

After studying this chapter, you should be able to:

- A Describe five types of transformation processes.
- ▲ Explain the operations manager's task in the short run and in the long run.
- ▲ List the steps in capacity planning.
- A Identify key cost and noncost considerations in facility location.
- ▲ Describe three types of facility layout.
- A Explain the purchasing cycle.
- A Identify the fundamental elements of inventory control and discuss just-in-time systems and material requirements planning. A Identify the steps in the production planning and control process. A Define quality control and discuss how statistical quality control and quality circles work.
- A Describe three basic forms of maintenance. A Discuss the factory of the future, including the role of robotics.

Gavilan Computer Corp. unveiled a portable computer in April, 1983, promising delivery the following October. It didn't ship until June, 1984, and entered Chapter 11 bankruptcy-code proceedings in October, 1984, after selling only 3,000 units. Visicorp, the first star computer software company, unveiled a new software series in November, 1982, but failedTM to ship until early 1984; it agreed in October, 1984, to merge with a smaller firm. Ovation Technologies Inc., a Massachusetts software start-up, announced its flagship product in October, 1983, promised first-quarter delivery, and spent almost \$6.8 million. It never finished the program and subsequently sought a buyer. Osborne Computer Corp. filed for Chapter 11 protection in 1983 after a premature announcement and delays of its new computer dried up sales of its first product. Even IBM experienced delays of over six months in shipping a new disk drive for mainframe computers, and Apple was a year late with its promised link between its MacintoshTM and the IBM® Personal Computer.

Such delays have led to a new industry buzzword, "vaporware," for publicized products that don't yet exist. When companies hurry to meet the promises of overly optimistic announcements, they worsen the industry's credibility further by shipping products containing bugs.'

These examples illustrate that, even in today's high-tech industries, basic concerns about getting a product out on time and maintaining;

1. This introductory material is adapted from *The Wall Street Journal* (January 1985), 1,31.

its quality are crucial. Maintaining satisfactory productivity and quality are among the most pressing challenges facing American business today. While the absolute level of productivity in the United States is still quite high relative to other nations, the growth rate of productivity does not compare so favorably. The annual rate of manufacturing productivity gain averaged 3.4 percent in the United States for the 1970-1975 period, slumped badly to 1.7 percent for 1975-1980, and recovered to 3.2 percent for 1980-1984. However, as seen in Figure 20-1, even that 3.2 percent figure substantially lags behind gains in such countries as Belgium, France, and Japan. Similarly, quality differentials between U.S. products and those of other developed countries have generally narrowed, if not reversed. Whether these productivity and quality challenges are successfully met will depend largely on operations management.

Figure 20-1
Annual Percentage Change of Output per Hour of Manufacturing Activity:

ANNUAL PERCENTAGE CHANGE OF OUTPUT PER HOUR OF MANUFACTURING ACTIVITY:



*1980-1983

Source: *Statistical Abstract of the United States*, 106th ed., 1986 (Washington, DC: U.S. Department of Commerce, Bureau of the Census, December 1985), 849

In this chapter we will explore the nature of operations and operations management. We will examine capacity planning, facility location,

2. *Statistical Abstract of the United States*, 106th ed., 1986 [Washington, DC: U.S. Department of Commerce, Bureau of the Census, December 1985), 849.

and facility design and layout. We will discuss materials purchasing, inventory control, and the production planning process. Then, we will consider quality control and maintenance policies. Finally, we will take a look at the factory of the future, including the role of robotics.

THE MEANINGS OF OPERATIONS AND OPERATIONS MANAGEMENT

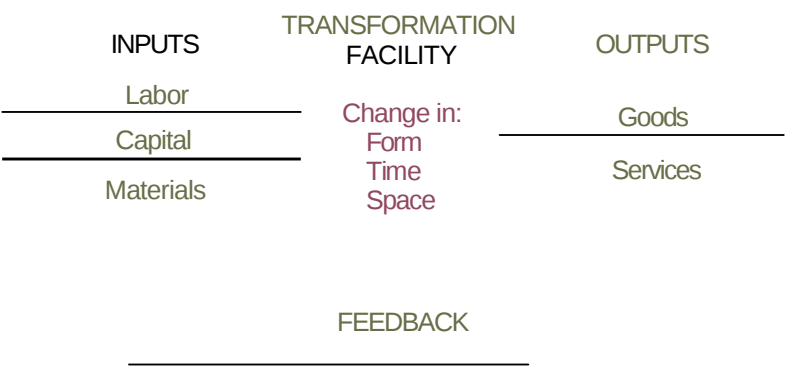
Before we begin examining specific operations management issues, an overview may be useful. Let's examine the nature of operations and operations management and the tasks of the operations manager.

Operations

Operations include any process that accepts inputs and uses resources to usefully change those inputs.³ A basic operations system is shown in Figure 20-2. Inputs to the system include labor, capital, and materials. The **transformation process** alters the inputs in some useful way. The outputs are goods or services. The nature of the outputs may provide feedback to both the inputs and facility concerning needed changes in quality, strategy, or other factors.

Inputs may be transformed in a variety of ways. An assembly line, **in** which a radio or other product moves **from** one work station to the

Figure 20-2 THE TRANSFORMATION PROCESS



3. J. O. McClain and L. 1. Thomas, *Operations Management: Production and Servian*, 1st ed. (Englewood Cliffs, NJ: Prentice-Hall, 1985), 5-

next, is an example of processes involving a form transformation. Whenever raw and semifinished materials are processed and converted into finished products, a form transformation occurs. In a synthetic transformation process, basic parts, components, or chemicals are combined to form a finished product. The production of appliances from steel, plastic, and other inputs is an example of a synthetic transformation in form. In an analytic transformation process, a basic material is broken down into one or more final products. Examples include the refining of iron ore or crude oil and the milling of logs into lumber, plywood, composite board, and other building materials.

Inputs can also be transformed in time or space — temporal transformation and spatial transformation, respectively. Storage is an example of a temporal transformation, Rental warehouse space is the output, and it is purchased for a period of time. A transportation service, such as commercial air travel or package shipment via Federal Express, is an example of a spatial transformation. Here, the transformation process involves the movement of people or packages from one place to another.

As these examples show, operations may include both production operations and service operations. Production operations, aimed at producing goods, would include such organizations as computer manufacturers, building contractors, and coal mines. The goal of service operations, such as a hospital, university, or bank, is to provide personal services. Examples of production and service operations, based on the degree of process repetitiveness and the purpose of the operation, are shown in Figure 20-3. While there are some basic differences between production and service operations, many operations management techniques are applicable to either,

Operations Management

Operations management is the process of planning, organizing, and controlling operations to reach objectives with efficiency and effectiveness.⁴ As we will see, this may include such activities as capacity planning, purchasing, quality control, and maintenance. Again, while operations management is often associated with production operations (due in part to common use of the term production management to describe the area), it is equally relevant for service operations.

The Tasks of the Operations Manager

Economists make a basic distinction between the short run and the long run. In the short run, the basic plant and equipment cannot be

4. S. E. Bamdc and D. W. Carvey, *Essentials of Operations Management* (Englewood Cliffs, NJ: Prentice-Hall, 1982), 1.

Figure 20-3: »

EXAMPLES OF OPERATIONS,

i ^ 1

Degree of Process Repetitiveness	TYPE Of Manufacturing	OPERATION — PRODUCTION	
		Converting	Repairing
Continuous flow	Paper mill	Electrical power plant	Water-treatment plant
Mass	Automobile assembly plant	Open-pit coal mine	Large auto paint shop,
Large batch	Ironery	Scrap-metal reduction plant	Road-repair contractor
Job lot	Furniture Store*	Custom slaughter-house	Auto-body shop J
Unique item	Office-building construction firm	Ship salvage company	Major ship-repair yard 1
Degree of Process Repetitiveness	TYPE Protection	OF OPERATION — SERVICE Logistics	
		Well-Being	J
Continuous flow	Prison	Gas pipeline	Hospital intensive-care ward 1
Mass	U.S. Secret Service	Airline	Public school 1
Large batch	Traffic court	Garage	Military basic-training camp 1
Job lot	Fire department	Trucking firm	Travel tour guide J
Unique item;	Lloyds of London insurance	House mover	Management consulting firm 1

Source: Stephen E. Barndt, Davis W. Carvey, ESSENTIALS OF OPERATIONS MANAGEMENT, © p, 9. Reprinted by permission of Prentice-Hall, Inc., Englewood Cliffs, NJ.

changed in size or design; in the long run, they can. That is to say, production capacity of the plant is fixed in the short run but variable in the long run.

The operations manager's task in the short run is to use existing facilities in the best ways possible through such actions as proper maintenance, inventory control, and production scheduling. In particular, operations manager can:

- A Vary the amount or type of inputs such as by purchasing materials.
- A Use the facility more effectively through multitask operation, overtime, or improved work methods.

- ▲ Temporarily add capacity by hiring another company to do part of the work [this is called subcontracting).

Over the long run, the operations manager's job is to search for ways to improve existing facilities and to modify or expand them as needed. Inland Steel Company,, the nation's seventh largest steel producer, recently completed a \$1 billion plant expansion and modernization program to lower production costs, improve product quality, and increase its share of the steel market.

CAPACITY PLANNING⁵

The capacity planning of a firm is a primary reflection of its long-range operations strategy. In capacity planning, the firm must consider such issues as market size and trends, probable technological changes in products or services, the possible addition of new products or services, the likelihood of the future development of new production methods, the desirability of a single or multiple facilities, and many others. The process of capacity planning includes:

- ▲ *Predicting future demand, including the possible impact of technology, competition, and other events.* This requires an assessment of contingencies. Future demand prediction is especially difficult for new products and risky situations.
- ▲ *Translating predictions into physical capacity requirements.* A basic concern here is determining the unit or units of measurement of capacity. This may be easy for a canner of vegetables which can identify hard measures of output but more difficult for a police department or law office. In the latter cases, a measure of inputs, such as number of police officers or lawyers, may serve as a proxy for capacity.
- A *Generating alternative capacity plans related to requirements.* When gaps between current and needed capacity are identified, alternative plans can be considered. These may involve the size and timing of needed capacity [for instance, should capacity be added in large or small increments), use of overtime or multiple shifts, outside capacity sources, absorption of lost sales (a risky option if sales might be permanently lost), and the location of new capacity.

5- This section, including the listing of process steps, is drawn primarily from E. S. Buffa, *Essentials of Production/Operations Management* [New York: John Wiley & Sons, 1981], 49-64.

A *Analyzing economic effects of alternative plans.* These alternative plans may involve units differing in size and, thus, economies of scale. Also, the timing of needed investment might vary from one alternative to another. If an alternative involves lost sales, that opportunity cost must be considered.

▲ *Identifying risks and strategic effects of alternative plans.* Plans¹ may impact on competition, flexibility of operations, market locations, labor policies, market share, and so on. Attempts should be made to identify such risks and effects and to assess, their likelihood.

A *Deciding on a plan for implementation.*

Capacity planning involves the operations manager in decisions with key strategic implications. These decisions interface with such functional areas as marketing, finance, and engineering and have an impact on almost all other operations management activities.

FACILITY LOCATION

For most companies, the decision of where to locate a new facility or to relocate an old facility is a critical one. The location of a manufacturing plant with respect to raw materials, a skilled work force, or customer markets can mean the difference between success and failure:

Many factors
must be
considered when
locating and
designing a
facility.



Firms compete with one another by keeping transportation, labor, and distribution costs low. A bio-engineering firm without a nearby supply of college graduates or a sod farm located far from its customers would be at a severe competitive disadvantage.

Figure 20-4 suggests some important factors in facility location decisions. As the figure shows, both cost and noncost factors are consid-

Figure 20-4

FACTORS IN THE FACILITY LOCATION DECISION



FACTORS	Industry Where This Might Be Especially Important	Recent Developments
Cost Factors		
Labor Costs	Automotive	Labor costs are up> but minimum wage laws and nationwide competition for skilled labor have evened them out across the country.
Transportation Costs	Cement	These have gone up very rapidly since 1975. Trucking rates more than doubled and rail rates went up about four-fold.
Construction Costs	Warehousing	These have doubled since 1975. They still vary substantially across the country.
Utility Costs	Steel	Energy resources are quickly being used up. Costs are skyrocketing and will continue to be a major consideration.
Taxes	Oil	Many states and territories [particularly Puerto Rico] are now giving industries substantial tax breaks.
Noncost Factors		
Environmental Conditions	Paper	New laws and social pressure have had great impact on many companies. Industry has spent tremendous amounts on air pollution and waste disposal equipment.
Living Conditions	Various	Many employees are no longer willing to just go where the company tells them. Quality of life in the community is becoming more important.
Availability of Resources	Canning	Industry use of water will more than triple by the year 2000. Supplies are low in Los Angeles, Denver, and Chicago. The Gulf Coast from Texas to Alabama suffers from a shortage of groundwater.
Availability of Skilled Labor	Genetic Engineering	The labor force will decline in numbers by 1990, creating new labor shortages.

Source: William H. Cunningham, Ramon J. Aldag, and Christopher M. Swift, *Introduction to Business* [Cincinnati: South-Western Publishing Co., 1984], p. 206. Reproduced with permission.

ered in these decisions. When General Motors was deciding on the location of its new Saturn plant, it used computers to weigh the many relevant variables. States competed aggressively for the facility.

In times of economic slump, states and localities work especially hard to attract desirable industries. In the late 1970s, the number of states granting tax breaks to attract firms almost doubled. In addition, Ireland, Puerto Rico, and Canada are actively vying for new facilities. Federal minimum wage laws and other nationwide standards may make locating outside the United States more attractive in years to come.

FACILITY DESIGN AND LAYOUT

The goal of facility design and layout is to develop a plan that, when executed, will result in a businesslike environment that allows and promotes efficiency. Specifically, design and layout efforts are aimed at minimizing the machine and employee idle time otherwise resulting from unnecessary movement, bottlenecks, and uneven utilization; minimizing in-process inventories; minimizing materials-handling costs; minimizing facilities operation and maintenance costs; and providing a safe and pleasant place to work and do business.⁶

Facility layouts may be categorized as process layouts, product layouts, and fixed-position layouts, depending on the function of the facility. In a process layout work of a similar function is grouped together in a single department or work center. In a clinic, for instance, radiology is in one location, occupational therapy in another, and internal medicine in yet another.

In a product layout, the organization of the work is dictated by the sequence of production or service steps common to all jobs. Parts move from one operation to the next with a minimum of movement required. The auto assembly line is a well-known form.

Finally, in a fixed-position **layout** the workers, rather than the material or part, move from one work center or machine to another. Such a layout is used when the product is very large, such as an aircraft carrier, or could be damaged by movement. The fixed-position layout is costly since tools and skills are duplicated across projects, so it is basically used when there is no good alternative. One advantage is that many workers prefer to move about rather than being tied to one spot.

While the choice of an appropriate layout depends on many things, primary considerations are the nature of technology (discussed in Chapter 8), repetitiveness, and volume. The applicability of layout types to these characteristics is summarized in Figure 20-5.

6. Bamdt and Carvey, *Operations Management*. 45-46.

Figure 3&S APPLICABILITY OF FACILITY LAYOUTS

Characteristic	TYPE OF LAYOUT		
	Fixed	Process	Product
Type of technology/ method of production	Unique item	Job lot and large batch	Mass and continuous
Repetitiveness	One-time	Intermittent	Continuous
Volume	Low	Intermediate	High

Source: Stephen E. Barndt, Davis W. Carvey, *ESSENTIALS OF OPERATIONS MANAGEMENT*, © 1982, p. 47. Reprinted by permission of Prentice-Hall, Inc., Englewood Cliffs, NJ.

MATERIALS PURCHASING

Purchasing is the link between the firm and its suppliers. It involves decisions about which supplies to buy, when, from whom, and for how much. Purchasing and materials handling have a major impact on company profits. For instance, it has been estimated that moving materials from one place to another, such as from a pipe company to a plumbing supply house, accounts for 20 to 50 percent of all production costs. The total amount of money spent on supplies and raw materials in any given year exceeds the gross national product, and 50 percent of the sales dollar of most large firms is spent on purchasing.⁷ Clearly, even a small savings in the purchasing budget can be very important.

Understanding the purchasing cycle is the key to understanding materials purchasing. The purchasing cycle begins with a decision to buy materials for production and ends when the materials are accepted by the department requesting the order. There are six steps in the cycle:

1. *Requisitions.* Personnel from various production units turn in purchase requisitions to the purchasing agent or buyer. These requisitions indicate the type and number of items needed.
2. *Value analysis.* The purchasing agent conducts a systematic appraisal

7. R. A. Johnson, W. T. Newell, and R. C. Vergin, *Production and Operations Management: A Systems Concept* (Boston: Houghton Mifflin Company, 1974), 335J. The reason the amount spent on supplies and raw materials can exceed the gross national product is that purchasing occurs at various points on the way to final delivery of a product or service. Thus, the same material may be purchased, repurchased in an altered form, and so on.

of the purchase requisition to find the lowest cost way to satisfy the request. Questions asked by management at this stage are: Do the requested items include too many unnecessary features? Can packaging or shipping requirements be reduced? How available are these items in the form needed?

3. *Supplier selection.* A list of approved suppliers is developed. The list rates suppliers on the basis of price, quality, reliability, and services. The purchasing agent then obtains quotes on prices and delivery times.
4. *Order placement.* A formal purchase order is completed. The purchase order describes the goods requested, unit prices, quantities desired, shipping instructions, and so on. The purchasing agent can often obtain quantity discounts by ordering large amounts of requested materials at one time. Buying more than is needed right away is called forward buying.
5. *Order monitoring.* The purchasing agent regularly checks important orders to make sure they are on schedule. Communicating with the supplier is crucial at this stage.
6. *Order delivery.* A receiving clerk checks the delivered goods against a copy of the purchase order. If the shipment is correct, the purchase is recorded and payment is made.

INVENTORY CONTROL

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Inventories held by firms in the United States exceed \$500 billion, in value.⁸ By maintaining inventories, firms are protected from such threats to their supply as a strike by the employees of a supplier. Ample inventories of finished goods also enable firms to meet a sudden surge of customer demand. Consequently, we say that inventories cushion against supply-side and demand-side shocks. Holding inventories is expensive, however, and this forces the production manager to evaluate the benefits of large inventories against the costs. This trade-off is pictured in Figure 20-6, along with other typical operations management trade-offs.

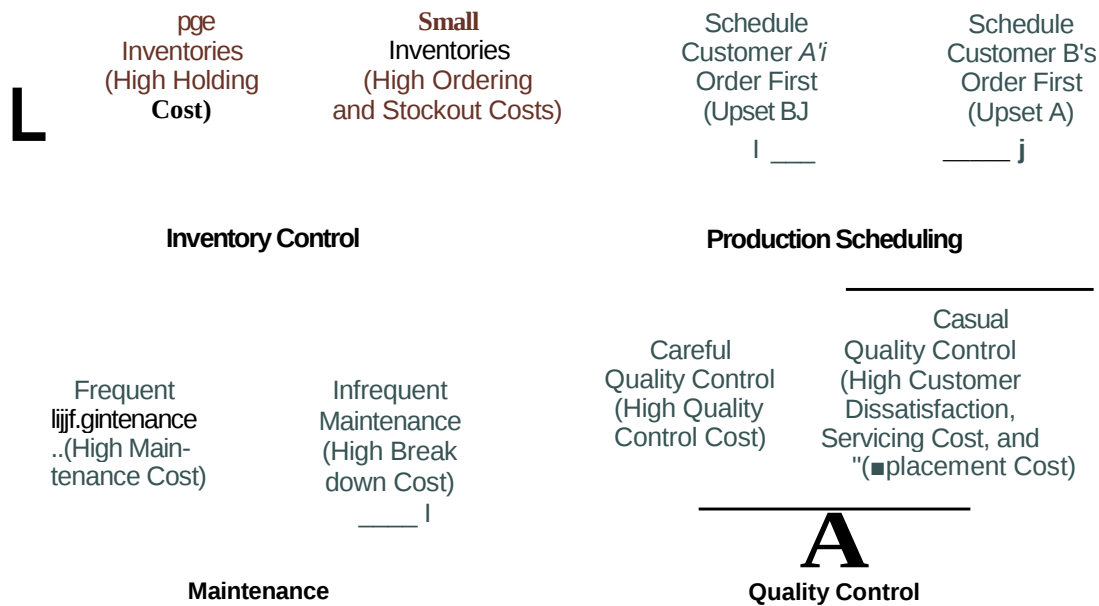
Inventory Costs

Three types of costs must be considered for proper inventory control: holding costs, ordering costs, and stockout costs. Holding or carrying costs refer to the expense of storing the inventory in the firm's warehouse or on its stock shelves. Examples of such costs are warehouse rental and utility bills. It is estimated that holding costs may total over \$125 billion

8. *Survey of Current Business* vol. 65, no. 3 [March 1985]

Figure 20-6

OPERATIONS MANAGEMENT



Source: William H. Cunningham, Ramon J. Aldag, and Christopher M. Swift, *Introduction to Business* [Cincinnati: South-Western Publishing Co., 1984], p. 199. Reproduced with permission.

annually, or about 4 percent of the gross national product.⁹ **Ordering costs** are the expenses involved in placing an order. These are generated largely by paperwork and management time. **Stockout costs** result when the **firm** runs out of inventory. The dollar value of lost production time or the value of a lost sale and the possible decline in customer goodwill are examples of stockout costs.

As an example, holding costs for a Toyota retail dealership include the interest on loans required to purchase an order of cars from the factory and the cost of showroom space, and the costs of accessories (such as radios and tape decks) which are mounted in the cars and cannot be sold separately. Ordering costs include the cost of paperwork, customs fees, arranging shipping to the dealer's lot, taxes and title fees, and so on. If the dealership is out of a model, stockout costs include the profits lost when customers give up on a Toyota and buy a Honda instead. The long-term costs of stockout include the failure of those customers to return to the Toyota dealer when they buy another car. Also, repeated reports of stockouts may spread to other potential customers.

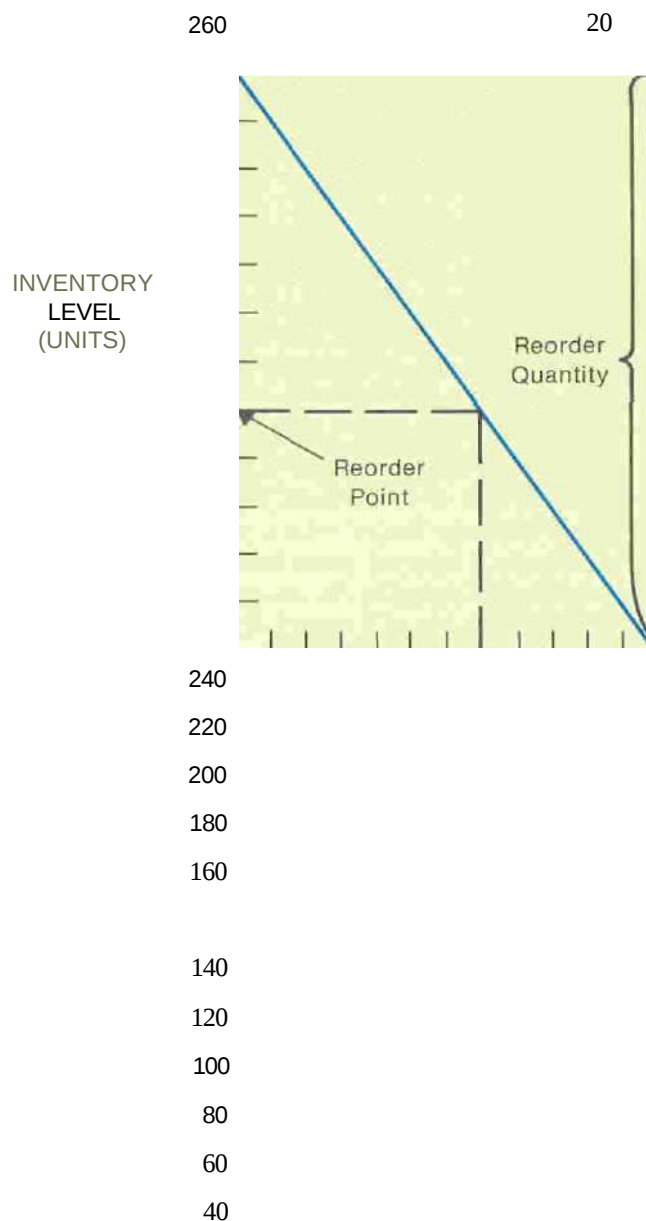
9. McClain and Thomas, *Operations Management*, 528.

Reorder Point and Reorder Quantity

The total of the three inventory costs depends on the size of inventories at the **reorder point** (when an order is placed) and the reorder **quantity** (size of the order). Figure 20-7 shows possible variation of inventory levels over time, the reorder point, and reorder quantity. If demand is known and steady from one day to the next, the reorder point is chosen so that new supplies are delivered just as the last product moves off the shelf. In the figure, average daily demand is 20 units, and the time from order placement to delivery, called **lead time**, is 5 days. The firm reorders when the level of inventory drops to $20 \times 5 = 100$ units, and the reorder quantity is 240 units.

It is usually best to build some slack into an inventory control system. For example, it might be safer to reorder when inventory levels drop to 120 units rather than 100.

Figure 20-7 INVENTORY LEVELS



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Economic Order Quantity

The choice of the best reorder quantity requires a balancing of the various inventory costs. If the reorder quantity is large, average inventories will be high, so holding costs will be high. If the reorder quantity is small, the number of separate orders will be high, so total ordering costs will also be high, *if* demand is not known with certainty, which is almost always the case, small inventories may result in disappointed customers. Here, a small reorder quantity may lead to high stockout costs. Holding costs, on the one hand, versus ordering and stockout costs on the other, determine the least-cost reorder quantity, or the economic order quantity (EOQ).

A Safeway store, which holds inventories of perishable goods, must determine an accurate EOQ for each of its products. Accuracy is especially important since profit margins are extremely small in the grocery trade and are quickly eaten up if inventories are too large and produce spoils, or if inventories are too small and customers are lost to other stores. The EOQ will be different for fresh lettuce than for canned soups or dried beans.

For the simple case where demand and lead time are known and constant (and where stockouts, therefore, need not occur]:

$$EOQ = \sqrt{\frac{2DO}{H}}$$

Where:

D = annual demand for the product
O = fixed cost of placing and receiving an order
H = annual holding cost per unit

For instance, if:

D = 8000 units per year
O = \$20 per order
H = \$2 per unit per year

The
n;

$$EOQ = \sqrt{\frac{2DO}{H}} = \sqrt{\frac{2 \times 8000 \times 20}{2}} = \sqrt{160000} = 400 \text{ units}$$

Keeping Track of Inventories

Many companies today keep a running count of their inventory levels. This is called a perpetual inventory. Under such an inventory

system, the firm knows exactly how much inventory it has at any moment. Both things added to inventory and taken from it are immediately noted on the inventory records. This continuous method of accounting for inventory is maintained on a transaction-by-transaction basis. Computers are often used for this.

Under a **periodic inventory** system the firm does not keep a continuous count of inventory. Rather, at the end of each accounting period—six months or a year—the firm takes a physical count of the inventory. These periodic counts are often used as a check on the accuracy of a perpetual inventory system.

New Developments in Inventory Control

Two recent developments are changing the nature of inventory control. They are just-in-time and material requirements planning.

Just-in-Time. Just-in-time (JIT) or **kanban** (a Japanese term for the cards used in the process) is a method of inventory control whereby the firm maintains very small inventories.¹⁰ When an order is received for a finished product, a kanban is issued instructing workers to finish the product. The finishing department chooses components and assembles the product. The kanban is then passed back to predecessor stations to replenish the components. This process continues all the way back to the material suppliers. At each stage, parts and other materials are delivered "just in time" for use.

One consequence of just-in-time is that all inventories are kept extremely low. Thus, firms markedly reduce their holding costs. However, beyond this, JIT represents a fundamental rethinking of the relationship between producer and supplier. For JIT to work, it is important that a stable, symbiotic relationship be developed. Long-term contracts reduce ordering costs and increase predictability. Since supplies are delivered only as they are needed, lot sizes are small and deliveries become frequent—perhaps more than once a day. This may require suppliers to devote themselves exclusively to one purchaser and locate nearby.

John McClain and L. Joseph Thomas suggest that there are three basic JIT philosophies:¹¹

- ▲ *Setup time and cost must be reduced.* The goal is to make setup so low that small batch sizes are economical—preferably batch sizes of size 1!
- ▲ *Safety stock is a bad thing.* It costs money and hides problems such as inefficient production methods. Just-in-time replaces just-in-case.

A *Productivity and quality are inseparable.* JIT is not possible if poor-quality components are produced. The firm will not be able to test, rework, and deliver products in a timely fashion. Thus, JIT requires not only small batches, low inventories, and quick production, but also a very high level of quality. The goal is 100 percent good items at each step.

There are many apparent benefits of JIT to producers.¹² They include the following:

- A Part costs—low scrap costs, low inventory holding costs.
- A Quality—fast detection and correction of unsatisfactory quality and, ultimately, higher quality purchased parts.
- A Design—fast response to engineering change requirements.
- A Administrative efficiency—fewer suppliers, minimal expediting and order release work, simplified communications and receiving activities.
- A Productivity—reduced rework, reduced inspection; reduced parts-related delays.
- A Capital requirements—reduced inventories of purchased parts, raw materials, work in process, and finished goods.

For suppliers, JIT provides the benefit of a long-term, stable relationship. A supplier often becomes the sole supplier to a purchaser, thus reducing the long-run risk of doing business. Communication with the buyer is frequent, reducing communication problems. Capacity needs can be better predicted. And, if the supplier adopts JIT with its own suppliers, its own purchased inventories are reduced.

The cost savings of reduced storage under a precision JIT approach can be substantial. By using JIT principles, Huffy Corp., a bicycle maker, cut its inventories almost in half, from a spring 1982 level of \$69 million to a peak spring level of \$36 million in 1984. Ford and Chrysler have recognized savings of hundreds of millions of dollars by applying JIT techniques. General Motors is estimated to spend \$3 billion annually to maintain its inventories valued at \$9 billion. With JIT, analysts believe General Motors could cut this cost to about \$1 billion. The Buick Motor Division of G.M. is rejuvenating a complex in Flint, Michigan, dubbed "Buick City," which will rely heavily on JIT. Cars will be produced in about half the space of conventional facilities. Within Buick City, major vendors will be located in eight adjacent industrial parks. Kaskle Steel's role in Buick City is described in Situation 1.

12. R. f. Sthonberger and A. Ansari, "'Just-in-time' Purchasing Can Improve Quality," *Journal of Purchasing and Materials Management* [1984], 3.

SITUATION 1

Kasle Steel Is an Integral Part of Buick City

The success of Buick City, an experiment in coordinated materials supply and manufacturing by General Motors Corp., will greatly depend on preproduction processing and just-in-time delivery systems such as the in-plant steel service center facility being developed by Kasle Steel Co.

Cold-rolled and galvanized sheet steel from Jones & Laughlin Steel Corp. plants in East Chicago, Indiana, and Cleveland, Ohio, will be shipped in coil form to the Kasle Steel plant within the Flint, Michigan, car-making complex. The service center will unroll and wash the metal to remove surface grime and dirt and thread it onto a processing line where a "blanking machine" will press specific flat configurations for 29 potential end-uses.

After blanking, the sheet will be removed robotically and inspected for surface quality, and then either rewashed or stacked for delivery. Shipment to the GM stamping plants will be computer-controlled, on a 24-hour-a-day basis, to coincide with manufacturing runs.

For GM, the system removes manufacturing cost components such as metals storage and handling, surface quality inspections, scrap disposal, and production-line preparation and delivery. For Kasle Steel, the \$8 million investment includes the development of computerized receipt-storage-process-delivery, automated coil- and blanked sheet-handling and inspection, and scrap-removal and blanked palletizing.

"This is a paperless system," Leonard Kasle, president, says. "Every day the GM computer will tell the Kasle Steel computer the number of blanks needed 30 days ahead and reconfirm that amount 10 days before production and again 24 hours before production." The GM computer will also tell the Kasle computer the exact number of blanks needed for each of the three-day stamping shifts to be operating on the date of delivery. Similar "computerized discussions" between the GM and J&L computers will take place ensure that the coils to be blanked are at the Kasle plant.

Kasle Steel must ensure that the blanks are free of physical and visual defects—that they don't have carbon smudge, smoke, or ash on the surface. J&L is responsible for the steel's quality.

Kasle Steel's integral role in the car-making process is a first for the domestic metals service center industry, one which is being watched by other service center and automotive manufacturing executives.

Source: Reprinted from *Purchasing Magazine* (May 24, 1984), 62-63. Copy by Cahners Publishing Company, 1984.

In the United States, JIT is currently best developed at Kawasaki Motors, a manufacturer of motorcycles and jet skis in Lincoln, Nebraska. Kawasaki began JIT work-in-process parts delivery on the factory and in the purchasing department in 1980. One of its suppliers, CON, has been supplying motorcycle seats on a just-in-time basis; 1977, typically making two deliveries a day. It followed the standard Japanese supplier practice of moving close to the parent firm, and

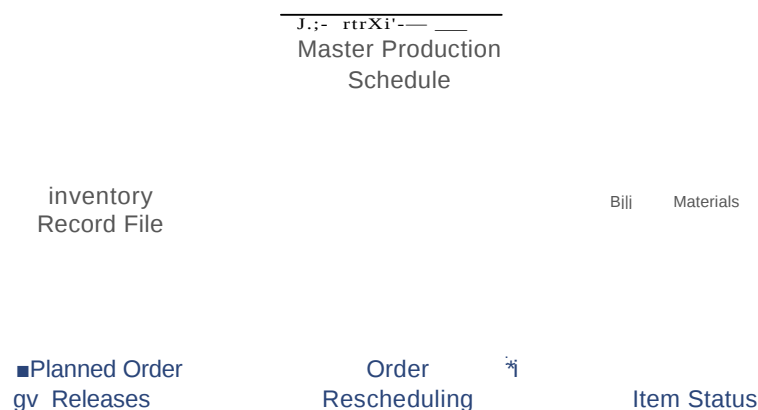
JIT with its own suppliers. Kawasaki is **now** expanding the JIT **concept** to other suppliers.

JIT doesn't work everywhere. It is most difficult to implement when a product line is very diverse, there is very high variation in demand throughout the year, setup times and costs are high and cannot be reduced, or scrap rates are high.¹³ While these situations limit the applicability of JIT, each should be carefully evaluated before JIT is rejected.

Material Requirements Planning. Material requirements planning (MRP) is a method for planning and controlling inventories in which projected inventory levels are computed from present inventories and from planned transactions affecting inventory levels.¹⁴ When component parts are assembled into products such as automobiles, they are not used independently of one another, - instead, they are needed at exact times in the production cycle. They have to be ordered to fit that cycle. This is a job of material requirements planning.

As shown in Figure 20-8, there are three major inputs to material requirements planning.¹⁵ First, the **master production schedule** is the

^ Figure 20-8 THE COORDINATING HOLE OF MRP



13. McClain and Thomas, *Operations Management*, 391. For more on "just-in-time," see B. S. Moskal, "Just in Time: Putting the Squeeze on Suppliers," *Industry Week* (July 9, 1984), 59-63; _____, "Delivering Just in Time," *Industry Week* (October 1, 1984), 44-48; R. J. Schonberger, "The Transfer of Japanese Manufacturing Management Approaches to U.S. Industry," *Academy of Management Review* 7 (1982): 479-87; and R. J. Schonberger and J. P. Gilbert, "Just-in-Time Purchasing: A Challenge for U.S. Industry," *California Management Review* vol. 26, no. 1 (1983): 54-65.

14. A. C. Laufer, *Production and Operations Management*, 3d ed. [Cincinnati, OH: South-Western Publishing Co., 1984]. For more on MRP, see J. C. Anderson and R. G. Schroeder, "Getting Results from Your MRP System," *Business Horizons* vol. 27, no. 3 (May-June 1984): 57-64.

15. The following discussion is based on Laufer, *Production and Operations Management*, 1984.

overall production plan for the end items. It is expressed in terms of timing and quantity requirements. Second, the inventory record file contains information about the status of each item held in inventory. Finally, the bill of material is a listing of all of the components of an end item. Working down from the final product, it shows the subassemblies used in the final product, the components going into each subassembly, and the raw materials needed for the components. MRP relies on computer programs to coordinate this information and provide outputs which help to insure that materials are available when needed.

Some of the regular outputs of the MRP system are also presented in Figure 20-8. They include planned order releases, open-order due dates,¹ altered as a result of rescheduling, notices of cancellation or suspension of open orders, and inventory status data. In addition, there are a variety of optional MRP outputs, such as exception reports noting errors or inconsistencies which exist and performance reports supplying additional information to management needed to provide control over the elements in the functioning of the overall system.

Typical reductions of inventory levels with MRP are 30 percent or less, though figures as high as 50 percent are sometimes cited. Direct labor costs for some companies using MRP have fallen as much as 10 percent, and indirect labor costs as much as 25 percent. There have been up to 35 percent reductions in late orders and total service improvements of up to 20 percent. However, these figures are from selected experiences, and may overstate the average impact of material requirements planning.

Y

PRODUCTION PLANNING AND CONTROL

Production planning and control is concerned with the ordering and monitoring of work in process. It includes control of the flow of materials, people, and machines. The aim is to use these resources in the most efficient way possible.

The Planning and Control Process

Effective planning and control involves seven basic steps or actions. Let's examine each of those steps.

Routing. The movement of a mechanical part or other piece of work from one operation to the next traces out a route. Routing is the process of determining these work flows. In the case of an assembly kit,

562. 16. These figures are drawn from Lanfer, *Production and Operations*

the routing of work is built into the design of the plant itself. Volvo, for example, is famous for the efficiency of its automobile assembly lines. Even the Japanese auto makers have inspected Volvo plants closely before building their own factories.

Loading. **Loading** refers to the process of determining how long it takes to perform a particular operation at a machine or work station and then adding that amount of time to the time for work already scheduled there. The result is a "load chart" showing how much each machine or work station will be used. Because of setup time, maintenance, and other factors, most machine tools cannot be used for more than seven hours of an eight-hour shift.

General Electric faces heavy production schedules for its Hotpoint air-conditioner assembly plants just before the summer starts. The company prefers to schedule its maintenance around this busy period so that it can load its plant as full as possible. When the assembly line has to be set up for a new product, maintenance work is often done at night so it does not interfere with normal shift operations.

Scheduling. The planning and control function of scheduling refers to the process of determining when an operation is to be performed at a machine or work station. At McLouth Steel, foundries sometimes have to be booked weeks or months in advance for an operation that may take only a few hours. If the facilities are not available on time, an expensive batch of iron can be lost.

Dispatching. After the routing, loading, and scheduling functions are performed, the start of each operation on the shop floor is authorized through dispatching, or the preparing and issuing of work orders. For example, if four machine operations are required, work orders for each operation are prepared and issued at this point.

Follow-Up. Another function of production planning and control is keeping track of work completed and any time lags or delays that may have occurred. This is called **follow-up**. Some jobs will run behind schedule and others will run ahead. With effective follow-up procedures, the time savings from jobs running ahead of schedule can be used to bring lagging jobs back on schedule.

Corrective Action. We might think that a well-managed plant would have everything running on schedule. In fact, though, a plant that does not sometimes encounter production delays probably is not being used efficiently. Because delays have to be expected in a well-run plant, management should be ready to deal with them. It may take such corrective action as scheduling overtime or shifting work to other machines.

The United States Postal Service usually operates at maximum capacity. When delays are encountered, post office managers schedule

overtime or send part of their volume to post offices with additional automation, where sorting and delivery can be completed more efficiently.

Replanning. In response to changing market conditions, manufacturing methods, or labor force availability, new plans may sometimes be needed. The development of new routing, loading, and scheduling is called **replanning**. In the semiconductor industry, operations managers have, to develop new production schedules for new products weekly or monthly.

Planning and Control Procedures

Operations managers have several analytical tools available to help them with production planning and control. We'll consider two such tools.

Schedule Charts. One simple way to keep track of work in process is with the schedule chart. The **schedule chart** shows when each of a series of job orders is to be performed at each machine, work station, or department. One such schedule chart, known as a Gantt chart, is shown in Figure 20-9.

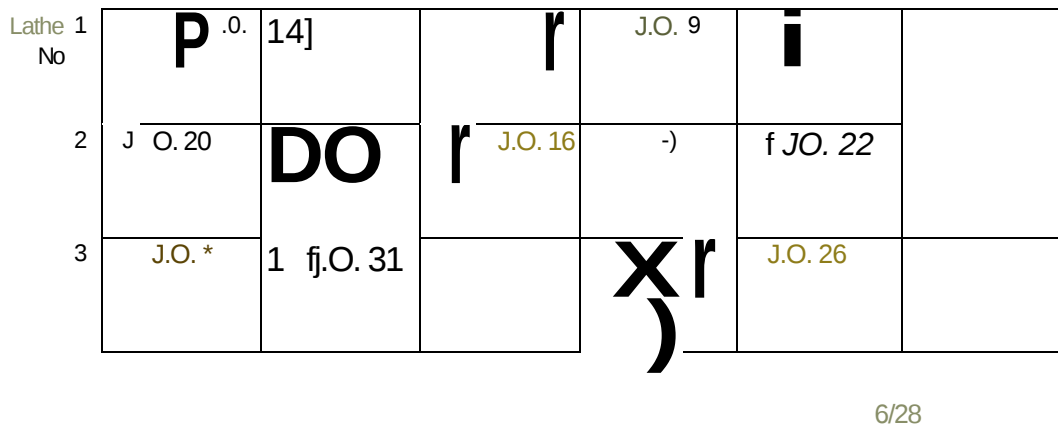
According to this figure, the operations manager has scheduled several job orders on each of three lathes over a six-week period. Notice that lathe No. 1 is frequently idle and that the operations manager has anticipated maintenance time and delays on lathes No. 2 and No. 3. Also, job order No. 16 is ahead of schedule. With scheduling charts, operations managers are able to monitor the flow of materials through a production process or the flow of work through a job shop. And the operations manager always knows the status of work performed in relation to work scheduled.

PERT and the Critical Path. Many times, an operations manager has a major project to finish by a contract deadline. The **project** is made up of many separate activities or steps, each of which requires a certain amount of time for completion. Usually, one activity cannot be started until another is completed. This activity, in turn, is followed by still others. The goal is to coordinate all these activities. Most projects, from the company picnic to the construction of an offshore oil drilling platform, fit this description. Some projects can involve many thousands of separate activities.

The operations manager who is faced with such a project often develops a program evaluation and review technique (PERT) chart, an example of a PERT chart is shown in Figure 20-10. It depicts each activity involved in the completion of a project, the sequencing of these activities, and the time allotted for each activity.

Figure 10-9
e

A GANTT CHART



5/24

5/31

6/7

6/14

Indicates Current Date

Indicates Time Reserved for Maintenance and Delays

J.O. Indicates Job Order Number

[] Bracketed Line Shows Time Allocated for Completion of the Order

[] Line Below Bracket Shows Portion of Work Done by Current Date

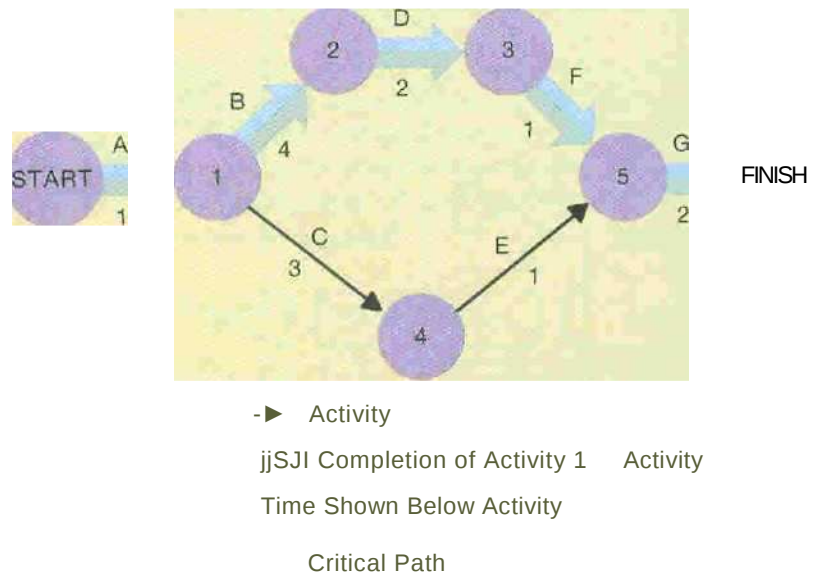
Source: William H. Cunningham, Ramon J. Aldag, and Christopher M. Swift, *Introduction to Business* (Cincinnati: South-Western Publishing Co., 1984), p. 204. Reproduced with permission.

Whenever possible, it is desirable to carry out several activities at the same time ("in parallel") rather than one after another ("in series"). In Figure 20-10, Activities B and C can be performed at the same time because the start of one does not depend on the completion of the other. However, Activity A and Activities B and C must be performed "in series." In an employee attitude survey, for instance, the choice of specific research goals necessarily precedes the writing of the survey questionnaire and the selection of data analysis methods.

The aim of a PERT network is to minimize project delays through effective scheduling of project activities. Such scheduling depends on the identification of the critical path. The **critical path** is the sequence of in-series activities requiring the longest time for completion. In Figure 20-10, the sequence of activities along the critical path is such that the project cannot be completed in fewer than ten weeks. Activities B and C are in parallel, but Activity B is along the critical path because that path

[ABDFGJ takes the most time to complete. Activity C is on a path (ACEG) which takes only seven weeks to complete. So, Activity C could

"figure 20-10 A PERT CHART



Source: William H. Cunningham, Ramon J. Aldag, and Christopher M. Swift. *Introduction to Business* [Cincinnati: South-Western Publishing Co., 1984], p. 205. Reproduced with permission.

be delayed as much as three (10 - 7) weeks without slowing project completion. Because Activity C can be delayed without slowing down the project, it is not on the critical path. Instead, it is said to have three weeks of slack time.

It should be apparent by now that the completion of a project in time depends on the careful management of activities along the critical path. When necessary, the operations manager can divert resources from noncritical activities to critical activities to get them done sooner. As the operations manager can look for other opportunities to schedule activities in parallel which are now in series.

QUALITY CONTROL

At one time, the phrase "Made in Japan" was synonymous with cheap products and inferior construction. It was usually written on the bottom of products found in discount bins. Now, however, consumers

speak with pride about their Japanese autos, cameras, televisions, stereo systems, watches, and porcelain dinnerware. More often than not, it is American products that are thought to be of inferior quality. For instance, one researcher visited every Japanese manufacturer of room air conditioners *and a// but one American manufacturer.*"He found tremendous variations in failure rates across companies—sometimes by a factor of 500 or 1000. The average Japanese plant had assembly-line defect rates 70 times lower than those of American plants. First-year service call rates were almost 17 times better for the Japanese plants. The poorest Japanese company typically had a failure rate less than half *that of the best American manufacturer.*¹⁵

Many companies in this country have responded to the problem of declining quality by setting up quality improvement programs for employees. For instance, "zero defects" programs use a combination of posters, slogans, pep talks, and praise to encourage employees to work more carefully. In general, firms are placing greatly increased emphasis on quality control.

Inspection

We can define quality control as the process of setting manufacturing standards and measuring products against these standards.¹⁶ The second part of the definition refers to inspection. Inspection involves comparing products to the standards, approving those that meet them, and rejecting those that do not. Inspection serves as a check on the quality of incoming material and finished goods—Many advanced techniques, including ultrasonic and magnetic tests, X-rays, computerized scanners, and television cameras, are used for inspection. But some judgments, such as whether a wine tastes "bad" or a flaw is "serious enough" to cause rejection, cannot be made so objectively.

Statistical Quality Control

The assumption behind statistical quality control is that most quality problems, perhaps as many as 85 percent, are the result of flaws in manufacturing systems, not of errors by production workers. Statistical quality control was first applied in the Bell Telephone Laboratories in the

17. D. A. Garvin, "Quality on the Line," *Harvard Business Review* vol. 61, no.5 (September-October 1983), 64-75.

18. M. R. Smith, *Qualitysense: Organizational Approaches to Improving Product Quality and Service* (New York: AMACOM, 1979)

19. For a discussion of dimensions of product quality, see D. A. Garvin, "Product Quality: An Important Strategic Weapon," *Business Horizons* vol. 27, no. 5 (May-June 1984), 40-43.

early 1920s. W. Edwards Deming introduced statistical quality control concepts to Japan in 1950 and is widely credited with turning around product quality there in just a few years. Deming's "14 Points" are presented in Figure 20-11.

Figure 20-11 DEMING'S 14 POINTS

1. Create constancy of purpose toward improvement of product and service, with the aim of becoming competitive to stay in business and to provide jobs.
2. Adopt the new philosophy: We are in a new economic age, created by Japan. Transformation of Western style of management is necessary to halt the continued decline of industry.
3. Cease dependence on mass inspection to achieve quality. Eliminate the need for inspection on a mass basis by building quality into the product in the first place.
4. End the practice of awarding business on the basis of price tag. Purchasing must be combined with design of product, manufacturing with sales, to work with the chosen supplier. The aim is to minimize total cost, not merely initial cost.
5. Improve constantly and forever every activity in the company, to improve quality and productivity and thus constantly decrease costs.
6. Institute training and education on the job, including management.
7. Institute supervision. The aim of supervision should be to help people and machines and gadgets do a better job.
8. Drive out fear, so that everyone may work effectively for the company.
9. Break down barriers between departments. People in research, design, sales and production must work as a team, to foresee problems of production and in use that may be encountered with the product or service.
10. Eliminate slogans, exhortations and targets for the work force asking for zero defects and new levels of productivity. Such exhortations only create adversarial relationships, since the bulk of the causes of low productivity lie beyond the power of the work force.
11. Eliminate work standards that prescribe numerical quotas for the day. Substitute aids and helpful supervision.
- 12a. Remove the barriers that rob the hourly worker of his pride of workmanship. The responsibility of supervisors must be changed from sheer numbers to quality.
- 12b. Remove the barriers that rob people in management and in engineering of their right to pride of workmanship. This means abolishment of the annual or merit rating and of management by objectives.
13. Institute a vigorous program of education and retraining. New skills are required for changes in techniques, materials and service.
14. Put everybody in the company to work in teams to accomplish the transformation.

Source: Reprinted from *Out of the Crisis* by W. Edwards Deming by permission of MIT and W. Edwards Deming. Published by MIT, Center for Advanced Engineering Study, Cambridge, MA 02139. Copyright 1986 by W. Edwards Deming.

Random Variation or Out of Control. The goal of statistical quality control is to determine whether something has gone wrong with the manufacturing system. It relies on the laws of probability to do this. By checking a sample of the output of a process and applying the right statistics, it is possible to tell whether the system is "out of control."

To illustrate, suppose that our plant produces a machine part for oil well pumps. The part is designed to be 6 inches in diameter, but we know from experience that an individual part is sometimes slightly more or less than 6 inches. Now suppose we pull one of the finished parts off the assembly line and find its diameter to be 6.01 inches. Is this deviation of .01 inch simply a random, unimportant variation, or is the deviation a sign that the production process is out of control, therefore requiring adjustment?

The Control Chart. To answer this question, we need to look at the past outputs of our production process and determine their average characteristics (such as the average diameter of 6 inches! and the typical variation around these averages. We also need to know the probability that various deviations may have occurred by chance alone. These probabilities are provided by statistical analyses.

For example, it might be known that a part with a 6.01 -inch diameter occurs ten times in a hundred by chance alone. Thus, our sampled part with the 6.01-inch diameter does not concern us very much because the deviation is very likely due to chance. But suppose the diameter of the sampled part was 6.03 inches and the probability of this occurring by chance was known to be only one in ten thousand. What then? In this case, we can be fairly sure that the production process is out of control and that more defective parts will be produced.

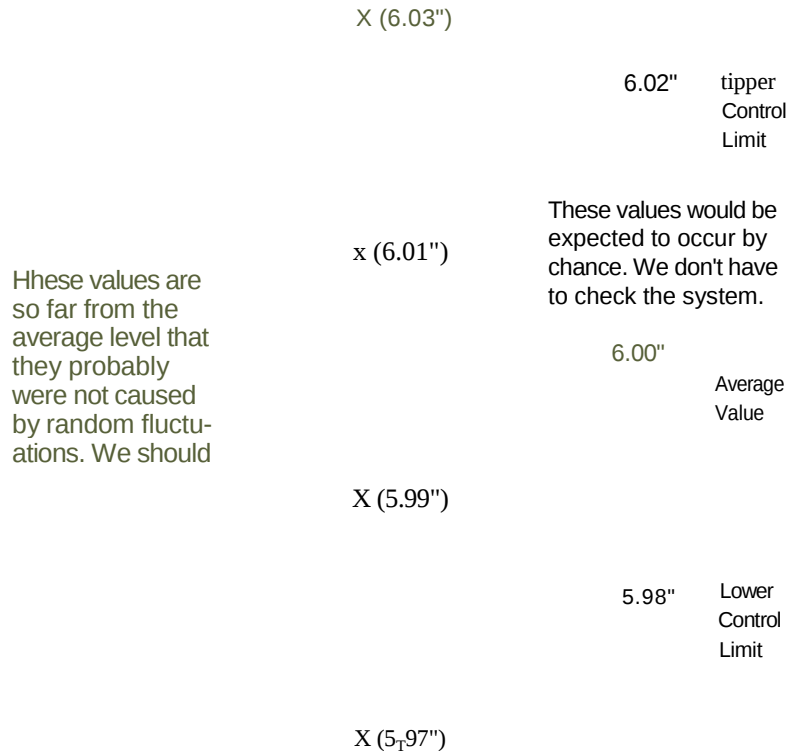
A control chart is used in conjunction with statistical control. A control chart for our example is shown in Figure 20-12. The chart shows the average diameter as well as an upper control limit and a lower control limit. If a part has a diameter greater than the upper control limit or smaller than the lower control limit—in this case, 6.02 inches and 5.98 inches, respectively—the production system is somehow flawed. If the diameter is within that range, then the system is operating satisfactorily. These control limits might be measurements (such as the diameter in our example), frequencies (such as the number of bad light bulbs in a sample), or number of defects per unit (such as the number of flaws on a piece of glass).

Quality Circles

Another outgrowth of W. Edwards Deming's statistical quality control concepts was the quality circle. Quality circles (QC) use a committee of workers that analyzes and solves problems relating to quality. They provide a form of participative management by letting workers

20-12 A CONTROL CHART

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Source: William H. Cunningham, Ramon J. Aldag, and Christopher M. Switi
Introduction to Business [Cincinnati: South-Western Publishing Co., 1984], p.
 207. Reproduced with permission.

make important inputs to key decisions. Typically, the committee consists of 6 to 12 volunteers from the same work area.²⁰ They receive training in problem solving, statistical quality control, and group processes. A facilitator, generally a specially trained member of management, help with training of circle members and sees that things run smoothly. The circles generally meet for about four hours a month on company time

20. This description is based on "E. E. Lawler, III, and S. A. Mohrman, "Quality Circles after the Fad," *Harvard Business Review* [January-February, 1985], 66.

QC objectives include quality improvement, productivity enhancement, and employee involvement.

Widely adopted in Japan since the 1950s, quality circles first appeared in the United States at Lockheed Missile and Space Company in 1974. Lockheed estimated that the circles had saved the company about \$3 million, and that savings from the circles exceeded costs by a ratio of six to one. It is estimated that there are now more than 3,000 circles in U.S. companies²¹ and that over 90 percent of the *Fortune* "500" companies now have QC programs.²² In fact, the acceptance of quality circles in the United States has been so rapid and widespread that they have taken on the appearance of "the managerial fad of the 80s."²³

Quality circles have some appealing characteristics—they encourage worker participation, provide an enriched job experience, develop problem-solving skills, and encourage goals of workers and the firm to be congruent—and their success in Japan is hard to deny. Further, since the circles only make recommendations, management does not give up control.

Nevertheless, a variety of concerns about QCs have been expressed. For instance, many people question whether the culture of the United States is right for quality circles. American management and workers differ in many ways from those in Japan, and a transplant may not take. Further, despite the initial appeal of QCs and the many anecdotes about their success, research shows that as many as 75 percent of initially successful QC programs were no longer in operation within a few years.²⁴ Rigorous empirical evidence concerning the effectiveness of quality circles is simply lacking.

The bottom line seems to be that quality circles often work and they often fail. Managers who consider using QCs must have realistic expectations and must consider their costs—often \$20,000 or more for a modest effort—as well as their potential benefits.²⁵ Quality circles cannot be forced onto organizations, nor do they seem to work well in situations of high stress. Finally, managers should check to make sure that the issues to be addressed by quality circles can realistically be expected to be improved by quality circle involvement. Problems caused by poor management planning or an inappropriate product mix will not be remedied by quality circles.²⁶

21. J. D. Blair and K. D. Ramsing, "Quality Circles and Production/Operations Management: Concerns and Caveats," *Journal of Operations Management* 4 (1983): 1-

22. Lawler and Mohrman, "Quality Circles," 66.

23. R. Wood, F. Hull, and K. Azumt, "Evaluating Quality Circles: The American Application," *California Management Review* vol. 26, no. 1 [1983], 38. See also M O'Donnell and R. J. CDonnell, "Quality Circles—The Latest Fad or a Real Winner?" *Business Horizons* vol. 27, no. 3 (May-June 1984), 48-52.

24. P. S. Goodman, "Quality of Work Projects in the 1980s," *Labor Law Journal* [1980], 487-94.

25. Blair and Ramsing, "Quality Circles and Production/Operations Management," 8.

26. These suggestions are drawn primarily from Blair and Ramsing, "Quality Circles and Production/Operations Management," 8-9.

Monitoring the Quality of Supplies

Quality control problems in production are often the result of poor quality inputs. Some companies have strong programs for ensuring the quality of incoming production materials and supplies. Xerox has a four-point program to assist suppliers. From the beginning of its new product development process, Xerox involves its suppliers in writing specifications for production materials and components. Xerox makes sure that its suppliers understand these specifications before supply orders are placed. It also operates a hotline for suppliers who have any last-minute questions. Finally, Xerox uses statistical quality control on its suppliers' manufacturing systems, and it uses a team approach for a check on the packing and handling of materials. Marked quality improvements have been attributed to Xerox's program.

MAINTENANCE POLICIES

A breakdown in a large piece of production machinery can be: extremely expensive in terms of lost production time and repair costs. Keeping production equipment in good repair is a big job: More than 514 billion a year is spent on maintenance alone by companies in the United States.²⁷ Maintenance can take one of three forms:

- ▲ **Corrective maintenance.** Fixing a machine that is not working properly.
- ▲ **Preventive maintenance.** Designing, inspecting, and servicing machinery so that breakdowns are less likely to occur.
- ▲ **Predictive maintenance.** Employing monitoring instruments to¹¹ estimate when machine failure is most likely to occur.

Preventive maintenance is usually less costly than corrective maintenance and so is preferred by most operations managers. Predictive maintenance is especially appropriate for complex, highly automated production processes.

Management should answer several questions concerning maintenance. For instance, how much maintenance is needed? Can computers and statistical methods be of help? Should an in-house maintenance staff be used or should outside people be brought in? Would preventive predictive maintenance be less expensive?

27. H. T. Amrine, J. A. Ritxhey, and O. S. Hulky, *Manufacturing Organization and Management*, 4th ed. [Englewood Cliffs, N]: Prentice-Hall, 1982), 315.

Most maintenance policies are just good common sense. For instance, it is usually best to try to schedule maintenance for periods when things are slow. If much maintenance is needed during peak periods, thought should be given to contracting out some work. And, there is usually a "best" time to replace or service equipment. If it is done too early, money is wasted; if it is done too late, repair may be costly or impossible.

THE FACTORY OF THE FUTURE

The increasing competition American manufacturers are facing in world markets has made them keenly aware of the need to improve their efficiency and effectiveness. To do so, some U.S. firms are now making major technological investments in what has been called the factory of the future. The factory of the future represents the computer-based integration of design, process, and control functions in the manufacturing environment. Such integration is made possible by the proliferation of inexpensive, yet powerful computers; advances in data communication technology and data base concepts; and the emergence of a computer software industry that can supply a growing selection of computer application software packages.²⁸

Manufacturing has historically been based on economies of scale, in which large numbers of identical components were manufactured on automated equipment in order to achieve low unit production costs. In contrast, the factory of the future tries to capture economies of scope, in which computerized controls allow the same automated machinery to produce a variety of products cheaply.²⁹ In this section we will describe the factory of the future and then look at one of its key elements, robotics.

Characteristics of the Factory of the Future

Mariann Jelinek and Toel Goldhar have presented the following characteristics of the factory of the future:³⁰

28. T. G. Gunn, "Factory of the Future—How to Get Starred," paper presented at the American Production and Inventory Control Society Operations Management Workshop (East Lansing, MI, July 1982), t.

29. J. C. Panzer and R. D. Willis, "Economies of Scale and Economies of Scope in Multi-Output Production," [J-folmdel, NJ: Bell Laboratories Discussion Paper No. 33, Bell Laboratories, August 1977]

30. M. Jelinek and J. D. Goldhar, "The Strategic Implications of the Factory of the Future," *Sloan Management Review* [Summer 1984], 29-37.

Academic Profile



RICHARD F. GONZALEZ

Richard F. Gonzalez (Ph.D., University of Iowa) is Professor of Management at Michigan State University and recently served as operations management consultant to the World Bank in Bangladesh. He is the author of *Manufacturing Resource Planning*, *The Operations Manager*, *Systems Analysis: A Computer Approach to Decision Models*, and several other books, and edited *Restructuring Operations to Meet the Competitive Challenge*. Professor Gonzalez's many roles in professional organizations have included editorial board member for the *Academy of Management Review*, vice-president of the National Decision Sciences Institute, and vice-president of the Operations Management Association.

Q: It seems that many issues in operations management, such as just-in-time, robotics, statistical quality control, and CAD/CAM are now generating considerable public interest and attention. Do you see this as a reflection of a growing recognition of the importance of operations management?

A: I'm not sure that public interest in these technologies reflects awareness of the strategic importance of operations management. News stories about the "factory of the future" capture the reader's attention. Descriptions of Japanese factories operating around the clock without the use of human operators stir the imagination.

The public knows that U.S. manufacturers have lost market share to foreign competitors. We have read accounts of the "production miracle" that enables Japanese automobile manufacturers to produce a vehicle, ship it to the United States, pay import duty, and still enjoy a cost advantage of \$2,000 when compared with a comparable vehicle built in Detroit.

The implications for U.S. manufacturers are very clear. They must develop new skills, technologies, and attitudes if they hope to stay competitive. I think it is the public's concern about the viability of U.S. manufacturing industries that accounts for the interest in JIT, SQC, and so on. Q: The GM Saturn plant is being heralded as a testing ground for new concepts, including heavy reliance on intelligent robots, modular construction, and just-in-time procedures. Are you optimistic about the probable success of that plant? Do you see it as a step toward a time when assembly lines as we now know them will cease to exist?

A: It's too early to speculate about the success of GM's Saturn project. Indeed, many details are not

yet reported. We know that the planned Saturn plant is the ultimate "factory of the future," a revolutionary blend of process, communication, and computing technologies. GM's goal is recapturing the lead it once had in all segments of the auto industry. The commitment of top management and GM's resources argue strongly that Saturn will succeed.

Because less-developed countries enjoy lower labor and energy costs, we should expect to lose out in markets for standard products which are mass-produced. Saturn is an attempt to remain competitive. But eventually the Saturn technology will become available worldwide just as mass production technologies were exported to less-developed countries.

Robert Reich in his book, *The Next American Frontier*, argues that U.S. manufacturers must prepare to produce small batches of specialized, high-valued products that are precision engineered, custom tailored to serve individual markets, and rapidly evolving technologies. The key to the future, according to Reich, is that most unique American resource: Americans themselves. Industries in the future will require a skilled, adaptable, and innovative labor force and a flexible, less hierarchical organization of work. With all the resources available to GM, the success of Saturn is dependent as much on the quality of people (especially management) as on the quality of hardware.

The assembly line as we know it will continue to be used to repetitively manufacture standard products. I expect to see a mixture of human and nonhuman operators (robots). And I expect modifications in product and process technology to enable the assembly line to produce items that are somewhat customized.

- ▲ *Flexibility.* With the flexible automation of the factory of the future, custom products can be produced at close to mass-production costs. Firms will find it easier to respond to needed change, quickly updating products and increasing their complexity and technological content as required.
- A *Information richness.* As computers and inexpensive electronic circuitry proliferate, firms will enjoy information richness at low cost. It will be easy to monitor, analyze, and ultimately optimize almost any operation process.
- ▲ *Control.* Through the use of computer controls, memory, and the sensors that generate improved knowledge of production processes, factory operations can be optimized far better than in the past. Quality will increase while costs for waste are reduced. More reliable operations will permit maintenance to be scheduled more predictably to ensure fewer stoppages and less down time.
- A *Integration.* Computer integration offers benefits beyond those of automation of individual processes. **Computer-integrated manufacturing (CIM)** will link computer-aided engineering (CAE); computer-assisted design [CAD]; and computer-aided manufacturing (CAM), each of which are discussed in Chapter 18, multiplying their individual benefits.
- A *Closely coupled systems.* In the factory of the future, the various functions of the firm will be tightly linked. For instance, close relations must be fostered among manufacturing, design, and marketing to ensure timely response to new features or product designs and to be sure that promises to customers are based on sufficient knowledge of manufacturing capabilities and schedules.

Robotics

One of the authors recently attended a week-long conference on new developments in operations management. Of the many topics covered and facts presented, perhaps the most thought provoking was a simple photograph. It was solid black, with only a pinpoint of white in the lower right-hand corner. The photograph showed the third shift at a Japanese auto plant. No lights were needed by the sightless robots that completely ran the plant. The pinpoint of white was from the flashlight of the lone guard.

The term robot comes from the Czech *robota*, meaning drudgery, servitude, or forced labor. Czech playwright Karl Capek introduced the term over 65 years ago. His satirical play *R.U.R.* raised questions about the dehumanizing impact of technological progress on humankind.³¹

31. For a discussion, see R. B. Blackey, "Will Robots Carry Union Cards?" *Business and Society Review* (Spring 1985), 33. For further discussions of robotics, see E. M. Knod, jr.,

Many predict that robotics will play an increasingly important role in the workplace of the future.



Now, a robot is defined as a machine that can be programmed to do a variety of tasks automatically.

The variety of robots is remarkable. There is now a bureaucratic robot that stamps signatures on letters, a nurse robot to assist handicapped persons in wheelchairs, a robot "janitor and dog" for the blind, and robots to give training to illiterates and to advertise products. Some industrial robots are mobile and have many arms, but most are nothing more than a mechanical arm attached to a stationary base. A programmable computing device controls the operations of the robot. Robots in U.S. factories are now performing such manufacturing tasks as spray painting, arc welding, die casting, assembling, and materials handling. Use of robots in manufacturing quadrupled between 1979 and 1981, and that growth is continuing. The robot population in this country could reach 100,000 by 1990.

The science-fiction-like qualities of robots have captured the public's imagination. Further, robots can be used for dangerous or unpleasant jobs, handle heavy loads, work odd hours, and provide flexibility. However, the great growth in use of robots is largely the result of simple economics. About 25 years ago, an assembly line robot cost \$4.20 an hour to operate, a figure that was slightly higher than the hourly rate paid to an average factory worker. By 1981, auto manufacturers were able to operate robots for \$6 per hour versus \$20 for skilled labor. Roger Smith, chair of the board of General Motors, stated, "Every time the cost of labor goes up \$1 an hour, 1,000 more robots become economical."³² As

et al., "Robotics: Challenges for the Human Resource Manager," *Business Horizons* no. 2 (March-April 1984): 38-46; and E. K. Foulkes and J. L. Hirsch, "People Make So' Work," *Harvard Business Review* vol. 67, no. 1 (January-February 1984): 94-102. 32. *The New York Times* [October 14, 1981]

household appliances company compared a conventional line and a robot line for parts manufacture. The results are presented in Figure 20-13. Because of its superiority, the robot line was chosen. Further savings of \$900,000 provided by shorter lead times with the robot plant paid back its higher initial investment in a year and a half.³³

A CONVENTIONAL VERSUS A ROBOT PRODUCTION LINE



	Conventional Line	Robot Line
Number of Operators	28	6
space	1,700 m ^a	300m ²
Lead time for part design change	.3-4 weeks	4 minutes
Investment costs	3450,000	\$850,000

Source: Reprinted from "The Strategic Implications of the factory of the Future" by Mariann (elinek and foel D. Goldhar, SLOAN MANAGEMENT REVIEW, vol. 25, no. 4 (Summer 1984), p. 30, by permission of the publisher. Copyright © 1984 by the Sloan Management Review Association. All rights reserved.

The number of robots in use in the United States is growing rapidly. At its Lordstown, Ohio, plant, GM has 26 advanced Unimate robots that apply 450 welds to every car that comes off the line. The Unimates have "super seniority"—they stay in the plant during layoffs and shut-downs and are back at work as soon as they are needed. A Unimate costs \$45,000 and pays for itself in less than 15 months by replacing two \$28,000-a-year welders. Robots are a key part of GM's revolutionary new Saturn plant, described in Situation 2.

SITUATION 2

Project Saturn

General Motors has decided on "Project Saturn¹⁷" as the name for its current, \$2 billion attempt to build a competitive small car. If Saturn fails, GM is likely to give up U.S. small-car production and sharply increase its purchases of small cars from affiliates in Japan, South Korea, and elsewhere.

33. Jelinek and Goldhar, "Strategic Implications," 30.

GM's Saturn effort is extremely ambitious. The company isn't just talking about building a new car; it is aiming to come up with a whole new production system. The company hopes to abandon the assembly line that has been standard in the industry since the first Henry Ford, to decrease dramatically the number of parts and the amount of labor needed to build the car, and to leapfrog competitors in the use of highly sophisticated robots. If GM succeeds, it could establish itself as one of the world's lowest cost auto producers and force its domestic competitors to revamp their operations at huge cost.

The overriding idea is to compensate for the Japanese \$8-to-\$10-an-hour advantage in labor costs by cutting drastically the number of person-hours required to build a car. GM may have to slash person-hours to 30 per car from its current 175 (compared with about 100 for Japanese manufacturers).

The biggest single change slated for Saturn is so-called modular construction. The modular method was first used in 1974 by Volvo AB at Kalmar, Sweden. Under modular construction, the parts are first subassembled into a few fairly large components called "modules." The final assembly isn't done on an assembly line at all. Workers or teams of workers posted at stationary work stations put the modules together, and instead of having one or only a few tasks to do, they perform a whole cluster of tasks, such as building a whole fender or front end. Trolleys carrying the partly completed cars move along a command from station to station.

Modular construction requires less space (because the long conveyors are eliminated) and (fewer workers (because each performs more tasks), it also lends itself readily to reductions in the number of parts and to greater use of sophisticated robots.

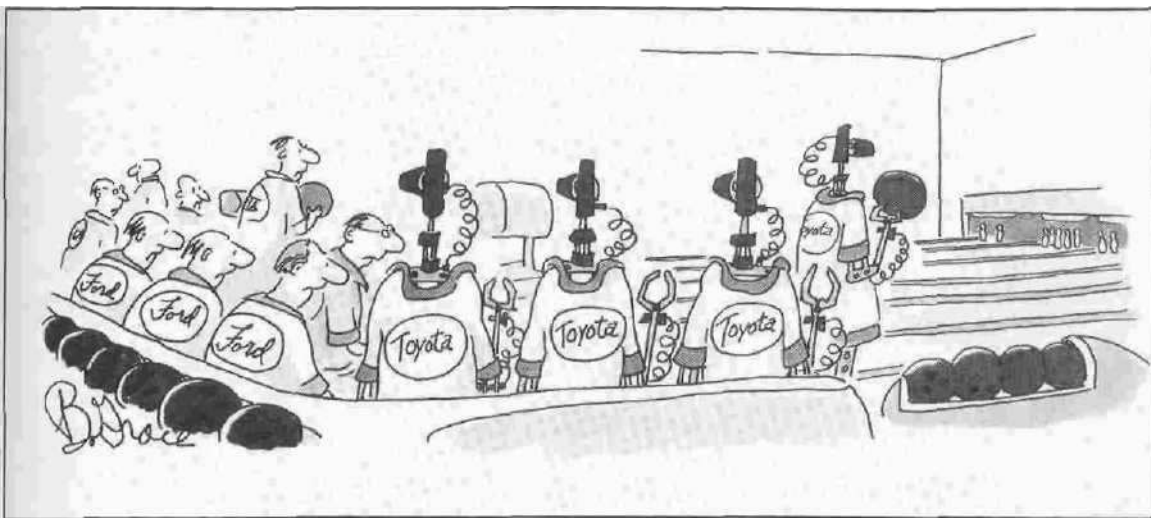
In building the subassemblies, GM plans to rely heavily on so-called intelligent robots. Currently, robots are used only in the final assembly process for spot welding and materials handling or for such relatively simple tasks as attaching a tire to a wheel. That is because current robots have sharply limited abilities. Intelligent robots would be able, in contrast, to "see" that a part is out of position, calculate how far out of position it is and adjust its own operations on the part accordingly. Thus, such robots could perform complex assembly steps such as installing interior trim. As robots got even more intelligent, they could do quick quality-control checks on the dimensions and tolerances of parts as well.

To make Saturn work, GM needs cooperation from the United Workers—possibly a big hurdle. Industry experts think that GM will have to drop most of its 140 or so job classifications to permit a single worker to fill various assembly, inspection, and equipment-maintenance tasks under modular construction.

Another hurdle will be to get GM's thousands of suppliers to make necessary sacrifices. To cut inventory costs and improve quality, suppliers have to invest in new equipment and locate plants close to GM's Saturn facilities. But many are wary; they fear they will be stuck with losses if Saturn fails.

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Robots are seen by many as threatening. While some people were formerly at least secure in the belief that someone would have to build the robots, there are now instances of reproductive robotics, in which robots build robots. They may cause unemployment, for instance, a Carnegie-Mellon study concluded that the current generation of robots has the technical capability to perform nearly seven million existing factory jobs—one third of all manufacturing employment. Sometime after 1990 it will be technically possible to replace all manufacturing operatives in the automotive, electrical equipment, and fabricated-metals industries. At the Fujitsu Fanuc Company, robots are allowed to join the union. The company pays their dues.³⁴



Source: Bud Grace © 1984- *Science* '84

The amount of unemployment which will ultimately result from automation is hotly debated. One estimate is that the effect of automation would be the loss of 1 percent per year of U.S. manufacturing jobs, and one-fourth percent per year of all U.S. jobs.³⁵ Others argue that negative effects will be short term and are overstated. According to this view, automation will result in higher productivity and, with it, new jobs.³⁶ While many people agree that long-run effects may well be beneficial.

34. L. Silk, "Strangf New Robotic World," *The New York Times* [May 4, 1983], D2.

35. R. Ayres and S. Miller, "Robotics, CAM, and industrial Productivity," *National Productivity Review* vol. 1, no. 1 (1982]

36. See, for instance, R. Vedder, "Robotics and the Economy," paper prepared for the Joint Economic Committee, U.S. Congress [March 26, 1982].

someone has accurately pointed out that in the long run, we're all dead. There will almost certainly be substantial short-term displacements as a result of automation. Companies, unions, and government will have to seek creative ways to deal with them.³⁷

IMPLICATIONS FOR MANAGEMENT

In the eyes of some people, operations management is a dull matter, something to do with keeping the boilers running. In fact, as we've seen in this chapter, operations managers are largely responsible for some of the most important issues facing American business, such as quality, on-time delivery, and productivity. Further, operations management is just as applicable to the rapidly growing service sector as it is to production operations.

The strategic role of operations management is evident in many of its facets. Capacity planning, for instance, forces the operations manager to anticipate future market and technological trends and developments. Capacity planning decisions, in turn, have an enduring impact on all functions of the firm. Decisions about the ways in which inventory will be maintained and quality assured also have remarkably strong impact, sometimes literally dictating the survival of the firm.

Operations managers are confronted with many of the most exciting new developments in management. The just-in-time inventory system, for instance, not only has major cost consequences for the firm, but also mandates patterns of buyer-supplier relationships, perhaps transforming entire industries. Quality circles provide a forum for worker participation in a crucial area. The emerging factory of the future holds both promise and threat. Its technological innovations offer firms flexibility, information richness, integration, and control. With heavy reliance on robotics, costs can be drastically reduced. Nevertheless, the initial investment required for such technology is great, and individual workers may be displaced.

On the surface, operations management is different from many of the other management topics we have examined. It seems to deal, after all, more with facilities than with people. A bit of reflection, though, will indicate that such a distinction is inappropriate. This chapter has shown decisions on plant capacity, materials purchasing, inventory systems, and technological innovation to be integral to organizational structure and strategic planning. And we have seen that decisions on facility layout, quality control methods, and robotics may have consequences for employee motivation, performance, and job security of individual workers.

37. See McCain and Thomas, *Operations Management*, 137-39, for more on this issue. H

firm, as we have repeatedly stressed, is a system. The strengths of its internal and external linkages are becoming increasingly evident.

It would be wrong to suggest that operations management bears the blame for declining productivity and poor quality, or that it holds the sole promise for their improvement. Motivation, leadership, communications, task design, and even simple respect for the individual may ultimately be just as important. Nevertheless, many of the conspicuous differences between American firms and, for example, their Japanese counterparts fall into the domain of operations management. This is an exciting area which will almost certainly take on greater strategic significance in coming decades. Managers, whatever their specialized interests, would do well to explore it.

KEY TERMS AND CONCEPTS

bill of material	ordering costs
computer-integrated	periodic inventory
manufacturing (CIM)	perpetual inventory
corrective maintenance	predictive maintenance
critical path	preventive maintenance
dispatching	process layout
economic order quantity (EOQ)	product layout
economies of scope	program evaluation and review technique (PERT) chart
factory of the future	quality circles (QC)
fixed-position layout	quality control
follow-up	reorder point
forward buying	reorder quantity
holding or carrying costs	robot
inspection inventory record	aiming
just-in-time (JIT)	routing schedule
kanban	chart
lead time	scheduling
loading	slack time
master production schedule	statistical quality control
material requirements planning (MRP)	stockout costs
operations	transformation process
operations management	

REVIEW QUESTIONS

1. Describe four types of transformation processes.
2. List three cost factors and three noncost factors in facility location.
3. What are the three types of facilities layout?
4. Describe four key trade-offs in operations management.
5. List and describe the steps in the purchasing cycle.

6. What are the three costs in inventory control? How does each vary with quantity ordered?
7. What are the characteristics of a just-in-time inventory system?
8. List the steps in the production planning and control process.
9. What is a Gantt chart?
10. Explain how a control chart is used.
11. How does a quality circle work?
12. What are three forms of maintenance?
13. Give four characteristics of the factory of the future.
14. What is a robot?

CASE 20 A Flexible Manufacturing Systems

Flexible manufacturing systems—the high-technology solution to factory production—are finally gaining acceptance on the plant floor. The sophisticated units, known as FMS installations, are production systems that contain two or more machine tools served by automated materials-handling equipment and supervised by a computer. They are capable of producing hundreds of different parts in random order as dictated by the computer. Typically, they require little, if any, direct labor.

Fifteen years ago, these systems promised to spark a revolution in domestic manufacturing. U.S. manufacturers thought that FMS, combined with computer-directed systems for assembling the parts produced by FMS, would help counter foreign competitors' lower labor costs. They were expected to be a boon to the domestic machine-tool industry, which is better able to provide the close cooperation with customers required in planning, installing, and debugging the systems.

But FMS have evolved slowly. With each system usually costing between \$5 million and \$20 million, they frequently aren't the least expensive way to make parts. However, considering their other benefits, from inventory reduction to quality improvement, FMS can still be a good investment.

U.S. manufacturers ordered 14 flexible manufacturing systems during 1984 and 1985, compared to four systems during the two previous years. There are between 20 and 50 systems in the U.S. today, industry analysts say, with the disparity reflecting an argument over how sophisticated a system has to be before it is considered an FMS.

A main reason for the increase in orders is manufacturers' interest in "just-in-time" inventory management, which emphasizes having parts available only as they are needed. An FMS is ideal in such a situation because it permits the economical production of just one part of each type. It can inspect the parts and keep track of what is produced. These parts can be assembled into a product as they come out of the FMS. Once manufacturers have completed the initial round of cost cutting, such as closing excess plant capacity and pushing down materials costs, the largest remaining savings opportunities are to reduce indirect labor, such as fork-lift operators and warehouse workers, and to cut inventories.

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1. For what sorts of products and situation?

would FMS seem to be most useful?
Least useful'

2. What do you see as factors inhibiting growth in adoption of FMS? Who might you expect to be opposed to their instal-

lation?

3. In what ways is the impact of FMS likely to be similar to that of other automation such as the assembly line? In what ways is it likely to be different?

PART 6 CASE A E. F. Hutton: Out of Control?

Eleven months after The E. F. Hutton Group Inc.'s securities unit pleaded guilty to 2,000 counts of fraud stemming from check overdrafting, the big financial-services company found itself mired in further problems. Despite moves to beef up management, Hutton Group sustained a string of reverses, unrelated to the overdrawing, that suggested it faced a tougher-than-anticipated job of patching up its internal controls and its reputation. At stake was Hutton Group's ability to grow and keep pace with larger, more diversified competitors, some backed by giant parent corporations.

Recently, Hutton was jolted by the following reverses:

A While most Wall Street firms were racking up huge fourth-quarter profits and gains for all of 1985, Hutton Group incurred a \$12.2 million loss for the quarter and a 17-percent earnings drop for the year, to \$43.7 million. The fourth-quarter red ink was largely due to a \$26.3 million reserve for a possibly bad loan, a \$14 million set-aside for losses in mortgage-backed securities and, despite one of the strongest bond rallies in history, a bond-trading loss of nearly \$7 million.

A In February of 1986, the E. F. Hutton & Company securities unit became embroiled in the case of Leslie Roberts, a 23-year-old broker arrested in Florida and accused of mail fraud by the Federal Bureau of Investigation for allegedly bilking a relative out of millions of dollars. Mr. Roberts, whose ap-

parent ability to generate commissions marked him as a wimderkind broker, allegedly had committed the fraud both at Hutton and, after he quit the firm, at Merrill Lynch & Company. A In March of 1986, Hutton Group's trust company in Delaware came under investigation by state banking authorities after a former officer of the bank charged, among other things, that Hutton brokers were churning trust accounts to inflate commissions.

All these problems and allegations suggest the possibility of "a central control problem at Hutton," says Rodney Schwartz, a securities analyst with Paine Webber Inc., a competitor. "There's a lot of work to do at Hutton before it's back on its feet."

In Washington, Hutton Chairman Robert Fomon is scheduled to testify before the Senate Judiciary Committee on what, if anything, Hutton's executives knew about the check-overdrafting scheme. The legislators are also expected to focus on why Hutton officials weren't prosecuted as part of the guilty pleas.

The House Judiciary Subcommittee on Crime will soon release a report on Hutton's check-writing operation that is expected to severely censure the firm's management. Bolstered by a recent federal court ruling in Scranton, Pennsylvania, the subcommittee is stepping up efforts to hold Justice Department officials in contempt of Congress if they fail to turn over additional documents related to the Hutton investigation.

In addition, the Justice Department is continuing what one prosecutor calls a "painstaking, extremely methodical investigation" of whether some Hutton officials or attorneys may have obstructed justice by withholding or destroying subpoenaed documents during the department's inquiry into the check writing.

Hutton has denied intentionally withholding or destroying documents and says it inadvertently overlooked some files at headquarters and elsewhere while it was turning over seven million pages of material to prosecutors. The company has said none of the disputed material "necessarily indicates knowledge of improper banking practices on the part of any particular individual."

In an effort to tighten controls, Hutton Group added a number of top managers with impressive Wall Street credentials. In June, 1985 it recruited Robert Rittereiser, a Merrill Lynch executive vice-president and quickly promoted him to the presidency of the Hutton Group and of the brokerage subsidiary. In 1986, the company hired executives from outside the firm to fill key upper management positions. The additions have raised questions as to whether Chairman Fomon, who is 61 years old, will remain chief executive officer until he turns 65—his stated intention.

Hutton has traditionally prided itself on its hands-off management style, delegating considerable autonomy to its regional and branch-office managers. But what insiders described as hands-off, outsiders and industry rivals called loose management controls. Former Attorney General Griffin Bell, who studied Hutton at the firm's request after the overdraft scandal broke, said in his report that poor management controls were at the root of the problem. Competitors and industry analysts add that Hutton's laissez-faire style, which it applied to trading and investment banking as well as

its retail securities business over the past decade as it expanded those lines, contributed to many of Hutton's difficulties since the overdraft scandal.

In November of 1985, for instance, the E. F. Hutton Mortgage Corporation unit, based in Little Rock, Arkansas, sued First American Mortgage Company in federal court in Baltimore. The suit contended that the Hutton unit was defrauded by the issuer of second and third mortgages. Baltimore-based First American filed for bankruptcy-court protection shortly thereafter. Hutton Group's resulting \$14 million fourth-quarter set-aside might have been smaller or avoided completely if the company had exerted tighter control over its purchases of these relatively risky mortgages, industry officials say.

Like other firms, Hutton courts **brokers** whose annual commission revenues run into seven figures. But competitors say it couldn't have investigated very closely the case of 23-year-old Leslie Roberts, who in 1984 and 1985 generated, both for himself and for the firm, a total of about \$2.5 million of commissions.

Mr. Roberts allegedly defrauded a relative, Frank Gory, out of millions of dollars while Mr. Roberts was at Hutton, and later, at Merrill Lynch, by sending Mr. Gory allegedly false trading statements. Hutton officials say they told Mr. Gory last year that he had large losses in his account. However, the alleged fraud wasn't uncovered until after Mr. Roberts left Hutton for Merrill. Another relative of Mr. Gory came to Hutton early this year and said he could get the account away from Mr. Roberts, and there! He produced an allegedly false trading statement.

In Delaware, the state banking Commissioner is investigating charges, filed with his office, accusing E. F. Hutton Trust Co. of churning trust assets and violating fiduciary obligations. Hutton has contended **that** the

excessive-trading allegations, lodged by Kay Shearin, formerly Hutton Trust's counsel, secretary, and vice-president, are baseless and were made by a disgruntled former employee.

In the wake of all these problems, industry officials say, Hutton has to tighten its management structure without alienating its sales force. To cement ties with the sales force, Mr. Rittereiser named a number *at* branch managers and brokers to a committee to work with him in evaluating the firm's strengths and weaknesses in their control systems. Says Mr. Schwartz of PaineWebber: "Rittereiser is moving in the right direction, but Hutton has to find its destiny."

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Do you believe a top-down or bottom-up control system would be most effective for solving the problems at E. F. Hutton? What influence do you think market, bureaucratic, and clan control had on the problems at E. F. Hutton? On the basis of the case material, thoroughly evaluate the management information system at E. F. Hutton. Specify some potential roles for decision support systems at E. F. Hutton.

