machinery.

The complete automation of the manufacturing plant can be accomplished using **computer-integrated manufacturing (CIM)** technology, in which a manufacturing plant uses computers to control all processes. CIM can be used with computer-aided design and manufacturing (CAD and CAM), computer-aided process planning (CAPP), NC machines, robots, FMS, and in different combinations of these processes, all of which are fully integrated. CAD and CAM are particularly important because they greatly facilitate the automation of product designs and manufacturing processes through the use of computer software. Dassault Systèmes SE (Vélizy-Villacoublay, France), for example, provides CIM software technology for aerospace customers like The Boeing Company (Chicago, IL) and Airbus SAS (Blagnac, France) to allow them to evaluate different design alternatives for their aircraft prior to full production. Although CIM can allow a firm to produce and deliver high-quality, customized products quickly and efficiently, it has some drawbacks. For example, the complexity of CIM manufacturing operations requires fully integrating all equipment, some of which may not be compatible with others.

Table 9.3 lists some other advances in technology that have improved productivity and efficiency for processes in both the manufacturing and service sectors. These technologies have been applied in a wide variety of areas, such as process control, materials handling, transportation, and patient care in hospitals.

Flexible manufacturing system (FMS): a processing method that can produce parts, allow changes to be made to products being manufactured, and handle varying levels of production

Computer-integrated manufacturing (CIM): a technological application in which a manufacturing plant uses computers to control all processes



A mobile data terminal such as the one shown in this police car is a computerized device that includes a screen and a keyboard. It is used in public transit vehicles, taxi cabs, police cars, and so forth as a means to communicate with the central dispatch office.

ddpphotos340872/NEWSCOM

TABLE 9.3: Examples of Advances in Process and Manufacturing Technologies

Technology	Description	Applications
Standard for exchange of product, model data (STEP)	An ISO standard for representing and exchanging the design and manufacturing-related information of a product in computer-interpretable format.	A Eurofighter designed by four industry partners using STEP technology to exchange product design and manufacturing data. ⁸
Computer-aided process planning (CAPP)	The use of computer technology to assist in planning the processes required to manufacture a part or product. Provides a link between product design and manufacturing.	CAPP can be used to link a product's design with the machines and tools used in the production process. ⁹
Automated storage and retrieval system (ASRS)	A computer-controlled system that uses various methods for the automatic placement and retrieval of loads to and from specific storage locations within a warehouse.	Automated storage and retrieval systems are useful in situations that require controlled access to high-value and sensitive materials that need to be stored and retrieved in harsh environments that may be hazardous to workers. ¹⁰
Automated guided vehicles (AGVs)	Electronically guided mobile vehicles are directed by wires or markers embedded on the floor or by radio frequencies, vision, or lasers to move materials in manufacturing, warehousing, and service facilities.	AGVs are used in many industries in the manufacturing sector for efficient, cost-effective movement of materials and for improving operations in many manufacturing facilities and warehouses.

Automated storage and retrieval systems are useful in situations that require controlled access to high-value and sensitive materials that need to be stored and retrieved in harsh environments that may be hazardous to workers.

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ANALYZING AND REDESIGNING PROCESSES

Markets change over time, and a process that once worked well may no longer achieve the firm's goals, particularly if the firm participates in global markets. It often is necessary to reexamine a process to determine whether it can be improved to make it more cost efficient or more responsive to customers. In some cases, the process may need to be entirely redesigned. Changes in the process may also be necessary to accommodate new product mixes or to integrate new technologies. To determine when it is time to redesign a process, the operations manager must answer questions like these:

- Does the existing process give the company a competitive edge in terms of the order-winning criteria of cost, quality, flexibility, and delivery time?
- Are there redundant steps or steps that do not add value in the process that can be eliminated?
- How can the process be improved or redesigned to enhance value provided to the customer?

Several tools can help an operations manager answer these questions and analyze a firm's processes. Many of these tools, such as process charts and assembly charts, are discussed in more detail in the supplement to this chapter. Table 9.4 contains a brief overview of them. A more comprehensive discussion of value-stream mapping, yet another useful process analysis tool, is presented in Chapter 9S.

TABLE 9.4: Tools for Process Analysis and Redesign

Tools	Description	Uses
Assembly drawing	An enlarged view of the product that has a detailed listing of all parts and subassemblies	Enables the user to understand how various parts of a product can be put together quickly and easily
Assembly chart	A step-by-step pictorial representation of the assembly process	Facilitates the assembly of a product through a well-defined sequence of steps
Process route sheet	A document that describes the sequence of different operations, places, or people involved in a process	Enables anyone to see all of the details of a work or customer order
Process mapping	A graphical technique that shows all process-related activities, including inputs and outputs, decision points such as approvals and exceptions, and any cross-functional relationships	Provides an integrated and unifying view of business processes so that all stakeholders have a clear understanding of the individual roles they play in the overall system
Value stream mapping (VSM)	A process mapping technique used to analyze and design the flow of materials and information across multiple processes required to bring a product or service to a consumer	Enables a process analyst to identify activities that do not add value so they can be eliminated to reduce waste and improve efficiency
Process simulation	A technique that uses computer software to provide a dynamic view of the actual process	Enables a process analyst to estimate the variability of task times and explore several what-if scenarios without changing or disrupting the actual process
Service blueprinting	A technique used to analyze service processes, particularly those that have high service content and require customer interaction, such as hospitality services, teaching, and counseling	Enables a service provider to focus on customer interaction as an integral part of the design process so that overall service quality can be improved

9.2 Designing Service Processes

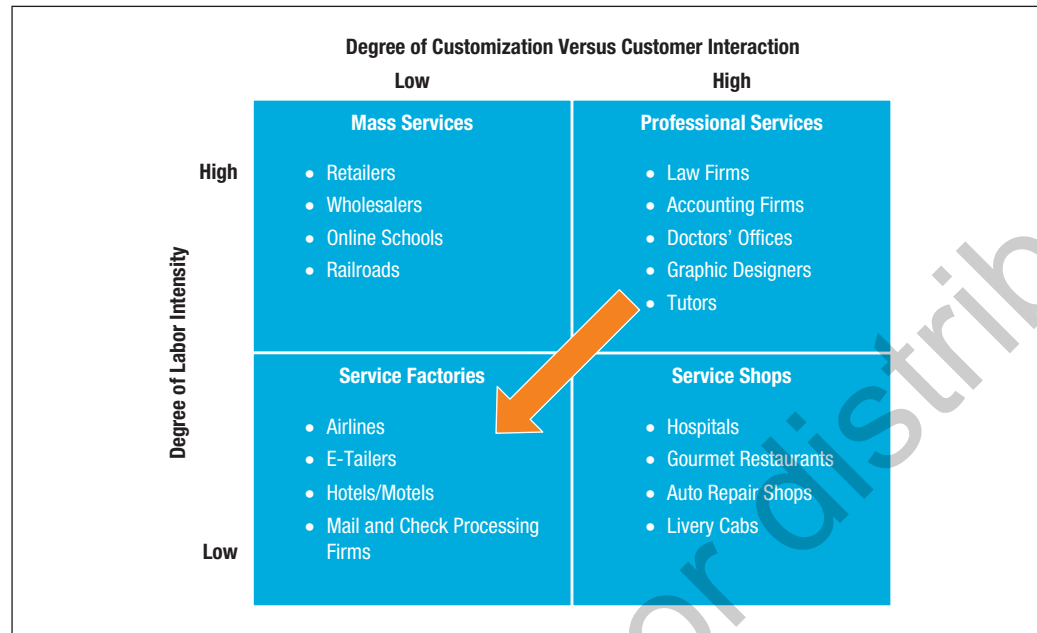
To design processes for services, the operations manager must understand the degree of customer interaction when performing the service and customization needed to satisfy the customer. Although service operations managers prefer to offer standardized services to reduce their firms' costs, customers prefer customized services that address their unique needs. Nonetheless, firms are also aware that customers value services they perceive as being tailored especially for them. High-end retail stores such as Saks Fifth Avenue (subsidiary of the Hudson's Bay Company, New York, NY); Neiman Marcus (Dallas, TX); and Nordstrom, Inc. (Seattle, WA) adopt this customized approach by employing personal shoppers to work directly with customers to find the most flattering colors and styles of clothing for them. The approach these firms use differs from the standard displays of clothing on racks that many retailers use. This trade-off between customers' expectations and service providers' desire for efficiency is what makes the design of service processes challenging. The better a company is at bridging this gap, the more competitive it will be.

9.2
List the unique features in the design of service processes.

Classifying Processes Within the Service Process Design Matrix

The service process design matrix shown in Figure 9.3 classifies from high to low various service processes in terms of their degree of customer interaction and customization and their degree of labor intensity. The degree of customer interaction is the extent to which the customer can participate in the service process. For example, a high degree of interaction means the customer can tailor the service provided by demanding more or less of some aspects of the service. Customization is the need and ability to alter the service so the individual customer's needs and expectations can be met. The degree of labor intensity is the labor time and effort required in comparison with the use of equipment or automation. A service process that uses a high level of automation, such as an ATM machine, with very little labor time and effort has a low degree of labor intensity.

Figure 9.3 includes examples of service processes that fall into each quadrant. The lower left quadrant, labeled *service factories*, contains service processes that have a low degree of labor intensity, customer interaction, and customization. This quadrant is similar to the repetitive assembly and continuous flow processes of goods-producing firms shown in Figure 9.1. Service firms in

FIGURE 9.3: Service Process Design Matrix

SOURCE: Schmenner, R. W. (1986, Spring). How can service businesses survive and prosper? *Sloan Management Review*, 212.

this quadrant operate like factory assembly lines, employing cheaper, unskilled labor and taking advantage of economies of scale. Service processes that have a low degree of labor intensity but a high degree of customer interaction and customization are shown in the lower right quadrant, labeled *service shops*. Livery cabs, hospitals, auto repair shops, and high-end restaurants fall into this quadrant. The upper left quadrant, labeled *mass services*, contains service processes that have little variety but high volumes. Not only is customization of the service to meet the individual needs of customers negligible, but also there is often limited contact between the customer and the service provider. Yet, the high volume of service requires high labor intensity. Examples of these processes include rail services, the services offered by retailers and wholesalers, and online schools. Finally, those service processes that have a high degree of labor intensity and a high degree of customer interaction and customization fall in the upper right quadrant labeled *professional services*. This quadrant is similar to the specialized job-shop and batch processes in the goods-producing industries shown in Figure 9.1. Doctors' offices, law and accounting firms, graphic designers, and tutors are examples of professional services.

We can use Figure 9.3 to determine how an organization can best design its service operations by finding the best combination of labor intensity (customer interaction) and customization for its needs. By drawing a diagonal arrow from the upper right corner to the lower left corner as Figure 9.3 shows, we can infer that processes requiring high levels of customer interaction and customization, such as professional services, or processes that involve a high degree of labor intensity experience high variability and, therefore, are less productive than standardized operations.

Positioning and Repositioning Processes Within the Service Process Design Matrix

Organizations can use the service process matrix to position their services relative to their competitors. Consider Nordstrom. Even though Nordstrom's service process falls into the mass services category, the company has made a conscious effort to position itself more toward the right of that cell (toward the professional services cell) by having highly trained Nordstrom employees personally interact with each customer to meet his or her unique needs and expectations.

Similarly, most hotels belong in the service shop category. Nevertheless, because the labor intensity and customer interaction is very high at luxury hotels such as the Red Carnation Hotels UK

Ltd. (London, U.K.), its service process lies on the border between the service shop and professional services categories. The process was not created by accident. The values of Red Carnation include giving “personalized, warm and consistently exceptional service” and creating “positive, memorable experiences for every guest.” If guests have a problem or need something special, the hotel’s highly trained employees are empowered to do whatever it takes to resolve the situation immediately, even if they have to break away from their regular duties. Clearly, given its mission and value set, Red Carnation did not want to belong to the service factory category and made a strategic decision to position itself toward the service shop and professional services category.¹¹

Managers can also use the service process matrix to understand the effect of a strategic change intended to reposition the firm’s operations. For example, assume that for competitive reasons a firm in the service factory category wants to move into the service shop category. To implement this strategic change, the firm will need to provide a higher degree of customer interaction and customization as well as manage higher costs that arise from the loss of economies of scale, which was an advantage the company had by being in the service factory category. Furthermore, moving to a service shop requires higher labor skill levels that add to the cost of providing service. Also, the span of supervision in a service shop tends to be wider. Hence, the firm’s managerial hierarchy needs to be flatter and less rigid.¹²

By contrast, to reduce the variability of its output and improve its productivity, a service firm might want to move the other way—down the diagonal in Figure 9.3 toward the service factory category. That is, the firm might want to decrease the degree of customer interaction and customization it provides along with the labor intensity of its processes. Over the past decade, many law firms have increased their television advertising to seek clients interested in will preparation, bankruptcy, and uncontested divorces. The law firms have chosen these tasks because these are standard cases requiring minimum customization, and a law firm can handle many of them in a single trip to the courthouse. It is a way for the law firm to replace customized services with standardized services. Banks that rely on ATMs for routine transactions and warehouse stores such as Costco (Costco Wholesale Corporation, Issaquah, WA) and Sam’s Club (Sam’s West, Inc., a subsidiary of Walmart Inc., Bentonville, AR) are examples of other service firms that have shifted their service processes toward the service factory category through significant reductions in labor intensity.

Even hospitals whose service processes traditionally belong to the service shop category have moved toward the service factory category. Consider, for example, the Hospital for Special Surgery in New York City, which specializes only in the diagnosis and surgical and nonsurgical treatment of musculoskeletal conditions. The hospital offers standardized services, which allow it to be run more like a service factory. Managers of service firms moving in this direction face several challenges. They must make capital decisions such as choice of plant and equipment, manage costs, keep track of technological advances, carefully manage demand, and schedule the delivery of services because services can’t easily be inventoried.¹³

Many other service businesses have also attempted to reposition their processes in relation to the service process matrix. For example, to achieve efficiency, some restaurants, which have traditionally fallen in the service shop quadrant because of their high degree of customization and customer interaction, have moved to the service factory quadrant typified by the fast food industry. In contrast, some fast food restaurants have moved away from the service factory model to one that allows for a limited amount of product customization and more variety of products to choose from. For example, the McItaly menu introduced in Italy by McDonald’s (Oak Brook, IL) consists of hamburgers made with all Italian meat and features Italian products such as extra virgin olive oil; parmesan cheese; bresaola (low-fat dried beef, sliced thinly and eaten cold); ham; artichokes; onions; and pancetta. The McItaly Marchigiana, for example, was introduced for the Marche region in Italy, and it includes locally sourced, fresh mozzarella cheese.¹⁴

Using Technology to Improve Service Processes

Advances in technology have improved service processes. Using the right technology can help firms improve the quality of their services, provide them more quickly and efficiently, and offer them at a lower cost. Voice recognition and call-routing technologies have improved service processes by directing the potential service consumer to the right department or employee who can address the customer’s needs. In addition, “live chat,” which is available on many websites, enables you to



Self-checkout lines are a win-win proposition: They give shoppers the flexibility to choose how they want to checkout and provide merchants with efficiencies and cost savings.

Bloomberg/Bloomberg/Getty Images



Designing Service Processes

9.3

Defend the reasons that it is important for companies to synchronize their internal processes with the external processes of their supply chain partners.

must employ at the service site. Customers uncomfortable with these innovations or who want the human touch can use regular checkout lines. Colleges and universities have embraced technology in their process of educating their students. By offering online classes, they provide students the flexibility and convenience of how and where they want to learn. Thus, the schools can educate students with smaller investment in physical plant (classrooms) and staff.

Technology has also enabled service firms to provide critical and timely information to their customers. Internet ticketing sites such as Orbitz, Travelocity, and Expedia (all three of which are owned by Expedia, Inc., Chicago, IL) have enabled airline companies to sell tickets directly to customers and scale back their ticketing phone lines. Mobile or smartphone apps remind fliers of departure, check-in, and arrival times, as well as notify them of flight delays. Through the use of the Internet, telephone, and social media, customers now have more efficient ways of requesting or ordering the products or services they want. In the final analysis, regardless of the technology used, the key objective is to use technology to simplify service processes so that they are easy to use and improve the service experience.

“talk” to a customer service representative instead of waiting endlessly on hold or waiting for an email reply. A tangible benefit of such technologies is that there is less delay in service delivery, thus saving the service firm time and money.

One of the most important benefits of recent advances in technology is that service processes have become more flexible. Customers now have the option of choosing how the services they want should be delivered. For example, self-checkout lines in retail outlets or ticketing kiosks at airports enable customers to get the services they want without interacting with the employees of the service organization, thus saving the customer time and allowing the service firm to reduce the number of employees it

9.3 Designing Processes for Supply Chains

To provide the customers with high-quality products and services at the lowest possible cost, and at the locations most convenient for customers, companies need to design their individual internal processes in ways that maximize the performance of their supply chains. In effect, companies need to not only synchronize their individual internal processes but also link up with the external processes of their supply chain partners. For example, a well-synchronized supply chain process for canned soup will produce and deliver defect-free cans of soup in the right quantities and at the right time to all grocery stores and supermarkets. In this section, we focus on designing a manufacturing process that is synchronized across the supply chain.

Classifying Manufacturing Processes by the Degree of Product Customization

Companies need fast and flexible manufacturing processes that can adapt quickly to change. To achieve this objective, the different manufacturing processes should be integrated across a customer-focused supply chain. In a manufacturing supply chain, depending on the type of product, different processes link multiple supply chain partners. Consider the processes in the supply chain for making shirts. First, yarn, which is a standardized product, is manufactured using a continuous flow process. The yarn manufacturer at this stage in the supply chain sells its products to a downstream weaving firm. The second step in the supply chain consists of another continuous flow process: weaving the finished yarn into fabric using looms. A manufacturer further down the chain then finishes the fabric by cutting it into patterns and sewing it into sweaters. Note that the cutting and

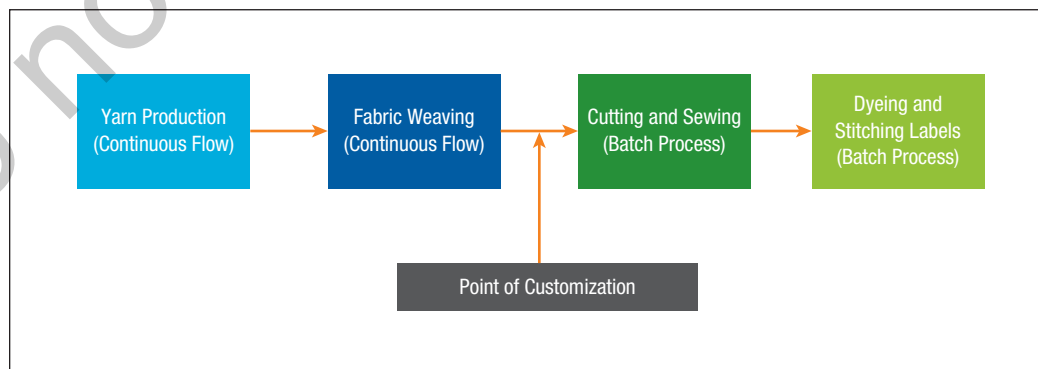
sewing portion of the supply chain is more labor intensive, and a batch-type process is used to make different types and quantities of sweaters. Before being packed and shipped, the manufacturer may use more batch processes to customize the sweaters even more, such as dyeing them and stitching different labels on them. Figure 9.4 illustrates the use of different manufacturing processes in a supply chain.¹⁵ The product customization begins after the fabric weaving process.

The basic types of customization occurring within manufacturing supply chains can be classified into four categories:

- **Make-to-stock (MTS):** This type of manufacturing method is used for products that typically require little or no customization, are produced in large volumes, and are stored as inventory for future use. They include crude oil; chemicals; and many consumer products such as sugar, flour, and salt that are sold in retail stores.
- **Make-to-order (MTO):** In this method, products are manufactured only after receiving a customer's order. A combination of standard and custom-made components is used to make the product, but its final configuration is specific for the customer. High-end automobiles, such as a Ferrari (Ferrari S.p.A., Maranello, Italy) or Porsche (Porsche AG, Stuttgart, Baden-Württemberg, Germany); engagement rings; wedding invitations; custom-built homes; and custom-tailored clothing are examples of products manufactured using this method.
- **Assemble-to-order (ATO):** In this process, the basic parts and components of a product are standardized, have already been manufactured, and are kept in stock. After receiving an order, these parts are quickly assembled based on the customer's requirements. This method is a hybrid of the MTS and MTO methods because it combines the advantages of both. Customization occurs at the last stage of the manufacturing process, and even then the degree of customization is still limited. By focusing on enhancing their information processing, General Electric (aka GE, Fairfield, CT) is creating more than 400 "brilliant factories," which allow customization and assembly-to-order manufacturing in a wide range of products, from locomotives to oil extraction machinery. Other examples of products produced using the ATO method include many automobiles, specialty chemicals, and sports t-shirts with team or organizational logos.
- **Engineer-to-order (ETO):** This process offers the highest degree of product customization. In the ETO method, products are designed, manufactured, and assembled to the customer's specifications from start to finish. ETO products include industrial equipment, tools, molds and dies, power generation equipment, custom signs, boats, and specific types of medical equipment.

As the matrix in Figure 9.5 shows, the four manufacturing methods can be categorized along the dimensions of demand variability and production complexity. Demand variability means there are likely to be modifications or multiple variations in the output produced by the manufacturing process. Production complexity refers to the complexity and time involved in producing the product.

FIGURE 9.4: Manufacturing Processes in the Supply Chain for Shirts



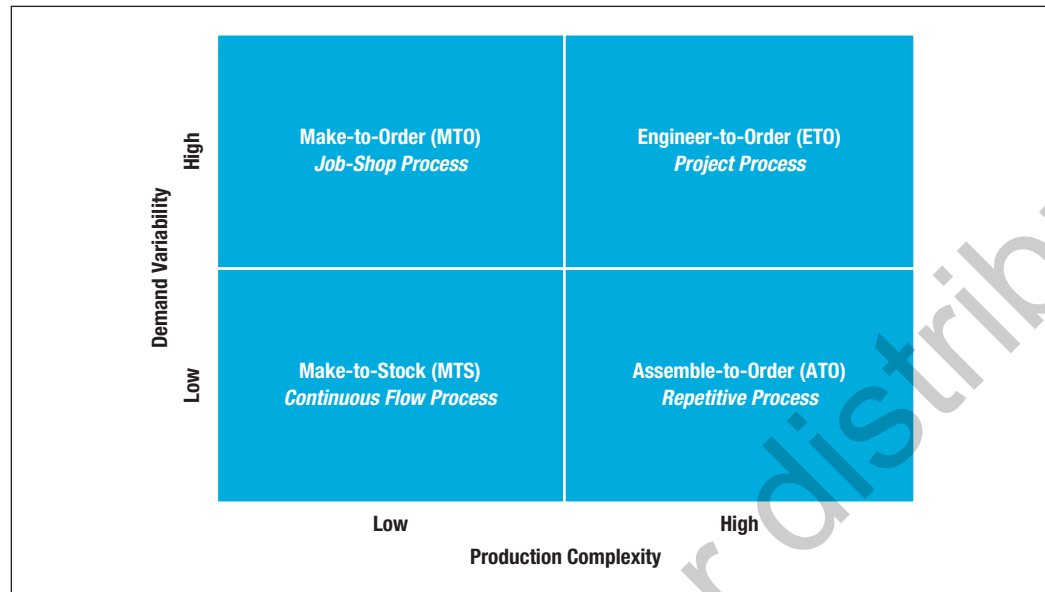
SOURCE: Adapted from Bozarth, C. C., & Handfield, R. B. (2013). *Introduction to operations and supply chain management* (3rd ed., p. 44). Englewood Cliffs, NJ: Pearson Prentice-Hall.

Make-to-stock (MTS): a manufacturing method used for products that typically require little or no customization, are produced in large volumes, and are stored as inventory for future use

Make-to-order (MTO): a manufacturing method in which products are manufactured only after receiving a customer's order

Assemble-to-order (ATO): a hybrid of the MTS and MTO methods in which the basic parts and components of a product are standardized, have already been manufactured, and are kept in stock until an order is received, when they are quickly assembled based on the customer's requirements

Engineer-to-order (ETO): a method in which products are designed, manufactured, and assembled to the customer's specifications from start to finish

FIGURE 9.5: Mapping Process Types to Manufacturing Methods

SOURCE: Adapted from Flores, H. (n.d.). *Manufacturing strategy: An adaptive perspective*. White paper. Montreal, Quebec, Canada: Technology Evaluation Centers. Retrieved from <https://www.technologyevaluation.com/research/white-paper/Manufacturing-Strategy-An-Adaptive-Perspective.html>

Mapping Manufacturing Methods Across Supply Chains

The manufacturing methods—MTS, MTO, ATO, and ETO—that a company within a supply chain should choose depend on factors such as the competitive business environment; the proliferation of products, customers, and distribution channels; and demand variability. To respond to all these factors, companies often use a mixture of these manufacturing processes; that is, they find the best blend of manufacturing processes. For example, Dell’s mass customization strategy is a hybrid of job-shop and repetitive processes. This combination allows Dell to offer unique products to its customers as quickly as possible.

Before we apply the various manufacturing methods to a supply chain, let us look at two manufacturing systems companies usually rely on—systems we will discuss in more detail in Chapter 14. A *push manufacturing* system is one in which production is based on forecasted demand or projected sales. Demand is often forecast using historical data or past trends; for example, manufacturers in many industries accelerate production to coincide with periods of high demand. Air conditioner manufacturers gear up for peak sales in the spring and summer. Companies that produce highly standardized products with relatively low demand variability and production complexity use push manufacturing systems with the goal of maximizing their capacity. MTS manufacturing processes are often a part of push systems.

In contrast, when the demand for a product is highly variable or its production is complex, companies often use a *pull manufacturing* system, which is based on actual customer orders rather than on demand forecasts. Ford Australia, for example, produces cars only after it receives an order from the customer. An MTO manufacturing process is often a part of a pull system. Supply chains that use pull manufacturing systems have the capacity and flexibility needed to produce a variety of products in an environment with variable demand.

Most companies use a mixture of push and pull manufacturing. As firms grow and expand their product lines, the variability in the demand for their products increases as does their production complexity. As a result, it becomes more difficult for companies to rely exclusively on either push or pull manufacturing systems. The hybrid manufacturing practices are also reflected in their supply chains. That is, certain portions of a supply chain rely on push manufacturing, whereas other portions rely on pull manufacturing methods.

The firm must determine which combination of push and pull systems best enables it to combine efficiency and customer responsiveness in their supply chains. As more companies embrace mass customization, they have to determine which portion of the supply chain can be managed using

a push approach and which portion works best as a pull system. The interface between the two is called the **push–pull boundary** or **decoupling point**.¹⁶ This is the point where customization occurs, splitting the supply chain into the distinct pull and push parts. Figure 9.6 shows how manufacturing processes use the decoupling point to divide the supply chain.¹⁷

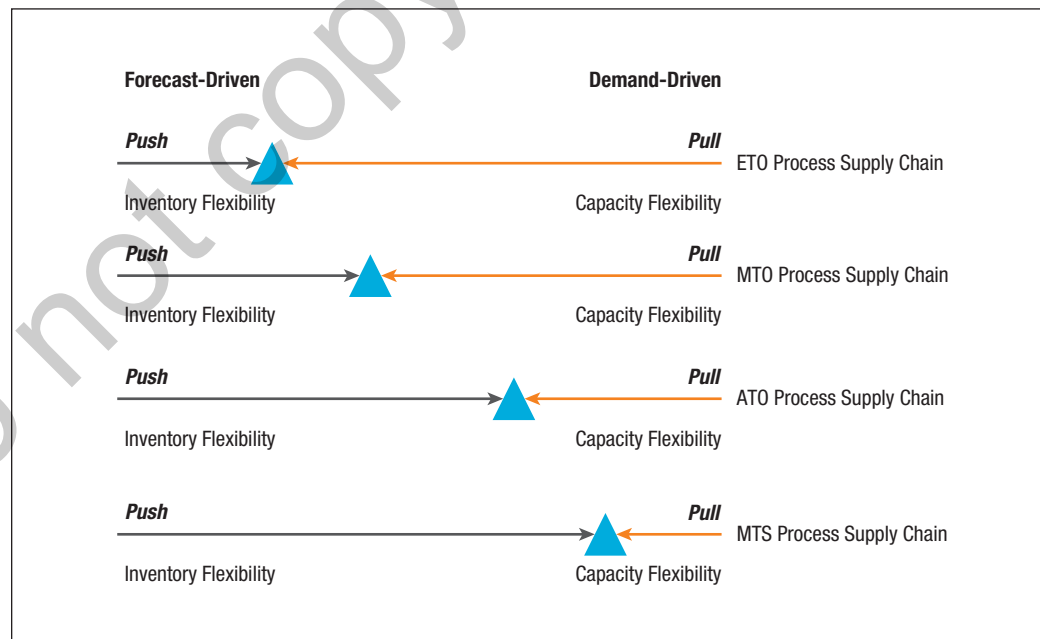
The decoupling point is also often referred to as the **point of postponement (POP)**.¹⁸ The POP is the point that divides the supply chain into the supplier side and the customer side. Push systems are aimed at gaining maximum efficiency by managing and streamlining the supply chain, whereas pull systems are intended to satisfy the demands of customers. The exact point where decoupling or the POP occurs depends on the type of manufacturing process (MTS, ATO, MTO, or ETO). The POP point is

- the point at which the variability in the demand for the product increases significantly.
- the point that denotes the longest lead time the customer will tolerate.
- the point of trade-off between inventory flexibility and capacity flexibility.

The supply chain process for companies that operate in an MTS manufacturing environment is completely forecast based, and it begins with the acquisition of raw materials and ends with the creation of finished goods. The firm takes customer orders and delivers products to them from the inventory in stock. The key supply chain challenge in this process is to maintain inventory flexibility because demand has to be met from inventory in stock. When the push influence on the MTS supply chain increases, there is a greater need for inventory flexibility, and the POP occurs further down the supply chain, as Figure 9.6 shows.

Figure 9.6 also shows that when there is greater demand variability for a product and more customization is needed, the firm should use ATO and MTO processes. Therefore, the pull influence on the supply chain is also stronger and greater capacity flexibility is needed. That is, the supply chain must be prepared to handle fluctuations. Work-in-process (WIP) inventory is often used as a buffer to increase the chain's flexibility to respond to demand changes. Items in WIP inventory are partially finished and waiting for work to be completed on them, or they are finished goods that have not yet been packaged and inspected. WIP inventory may also contain raw materials that have been

FIGURE 9.6: Determining Manufacturing Processes Based on the Decoupling Point in a Supply Chain



Push–pull boundary: the interface between the parts of a supply chain that can be managed using a push approach and the parts that can be managed as a pull system

Decoupling point: See push–pull boundary

Point of postponement (POP): the point that divides the supply chain into the supplier side and the customer side

SOURCE: Adapted from Flores, H. (n.d.). *Manufacturing strategy: An adaptive perspective*. White paper. Montreal, Quebec, Canada: Technology Evaluation Centers. Retrieved from <https://www.technologyevaluation.com/research/white-paper/Manufacturing-Strategy-An-Adaptive-Perspective.html>

moved to the production area. In a computer manufacturing company, many of the components such as the processor or printed circuit boards may be initially stored as work-in-process inventory. Subsequently, when a customer order for a computer is received, these WIP items are assembled in specific configurations to meet customer requirements. Whenever there is a high degree of product variety, as in MTO and ATO processes, the breadth and volume of WIP are also high.

The amount of WIP inventory determines where the POP occurs in the supply chains that use MTO and ATO processes. In an ATO process supply chain, the volume of WIP inventory is higher and occurs farther down the supply chain (closer to the finished product) than in an MTO process supply chain. In an ATO process supply chain, because the degree of customization is high and the volume of WIP inventory held as buffer is low, the POP occurs further upstream than in a MTO process supply chain.¹⁹

Finally, with the ETO manufacturing process, supply chain activities, such as ordering raw materials, production, etc., are triggered only after a firm customer order is received because the degree of customization is very high and occurs very early in the supply chain. Consequently, the POP occurs much farther upstream in the supply chain. Industries that have ETO process supply chains include aerospace and defense, capital equipment, and specialized machinery industries.

The careful design or redesign of production processes can enhance the performance of a supply chain. Strategies such as combining different processes and resequencing production operations to shift the POP can provide important benefits. First, shifting the POP enables companies in the supply chain to make production decisions after first getting more accurate estimates of the demand for a product, which then reduces the need to carry unnecessary inventory. Second, it enables the supply chain to be more responsive while keeping costs low. For example, the hybrid strategy that characterizes mass customization helps supply chains produce and deliver unique products, often with minimal increases in lead times. Benetton, the Italian clothing manufacturer, benefited from shifting its POP. By delaying the dyeing of its knitted garments until late in the production process, Benetton was able to respond rapidly to changes in customer demand for different colors of clothing. This postponement strategy not only made Benetton's supply chain highly adaptable and responsive, but it also created superior customer value.



Processes and the Supply Chain

9.4

Describe the unique challenges involved in designing global processes.

9.4 Global Process Design

Companies with global operations have to answer the following three questions when designing their production processes:²⁰

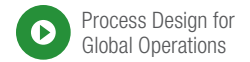
1. If the company is producing similar products in several plants located in different countries, should the company be using similar processes in all locations to produce these products?
2. If the company decides to use similar processes, how should they be designed?
3. If the company decides to produce new products that satisfy the unique needs of the consumers in a given country, then what should be the design of these new processes?

Companies that operate production facilities in a foreign country have to redesign their products to varying degrees to suit the needs of the local market. This high degree of variability makes mass customization necessary. The most important factor influencing sales is fulfillment speed; cost, quality, and availability are secondary. To increase how fast they can respond to customers, companies use concurrent engineering to integrate their product and process designs and collaborate more closely with their supply chain partners. Firms also use **adaptive manufacturing**, which combines lean and agile manufacturing with flexible manufacturing systems to adapt production in response to changing market conditions. Adaptive manufacturing relies on technology to create hybrid manufacturing processes, which may include MTS processes. In an adaptive process, the POP is flexible and can be adjusted to employ techniques of all manufacturing processes, such as MTS, ATO, MTO, and ETO.

With annual sales of US\$150 billion and projected steady increases for the next decade, the jewelry industry remains strong and highly profitable. Adaptive manufacturing allows jewelry makers to shift their focus constantly from customized, individual pieces of expensive jewelry that are created on an MTO basis to more generic rings or brooches that can be made with a wider, MTS

Adaptive manufacturing: a process that combines lean and agile manufacturing with flexible manufacturing systems to adapt production in response to changing market conditions

approach. The result is to allow jewelry manufacturers the broadest flexibility for responding to the newest trends in the industry, including unbranded jewelry and online, special-order shopping.²¹ This example illustrates the advantages of using an adaptive manufacturing strategy and a hybrid approach to capitalize on flexible processes and supply chains.



Process Design for Global Operations

9.5 Layout Planning

A **layout** describes the physical arrangement of work and storage areas, departments, or equipment within the confines of some physical structure such as a plant, office, warehouse, or service facility. A typical manufacturing facility has some or all of the following components: front area, production area, warehouse, shipping and receiving, maintenance and production support, and employee services and amenities. Warehouses may have their own shipping and receiving, maintenance, and employee services areas. All of these have people, equipment, and materials traveling and interacting with each other. Layout planning decisions involve arranging these components for new facilities and rearranging them in existing facilities. The goal is to arrange people, equipment, materials, and processes so the work flows smoothly and rapidly at all times. Other goals of layout planning are the following:

- Achieving the appropriate product or service quality
- Eliminating waste through the efficient use of workers and space
- Eliminating bottlenecks in product or service flows
- Minimizing material and manufacturing costs
- Eliminating the movement of materials, workers, and customers that do not add value to the product or service
- Improving productivity
- Maximizing the utilization of production capacity
- Reducing accidents and health hazards to ensure employee safety
- Reducing customer waiting times
- Making supervision and control easier

9.5
Construct the different layout types, identifying their features in the design.

The Strategic Nature of Layout Decisions

Layout decisions are strategic decisions because they affect the cost and efficiency of manufacturing and warehouse operations or, in the case of a service facility, the efficiency and quality of the customer service. In addition, firms often decide to change their layouts to respond more rapidly to market opportunities or to correct or improve operating efficiencies. Another reason the decisions are strategic is that an organization has to make a significant commitment of money, time, and effort when building a facility or when making changes to it—requiring planning, analysis, testing, and verification as well as the purchase of new machinery. Sometimes, operations have to be suspended until the new layout is completed, equipment installed, and workers trained to operate within the new layout. Moreover, mistakes made in the layout planning and implementation process cannot be easily rectified, and any problems will take time to emerge and correct.

Basic Types of Layouts

There are many different types of layouts. We will first discuss the three basic layout types: process, product, and fixed-position, and then we will describe alternatives.

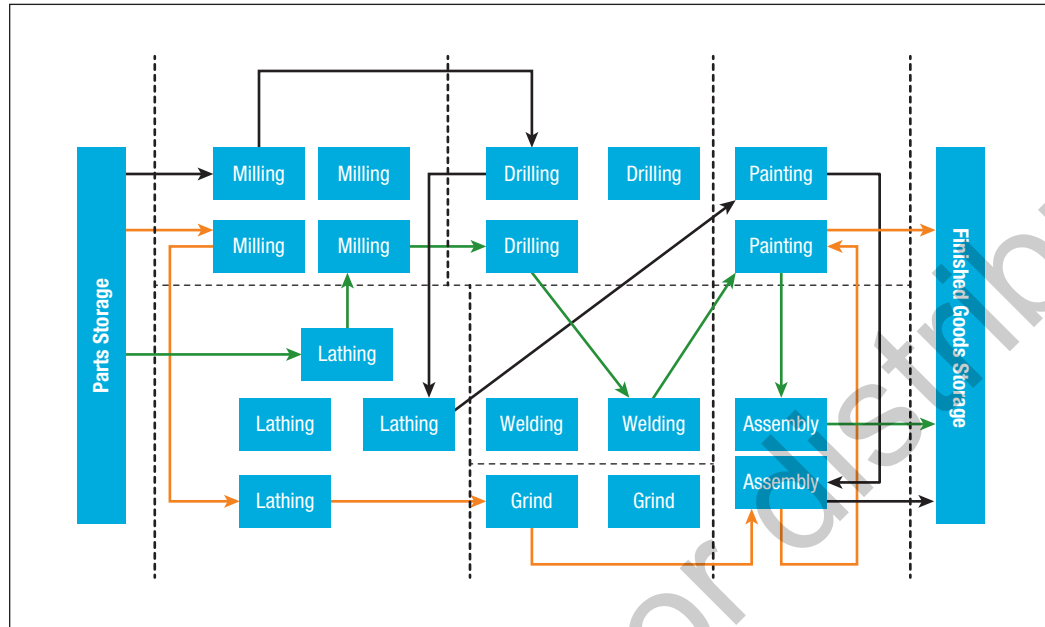
PROCESS LAYOUTS

A **process layout**, often referred to as a functional layout, is used when a firm produces low volumes of products using job-shop or batch production processes. A process layout enables the firm to meet the different needs of a variety of customers. Similar activities or machines in work centers or departments are grouped together based on the type of work or function they perform. Machines performing lathing operations are located in the lathing department, machines performing drilling operations are grouped in the drilling department, casting operations are in another location, and so on. The physical arrangement of departments in a process layout has no set sequence because the sequence of operations required to complete an order varies from customer to customer. Figure 9.7

Layout: the physical arrangement of work and storage areas, departments, or equipment within the confines of some physical structure such as a plant, office, warehouse, or a service facility

Process layout: a layout type used when a firm produces low volumes of products using job-shop or batch production processes, often referred to as a functional layout

FIGURE 9.7: Process Layout for a Manufacturing Facility

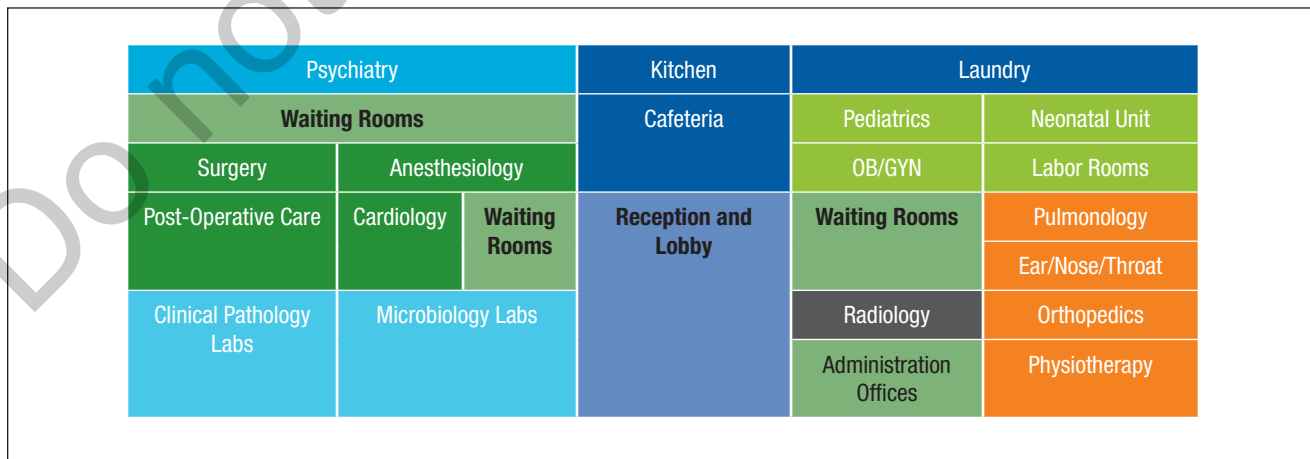


shows a process layout for a manufacturing facility. Although the machines are grouped into departments, the principal focus is on making special orders for each customer. One order may go directly to the milling department and then proceed to drilling, welding, painting, and so forth. Another order may first be sent to the lathing department and then directly to painting for final finishing before being assembled. Although equipment is organized into departments, the actual process flow is not uniform but varies from product to product.

Many service facilities also use process layouts. Figure 9.8 shows a process layout for a hospital. Notice how similar it is to the job-shop process for manufacturers. The arrangement is like that for a manufacturing process in the sense that it is based on the work done in each department. In a hospital, each patient receives customized treatment in a sequence that is unique to the patient's problem. So, for example, a patient enters the hospital and, after registering, is directed to the different departments that will administer treatment.

The biggest advantage of a process layout is that it allows a firm to treat each order as a special case, enabling the firm to process a variety of customer orders. The biggest disadvantage is its relative inefficiency. It is common for jobs to queue up on the department floor at various points

FIGURE 9.8: Process Layout for a Hospital



because processing or service times will vary from job to job or from customer to customer. These variances make it difficult to schedule workflows because companies must work on one order at a time, each of which has its unique characteristics and production or service requirements.

PRODUCT LAYOUTS

A **product layout**, also referred to as a *straight-line layout*, works well for repetitive or continuous flow processes used to produce a highly standardized product with high and constant demand. The machines or work centers are arranged according to a predetermined sequence of operations needed to produce the product. Materials enter the system at the first work center at one end of the line, and finished products come out from the last work center at the end of the line. In between, partly finished goods travel automatically from one work center to another, and the output of one work center becomes the input for the next. For example, if you visited a sugar factory, you would see that raw sugar cane fed in at one end of the mill comes out as refined sugar at the other end. Figure 9.9 shows a product layout for a sugar factory. A similar layout can be observed in a paper mill. The wood pulp is fed into the first work center and eventually comes out as paper at the other end.

The biggest advantage of a product layout is that high levels of efficiency and capacity utilization can be achieved. Product layouts can also provide a sort of closed system that works well if the production is highly automated and the product being produced cannot be contaminated, such as when pharmaceuticals are being manufactured. The greatest disadvantage of the layout is its inflexibility because it is built for a single purpose. Any change in the design of the product or significant increases or decreases in demand will require a complete redesign of the layout.

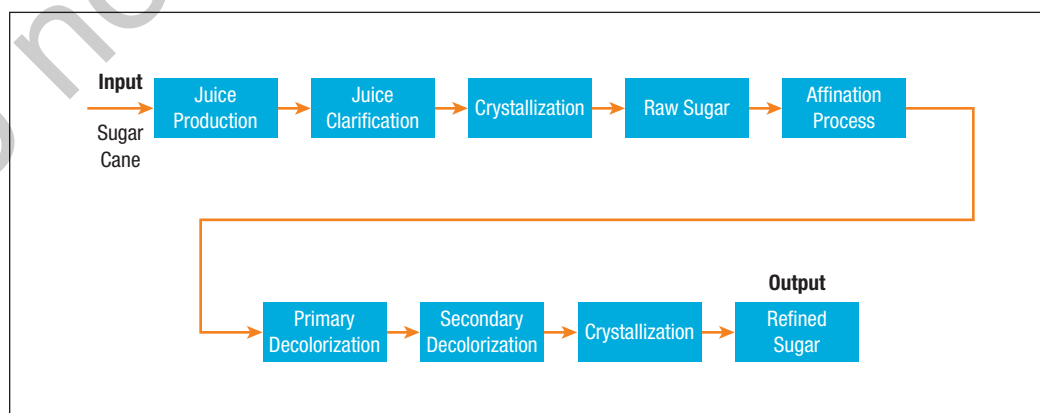
When increased communication and teamwork among workers on the shop floor is needed, then a **U-shaped layout** like that shown in Figure 9.10 is better than a product layout. Many household appliances such as blenders, coffeemakers, and toaster ovens can be produced using a U-shaped layout. A U-shaped layout is an improvement over the straight-line layout because it is more compact, which minimizes the handling of materials. It is also more flexible because workers can handle jobs in multiple workstations. In addition, U-shaped layouts allow workers, material handlers, and supervisors to have an unobstructed view of the entire line and to travel efficiently between workstations because there are typically fewer walls and partitions in a U-shaped layout. Research has also shown that under certain conditions, U-shaped layouts can significantly improve the labor productivity of assembly line processes.²²

FIXED-POSITION LAYOUTS

In a **fixed-position layout**, the product remains stationary in the plant. The resources such as workers, materials, machines, and tools needed to produce the product are brought to the product's location. This type of layout works well for project-type processes such as shipbuilding and house construction in which the product produced is bulky or fragile. It requires less time and money to move the resources to the product's location than to change the location of workstations.

Table 9.5 presents the features, advantages, and disadvantages of process, product, and fixed-position layouts.

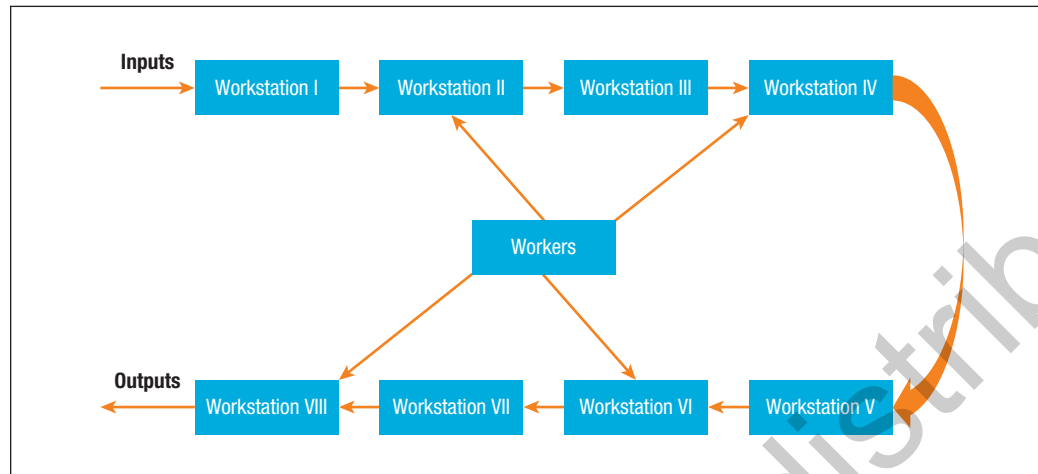
FIGURE 9.9: Product Layout for a Sugar Factory



Product layout: a layout type used for repetitive or continuous flow processes used to produce a highly standardized product with high and constant demand, also referred to as a straight-line layout

U-shaped layout: a compact layout in the shape of a U that allows workers to handle jobs in multiple workstations, gives workers an unobstructed view of the entire line, and allows workers to travel efficiently between workstations

Fixed-position layout: a layout type in which the product remains stationary in the plant

FIGURE 9.10: U-Shaped Layout**TABLE 9.5:** Features, Advantages, and Disadvantages of the Three Basic Types of Layouts

Layout	Features	Advantages	Disadvantages
Process Layout	<ul style="list-style-type: none"> High product variety with low volumes of production can be handled. General-purpose equipment and skilled workers can be used. No predetermined sequence of operations because each job has its unique sequence. 	<ul style="list-style-type: none"> Flexibility. Low fixed costs because general-purpose equipment is used. Job variety motivates workers. The availability of multiple machines reduces the impact of equipment failure. 	<ul style="list-style-type: none"> Managing queues of WIP inventory is challenging because jobs to be completed have to wait for the workstation to be available. Relatively inefficient because idle workers and equipment cause low-capacity utilization. The variety and volume of WIP inventory require large amounts of storage space. High levels of WIP inventory generate high-variable costs. Frequent setups cause high setup costs. Job complexity results in large supervisory costs. Accounting, purchasing, and inventory control are complex.
Product Layout	<ul style="list-style-type: none"> Sequential production because of the highly standardized nature of the product. Adaptable to high and constant product demand. 	<ul style="list-style-type: none"> High efficiency and capacity utilization. Straightforward and routine accounting, purchasing, and inventory control. Low supervisory costs because of the low complexity of jobs. High volumes of production lead to economies of scale and low variable costs. Job specialization and reduced training result in low labor costs. 	<ul style="list-style-type: none"> The inflexible layout makes product and process redesign difficult. High capital investment is needed for the highly specialized equipment. Low employee morale because the jobs are boring and routine. Risk of idle labor and equipment time if the equipment breaks down.
Fixed-Position Layout	<ul style="list-style-type: none"> Product is large, bulky, heavy, or fragile and cannot be easily moved. Production is based on a project type of process. Resources such as labor and equipment are brought to the project site. Project completion time and product quality are critical. 	<ul style="list-style-type: none"> Most useful when the product is unique and requires a specialized project type of process. 	<ul style="list-style-type: none"> Limited space can cause the worksite to be crowded and clogged. High variable costs because of the need for specialized workers. Low equipment utilization, idle time, and cost overruns can occur if there are unexpected project delays. The narrow span of supervision and higher administrative burdens result in high supervisory costs.

Other Types of Layouts

In addition to the more popular manufacturing layouts discussed to this point, some additional layout types combine characteristics of the ones previously covered, offer a degree of flexibility in that they can be modified to address specific manufacturing requirements, or relate to service operations.

HYBRID LAYOUTS

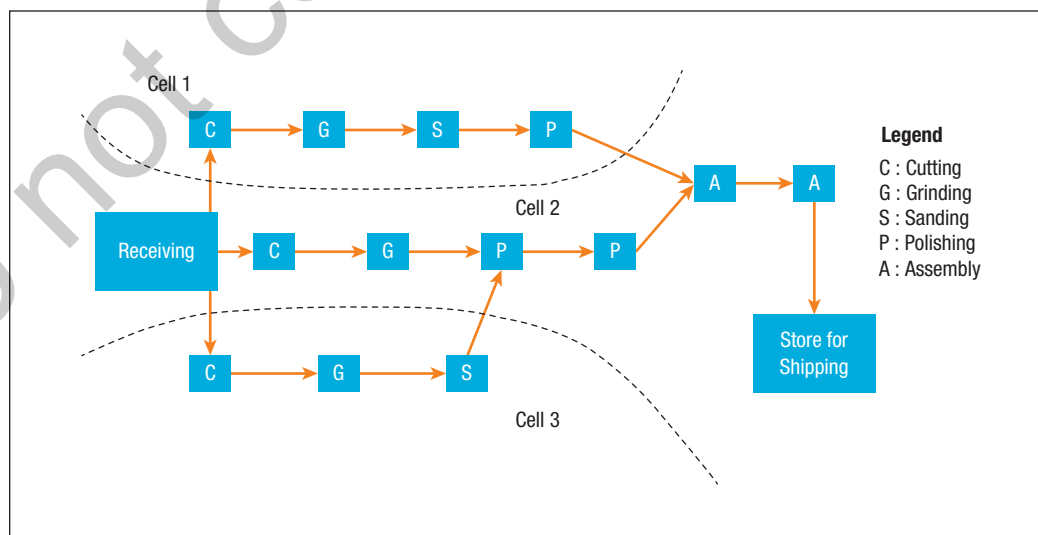
Hybrid layouts, also known as *combination layouts*, combine the advantages of the three basic layout types. For example, although hospitals typically use process layouts, they may frequently use some aspects of the fixed-position layout by bringing the doctors, nurses, medical equipment, and medicines to the patient. Similarly, supermarkets and grocery stores predominantly employ a process layout. Nevertheless, by using fixed-path equipment such as conveyors in stockrooms and at the cash registers, the stores combine some aspects of a product layout. Many manufacturers use hybrid processes with layouts that combine the advantages of both process and product layouts. Manufacturers that use flexible manufacturing systems, as discussed earlier in the chapter, typically rely on hybrid layouts.

CELLULAR MANUFACTURING LAYOUTS

A popular hybrid layout is a **cellular manufacturing layout**. Cellular manufacturing layouts are based on the principles of **group technology (GT)**, a parts coding and classification system in which parts or products with similar characteristics are grouped into families. The families of parts are distinguished by shape, size, or similar manufacturing or routing requirements. A typical cell in this type of manufacturing process is a self-contained production unit (within the larger plant) that is completely responsible for producing a product or process. Figure 9.11 shows a cellular layout. Notice how, unlike a process layout, the milling isn't all done in one area, the lathing in another, and so on. Instead, these functions are done in different cells, which are each responsible for producing different parts or products.

Cellular layouts can improve materials flows significantly because the operations needed to produce a family of parts are done entirely in a small cell, thereby eliminating the need to transport in-process parts to other areas of the factory. In addition, grouping products with similar processing requirements into a cell minimizes machine setups and changeovers. Cellular manufacturing also allows a company to modify the cells more easily to create new parts or products.

FIGURE 9.11: Cellular Layout



Hybrid layout:

a layout type that combines the advantages of the three basic layout types, also known as a combination layout

Cellular manufacturing layout:

a popular hybrid layout in which a self-contained production unit (within the larger plant) is completely responsible for producing a product or process

Group technology (GT): a parts coding and classification system in which parts or products with similar characteristics are grouped into families

Finally, each cell has a significant amount of operational autonomy because the work done within it is contained. The cell's workers are able to perform multiple processes, and they are responsible for making quality improvements, reducing waste, and maintaining the equipment in the cell, which reduces boredom and increases motivation. Because employees are empowered in this way, lead times and inventory can often be reduced and the number of workers required to complete the tasks is kept to a minimum. The net result is that cellular manufacturing layouts give a company flexibility and the ability to produce small batches of high-quality products at a low cost.²³ Cellular manufacturing has some disadvantages:

- For products that are highly customized, require high precision work, or are produced in low volumes, cellular layouts won't result in smooth and efficient workflows.
- For processes that require expensive equipment with low utilization, cellular layouts are not cost effective.
- Given different sequences of operation in a cellular layout, it is more difficult to balance the flow of work than it is with a single-product assembly line.
- Job rotation is a key element of cellular manufacturing, but workers might not be motivated to acquire the different skills needed. Furthermore, as cellular layouts require teamwork, there is a potential for personality conflicts among team members.
- It doesn't work well if a product has many components that can be assembled quickly or requires only one operation, or if the entire product cannot be assembled or completed within the manufacturing facility. For example, many consumer goods and automobile manufacturers prefer an assembly line rather than cellular manufacturing.

SERVICE LAYOUTS

To meet the different needs of their customers, hospitals, supermarkets, restaurants, banks, and law offices often use process layouts. Yet, service companies can use the other basic layout types. For example, landscaping and home-repair businesses use fixed-position layouts by bringing resources needed for the jobs to the customer's site. Similarly, services such as automated carwashes, dinner buffets, and school cafeteria lines use a product layout.

Despite their similarities to manufacturing layouts, different factors have to be taken into consideration when planning service layouts. One is the physical surroundings, known as the **servicescape**, in which a service is assembled and delivered and the seller and customer interact.²⁴ When laying out facilities, the right ambience and décor should be used to increase the satisfaction of customers. For example, Starbucks (Starbucks Corporation, Seattle, WA) has deliberately created a servicescape that mimics a homey, comfortable atmosphere, with Wi-Fi, couches, and comfortable décor. Patrons can sit and get work done or leisurely enjoy their coffee.

WAREHOUSE LAYOUTS

Warehouse layouts need to be designed with clearly defined objectives that align with a firm's overall corporate strategy. The objectives can be as broad as minimizing warehouse costs or maximizing customer service. They can also be as specific as maximizing the use of space and increasing flexibility or increasing warehousing efficiency without adding more resources. Operations managers need to analyze information that affects the warehouse's operations as compared with the firm's objectives. If the analysis shows the objectives can be met, then the next step is to create a detailed plan for the warehouse.

The detailed plan should map out all of the warehouse's functions, such as receiving and shipping, case picking, pallet storage, broken case picking, and packing, and correctly link them together. In the process, questions such as the following need to be asked:

- Is the warehouse large enough, or should more square footage be added?
- How much of the process can be (or should be) automated?
- Does the warehouse provide efficient paths for the movement of personnel and material handling equipment, such as forklifts?
- How many loading bays are needed?
- How many racks and storage structures must be installed?
- Where should products be stored?

Servicescape: the physical surroundings in which a service is assembled and delivered and the seller and customer interact



OPERATIONS MANAGEMENT: LESSONS LEARNED: *Facing Declining Sales, Subway Redesigns Its Stores*

Subway was one of the fastest growing fast-healthy restaurants in the United States, with steady sales increases from year to year and dozens of new stores being opened annually. In fact, Subway has more outlets than any other restaurant chain in the world, including McDonald's. Founded in 1965 in Bridgeport, Connecticut, Subway made a distinctive niche for itself with a retro-themed store décor combined with custom-made sandwiches with all fresh meats and vegetables. As Americans became more health-conscious, eating at Subway was seen as a popular and smart choice. That successful run ended in 2014, when the company experienced its first sales decline. Unfortunately, over the resulting 3-year period, sales levels did not improve and have, in fact, fallen by 11.3%. For 2016, U.S. sales fell an additional 1.7% to \$11.3 billion, marking the third straight annual decline. In 2017, industry analysts predicted a fourth consecutive year of revenue declines amid slumping sales. Subway responded by closing hundreds of locations, marking the biggest retrenchment in its history.

Subway's problems include increased competition from fast-healthy rivals like Jersey Mike's, Panera, Chipotle, and Five Guys. Competitors have lured away Subway customers with sleeker layouts, modern features, shrewd marketing touting locally sourced ingredients, and fast turnover, according to the analysts. Adding to the competition, a historic level of food deflation has made grocery-store meals relatively cheaper and easier to choose as an alternative. Critics also suggest the store layout at the average Subway, unchanged in nearly 20 years, has simply become an outdated, uninviting atmosphere in which to eat.

Subway has responded with a series of steps intended to upgrade its restaurants and enhance the dining experience for customers. Among the changes it is making are the introduction of brighter colors, sleeker furniture, and better lighting, all in an attempt by the company to improve guest experience. Subway conducted market research on its stores and found that while

lunch traffic is heavy, with most customers preferring to grab and go rather than stay and eat, at other times of the day (in the early mornings, afternoons, and evenings), diners are more likely to sit and linger over their meal. To accommodate these customers, Subway's new stores are incorporating cell phone charging stations and Wi-Fi in their dining spaces so that folks will be more inclined to remain in the restaurant.

As part of the redesign, Subway's new restaurants will now also incorporate a vegetable display behind the counter. While the chain has been cutting its vegetables in the restaurant for more than 50 years, their market research determined that the average customer had no clue that Subway stores did all their own fresh produce prep work at the location. The company wants to reemphasize the freshness of its ingredients.

Another major change as part of Subway's big redesign is the decision to embed more technology into the in-store experience. The company has added digital ordering kiosks to these stores so that customers who are in a rush don't have to wait in line to design their perfect sandwich. By immediately choosing their sandwich options on the touchscreen monitor, customers can cut down on the time to give specific directions to the employee. Subway is also introducing a mobile app, which includes a sandwich-customizing feature, and is testing the idea of having a dedicated pickup area for mobile orders, further moving away from the five-decade-old format of its restaurants.

These changes are in their early stage of development, and while some argue they are a long time in coming and were necessary to update the restaurant's image, franchisees are not thrilled that they are expected to bear the cost of the redesigns rather than the company. Still, regardless of who pays for the process changes and store redesigns, the majority of industry analysts applaud the changes and expect they will have an impact on stemming sales declines, with customers eager to become reintroduced to the sleeker, more tech-friendly stores.²⁵

Generally, items ordered more frequently are placed in the most convenient storage area, typically in the front of the warehouse. For example, a tire warehouse will store its most popular brands and sizes of tires where they are more easily accessible. Infrequently ordered items are typically stored in the rear of the warehouse or away from the busiest flow areas. Many modern warehouses use a procedure called **cross docking** to save warehouse space and minimize materials handling. With cross docking, materials from incoming transportation carriers are unloaded, and instead of storing them in the warehouse, they are directly loaded on outbound carriers intended for different destinations.

Cross docking: a process in which materials from incoming transportation carriers are unloaded and directly loaded on outbound carriers intended for different destinations

In addition, warehouses use different methods of storage and materials handling for different products, which can include liquid, minerals, and agricultural products. For products such as these, the layout should be designed to accommodate bulk material handling equipment such as conveyor belts, elevators, or silos. The layout should also be flexible to accommodate current and future business needs, such as anticipated growth, the adding of new functions including office support personnel, the adding of future loading docks, and providing for sufficient truck parking space.²⁶

The resources allocated to implementing the layout and the estimated start and finish time for completing it need to be determined as well. For example, if the firm decides to use robots in the warehouse, it is first necessary to lay out tracks for the robots before pouring concrete for the floor. The next step is to ensure all changes made in the warehouse are reflected in the warehouse management system. Modern warehouse management systems use automated storage and retrieval systems (ASRS). Walmart, for example, uses sophisticated ASRS technology that transmits point-of-purchase information directly from stores to the firm's warehouses, where shipments are then arranged for transport to replenish the stock at the stores. Suppliers get the same information so they can begin manufacturing new products, which are then shipped to the warehouse. In this way, the ASRS links every stage of the supply chain: Retail purchases trigger warehouse shipments, which in turn signal suppliers to manufacture and ship more products to the warehouse. A well-designed ASRS adds value and decreases costs by saving space and increasing the efficiency of warehouse operations.

The last step is post-implementation review. The new layout should be reviewed to determine the design is working and there are no operational problems that have occurred as a result of the new layout.²⁷

OFFICE LAYOUTS

There are two common types of office layouts: *traditional* and *cubicle*. A traditional office layout has offices with walls and doors to reflect the status of employees in the organization's hierarchy, reduce noise, and maintain privacy. In a cubicle layout, rows of cubicles are separated by aisles to facilitate communication among the cubicles' occupants. Many office layouts now have low-rise partitions instead of walls to separate offices. Office layout considerations are safety, facilitation of teamwork, and maximization of working conditions, all of which are applicable to both factory and service layouts.

Many modern offices have adopted an **open office layout** design to leverage the power of modern technologies such as laptops, Wi-Fi, and the Internet. An open layout opens up the traditional workplace by lowering or eliminating cubicle walls to facilitate more interaction and collaboration among colleagues and relocating private offices to provide everyone in the workplace access to a window view. The open layout also takes advantage of mobile technology by creating alternative workspaces in alcoves, bistro areas, lounges, cafeterias, and outdoor plazas. The benefits of an open office layout include more efficiency, higher productivity, increased flexibility, and collaboration. In addition, many modern offices now have cubicles that don't have permanent occupants. Instead, employees work at home and come in and work in unassigned cubicles when they need to.

RETAIL LAYOUTS

Most retailers use process layouts. The primary objective of the layout is to increase sales and profitability by increasing the customer's exposure to as many products as possible. To increase potential sales, a good retail layout employs aisle spaces that allow customers to move around easily and browse the entire store. This maximizes the amount of time the customer spends in the store and the opportunity for potential sales. In addition, retailers typically locate high-selling and high-profit items in the periphery of the store or in prominent locations to attract customers who initially may not want to venture into the store or off of the aisles. Lighted display cases can be used for expensive items to discourage theft and draw customers' attention to the displays. Other strategies to increase exposure include placing products with high profit margins on shelves at eye level or at the end of the aisles where they will be easily seen.

RESTAURANT LAYOUTS

A restaurant layout should be designed to help customers enjoy their dining experience and facilitate the movement of customers and restaurant staff. Service quality is a primary determinant of satisfaction. Other important layout considerations are the following:²⁸



Office Layouts



Retail Layout Design

Open office layout: a layout type that opens up the traditional workplace by lowering or eliminating cubicle walls; relocating private offices; and taking advantage of mobile technology by creating alternative workspaces in alcoves, bistro areas, lounges, cafeterias, and outdoor plazas

- *Entrance.* The entryway is made as attractive as possible because this is the part of the restaurant that customers see first. Open floor plans and room to meet guests and mingle help promote a positive first impression.
- *Waiting and Dining Areas.* The waiting and dining areas should have comfortable seats along with menus that customers can browse. The goal is to minimize wait times or provide a setting where customers can enjoy themselves while waiting. Many sports bars, for example, put television screens in waiting areas to distract customers. The atmosphere of the dining area typically emphasizes the restaurant's image; for example, fine dining uses soft lighting, music, and elegant features to reinforce customers' impressions.
- *Bar.* The bar area provides for the efficient flow of guests and workers because this is also the area where servers order and pick up drinks for their tables.
- *Kitchen.* The layout of the kitchen area is determined by the type of food served and the type of equipment needed to prepare food. An Italian restaurant might include a large pizza oven in the kitchen area. The size, layout, and location of the kitchen will have a significant effect on the efficiency of restaurant operation and the customers' dining experience.
- *Restrooms.* The same effort that was expended in creating the design and ambience for other areas of the restaurant should carry through to restroom layout.



Retail store layouts should emphasize aisle space, traffic flows, and the visibility of best-selling and high profit-margin products.

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9.6 Legal, Ethical, and Sustainability Issues

In addition to producing products and services that are cost effective, companies have added sustainability goals to their requirements for process selection. These goals are protecting people, guarding the environment, and making profits. The methods for designing and operating sustainable processes vary from industry to industry. Yet, they generally include the following:

- Using materials in production processes that are nontoxic, are recyclable, and require a minimum amount of energy.
- Designing or redesigning processes that prevent wasting resources or reduce the production of harmful by-products.
- Designing or redesigning processes so that by-products or scrap materials can be recycled or reused.
- Designing or redesigning processes and work areas to maintain the physical well-being of workers and the general public.

Designing lean processes, a practice that has been embraced by both manufacturing and service industries, can also help a company achieve sustainability. (Lean processes are discussed more extensively in Chapter 14.) Companies that design lean processes can also reduce their inventories and the sizes of their plants as well as lower defects, shorten the lead times for products, and reduce rework and scrap. In addition, lean processes tend to reduce the variations in a company's workloads, resulting in smoother production flows.

Ethical companies design their processes so the safety of workers and consumers is not compromised. Consider what happened to British Petroleum (BP plc, London, U.K.) in 2010 when one of its drilling rigs in the Gulf of Mexico exploded as a result of a buildup of flammable gas. A review of BP's processes found a consistent pattern of using minimal or substandard safety and maintenance

9.6

List strategies that companies can take to address the legal, ethical, and sustainability issues in process design and layout planning.

procedures. As part of the settlement, BP had to pay nearly US\$8 billion in legal penalties and fines to the U.S. government and to more than 100,000 plaintiffs.

It's not always easy to determine what constitutes an ethical course of action when it comes to designing a process. Sometimes, it can be difficult to determine what impact a process will have on the safety of workers and consumers or on the environment. Moreover, being too cautious in introducing new processing technologies could prevent the companies from passing on to consumers the benefits that new technologies offer, such as lower costs and better quality products. For example, the use of fracking technology to extract natural gas and oil (from depths that were unreachable by conventional technologies) can employ a lot of people and make countries more energy independent. Nonetheless, concerns over the potential impact of this technology on the environment may prevent some U.S. states and other countries from authorizing it within their borders.

Sustainable layouts promote energy efficiency, safety, and worker comfort, and they minimize environmental degradation. Starbucks excels at using minimal workspace as efficiently as possible; there is a lot going on behind the counter in a relatively small area. The Nike shoe factory in Ho Chi Minh City in Vietnam has achieved a comfortable work environment using sustainable building practices. A natural ventilation system cools the factory, and warm air is expelled through roof-mounted ventilation towers. In addition, the factory achieves natural ambient day lighting by installing high, open mesh windows that reach above surrounding rooftops to admit daylight to the factory interior.²⁹

Historically, factories were large, multifloored buildings because of the space limitations in cities. By the 1960s, however, more and more production facilities were built in suburban and even rural settings, where the cheap land allowed for many buildings and large campuses. The sheer sprawl of these complexes made them expensive to heat and cool, led to increased property taxes, and resulted in higher infrastructure and maintenance costs. In recent decades, factories have returned to a vertical structure, and the buildings have been built using green technology.

Organizations are also turning to sustainable energy sources for their facilities, often by using solar panels or wind power. For example, companies use solar power as a way to save money by generating most of the energy they need for their facilities. In fact, not only are companies saving money with wind and solar power, but they are also generating excess power that can be sold to other people and firms.³⁰ Table 9.6 shows that the top 10 U.S. companies with on-site solar energy capacity cumulatively have installed 1.2 million solar panels capable of producing US\$47.3 million worth of electricity a year. In fact, Walmart and Costco alone have more photovoltaic (PV) capacity than the entire state of Florida.³¹



TABLE 9.6: Corporate Sustainability: 10 Biggest Users of Solar Power in the United States*

Company	Energy Generated (in megawatts)
1. Target (Minneapolis, MN)	147.5
2. Walmart (Bentonville, AR)	145
3. Prologis (San Francisco, CA)	107.8
4. Apple (Cupertino, CA)	93.9
5. Costco (Issaquah, WA)	50.7
6. Kohl's (Menomonee Falls, WI)	50.2
7. IKEA (Delft, the Netherlands)	44
8. Macy's (New York, NY)	38.9
9. General Growth Properties (Chicago, IL)	30.2
10. Harz Mountain Industries (Secaucus, NJ)	22.7

*2016 data.

SOURCE: Adapted from Gabriel, W. (2016, November 24). Top ten companies using the sun for power. *Earth911*. Retrieved from <http://earth911.com/business-policy/top-10-companies-using-solar-power/>



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CHAPTER SUMMARY

9.1a Argue for the strategic importance of process selection to an organization.

Companies use the information they receive from the external environment, including customer demand for goods and services, technological changes, and the type of product or service, to help them make choices about capacity planning and process selection. All processes have to be implemented in the situations in which they will bring the highest benefit to the organization.

9.1b Identify factors that affect process choice.

Some factors that affect the choice of process are the type of product or service, varieties of products or services offered, risk of customer dissatisfaction, capital investment, and process flexibility. Understanding and correctly interpreting the effects that these different factors have on the choice of process can be critical. Other factors that should be included in process selection are market requirements, technological considerations, degree of automation available and desired, and sustainability.

9.2 List the unique features in the design of service processes.

Service process design focuses on how the most efficient combinations of customization and customer interaction should interact with labor intensity for service operations. Most service organizations seek to optimize these elements and find an efficient means to produce their services. The service process design matrix allows firms to categorize their services as compared with others in their industry and strike a balance between customization and labor intensity. Thus, in industries that gravitate toward efficient operations, which are organized as a service factory, it may be possible to market high-end services by employing more labor or customization of the product line to offer customers more choices.

9.3 Defend the reasons that it is important for companies to synchronize their internal processes with the external processes of their supply chain partners.

To provide customers with high-quality products and services at the lowest possible cost, and at the locations most convenient for them, companies need to design their individual internal processes in ways that maximize the performance of their supply chains. That is, companies need to not only synchronize their individual internal processes but also link them with the external processes of their supply chain partners. To succeed in a global competitive environment, companies need fast and flexible manufacturing processes that can adapt quickly to change. To achieve this objective, the different manufacturing processes should be integrated across a customer-focused supply chain. In a manufacturing supply chain, depending on the nature of the product, different types of processes link multiple supply chain partners.

9.4 Describe the unique challenges involved in designing global processes.

Companies with global operations often have several plants located in different countries, and they must decide what processes to use and how they should be designed. These companies have to redesign their products and processes to varying degrees to suit the needs of the local market. Because of the variability in global markets, companies must respond quickly to meet the requirements of their customers. In most cases, they rely on mass customization and adaptive manufacturing.

9.5 Construct the different layout types, identifying their features in the design.

After firms decide on the appropriate processes (usually intended to provide the best efficiency while allowing the firm to maximize its responsiveness), these decisions shape the design of layout. For both service and manufacturing operations, layout analysis and design contribute to the firm's competitive advantage. Layout planning decisions encompass designing layout for new facilities as well as redesigning layouts for existing facilities. Several different layout options are available for an organization to choose from, depending on such features as the demand

for their products, the type of products, and flexibility in producing the products. Among the more common layouts are process, product, and fixed-position. An innovative layout is the cellular manufacturing layout, which can offer workers a wider range of activities and job responsibilities, even though it requires extra training and may not motivate all employees. Service layout should consider the servicescape or the ambiance in the physical features and environment surrounding the service and how they affect service delivery satisfaction. There are various service layouts, each with its own features that must be considered in enhancing the servicescape. Among the types of service layouts are warehousing, office, retail, and restaurants.

9.6 List strategies that companies can take to address the legal, ethical, and sustainability issues in process design and layout planning.

A challenge for organizations in both the manufacturing and service industries is to design processes and layouts that are sustainable. Some strategies companies can use to design and operate sustainable processes include using nontoxic and recyclable materials, designing lean processes to prevent waste, and designing processes that ensure the safety of workers and the general public. Sustainable layouts employ a variety of strategies to ensure energy efficiency, safety, and the comfort of workers, and prevent environmental degradation. Finding better means to ventilate, provide electricity and light, improve working conditions to minimize worker fatigue, or economize on power sources are all necessary steps in making our layouts both more efficient and more sustainable.

KEY TERMS

Adaptive manufacturing	352	Fixed automation	342	Open office layout	360
Assemble-to-order (ATO)	349	Fixed-position layout	355	Point of postponement (POP)	351
Batch process	336	Flexible automation	342	Process	336
Cellular manufacturing layout	357	Flexible manufacturing system (FMS)	343	Process layout	353
Computer-aided manufacturing (CAM)	343	Group technology (GT)	357	Process selection	336
Computer-aided process planning (CAPP)	343	Hybrid layout	357	Process strategy	336
Computer-integrated manufacturing (CIM)	343	Industrial Robot	343	Product layout	355
Continuous flow process	336	Job-shop process	336	Product profiling	340
Cross docking	359	Layout	353	Project process	336
Decoupling point	351	Make-to-order (MTO)	349	Push-pull boundary	351
Engineer-to-order (ETO)	349	Make-to-stock (MTS)	349	Repetitive process	336
		Mass customization process	338	Servicescape	358
		Numerically controlled (NC) machines	343	Synchronous manufacturing	339
				U-shaped layout	355

DISCUSSION AND REVIEW QUESTIONS

- This chapter suggests that capacity planning and process selection serve as a link between external, market-driven demands and internal operational processes. Why is this the case?
- Under what circumstances would an organization consider producing a component in-house versus outsourcing it?
- Give examples of products that can be produced using the following process types:
 - Project
 - Job-shop
 - Batch
 - Repetitive
 - Continuous flow

4. Why might an organization consider using agile manufacturing? What pressures could the firm be facing? What advantages and disadvantages would the firm receive from using it?
5. How has the rise in automation dramatically altered the ways in which an organization develops its flow of processes? Give examples of automation and the subsequent changes that have occurred in a process.
6. Explain the service process design matrix. How can organizations use it when examining their service processes?
7. Explain the following manufacturing methods, and give an example of each one:
 - a. Make-to-stock
 - b. Assemble-to-order
 - c. Make-to-order
 - d. Engineer-to-order
8. The point of postponement (POP) is a useful idea for developing manufacturing strategies. Explain why an organization needs to be aware of the decoupling point as it develops its supply chain strategy.
9. Explain the three types of layouts, and give examples of products manufactured with these layouts:
 - a. Process
 - b. Product
 - c. Fixed-position
10. What are the advantages of cellular manufacturing layouts? What are their disadvantages?
11. List three principles that should affect the design and operations of a warehouse.
12. Visit a local restaurant and analyze its layout. What do you see as some limitations or drawbacks with how the facility is laid out? What suggestions might you make for redesigning it?

PROBLEMS

1. You have just been hired to redesign the layout of a moderately priced restaurant in midtown New York City. You serve two meals daily—lunch and dinner. In analyzing some of the critical elements in restaurant design (entrance, waiting and dining areas, bar, kitchen, and restrooms), what recommendations would you have for prioritizing your limited budget? In other words, which elements are the most critical to you and why?
2. Suppose that you were now considering the redesign of a low-priced, family-style restaurant in South Florida. How might your budget priorities for the various design elements change? Why?
3. The goal of a retail layout is to maximize profit per square foot of floor space. How does this principle affect your decision on how many products to stock in a retail clothing outlet?
4. Referring to Problem 3, is there a critical mass for stocking products on retail floors? In other words, how would you evaluate a retail clothing store that crowded the aisles with clothing displays? How would you expect stock display congestion patterns to differ at a Walmart versus a high-end retailer like Nordstrom?
5. Suppose you worked in a mass production environment for a company producing LED video screens and you were asked to help redesign their operations flow. What layout planning concerns would be a priority? Why?
6. What do you see as advantages and disadvantages of do-it-yourself process flows, such as self-checkout at grocery stores?
7. How would you characterize the primary goals of a product process design, and how would you differentiate these goals from those for a service process design, such as a hospital?
8. Examine the service process design matrix in Figure 9.3. Identify at least two other businesses that would be classified in each of the four quadrants. What are the implications of these different process design configurations; in other words, what are some keys to success for firms operating in each of these quadrants?

CASE STUDY 9.1 CHALLENGES OF REDESIGNING A PLANT LAYOUT

Sally has been working for Test-Prep Machining, Inc. for the past 5 years, since she graduated from college. Test-Prep Machining specializes in manufacturing gears and cutting tools for the tool and die industry. It is considered a high-quality company that prides itself on rapid response to customer orders. At the beginning of

the year, Sally was promoted to assistant manager for plant operations with a broad mandate to “analyze our operations to spot any problems that could affect customer satisfaction.” Sally spent time walking the plant floor to familiarize herself with the manufacturing system. Test-Prep Machining uses a cellular manufacturing layout.

The process flow works like this: All raw materials arrive at receiving and are sent to inventory. The actual plant layout consists of five cells:

1. Shaping—rough molding of alloys and steel gear bits
2. Cutting—mechanical cutting to specific shapes or orders
3. Grinding—rough finishing of gears or tools to remove debris or rough edges
4. Polishing—final finish for gears or tools
5. Testing—quality check against original specifications for all finished products.

Sally noticed the actual cells for the operations consist of two (2) shaping stations, three (3) cutting stations, two (2) grinding stations, four (4) polishing stations, and two (2) testing cells. She is concerned the current cellular layout is actually delaying manufacturing because of the difficulty of balancing the workers and

tasks among the five cells. Test-Prep Machining, Inc.'s production schedule calls for five 8-hour work days per week. The company has a current workforce of 80 for these five cells. The company's goal is to manufacture 600 units of the finished product per week. Sally has decided to present her concerns to her manager.

Questions

1. How would you design a cellular layout for Test-Prep Machining?
2. Can you identify any potential bottlenecks in the current layout?
3. What suggestions would you offer Sally on how to redesign the current cellular layout, keeping in mind the need to minimize costs and balance the workload among the 11 work stations?
4. How would you measure the efficiency of this revised layout?

VIDEO CASE

Watch this video case to learn about what factors the Rockefeller Gastropub took into account when planning the layout design of the restaurant.

CRITICAL THINKING EXERCISE

Visit or research online a manufacturing facility and a service organization in the area where you live.

1. In terms of the product-process matrix in Figure 9.1, to which category does the manufacturing facility belong, and how would you classify the layout of the manufacturing facility?
2. In your opinion, what are the drawbacks of process design and layout of the manufacturing facility? What suggestions do you have for improvement?
3. In which quadrant of the service process design matrix in Figure 9.3 would you classify the service organization you visited? What suggestions do you have, if any, for a redesign of this service process?



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