

# Chapter 1

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## The Industrial Enterprise

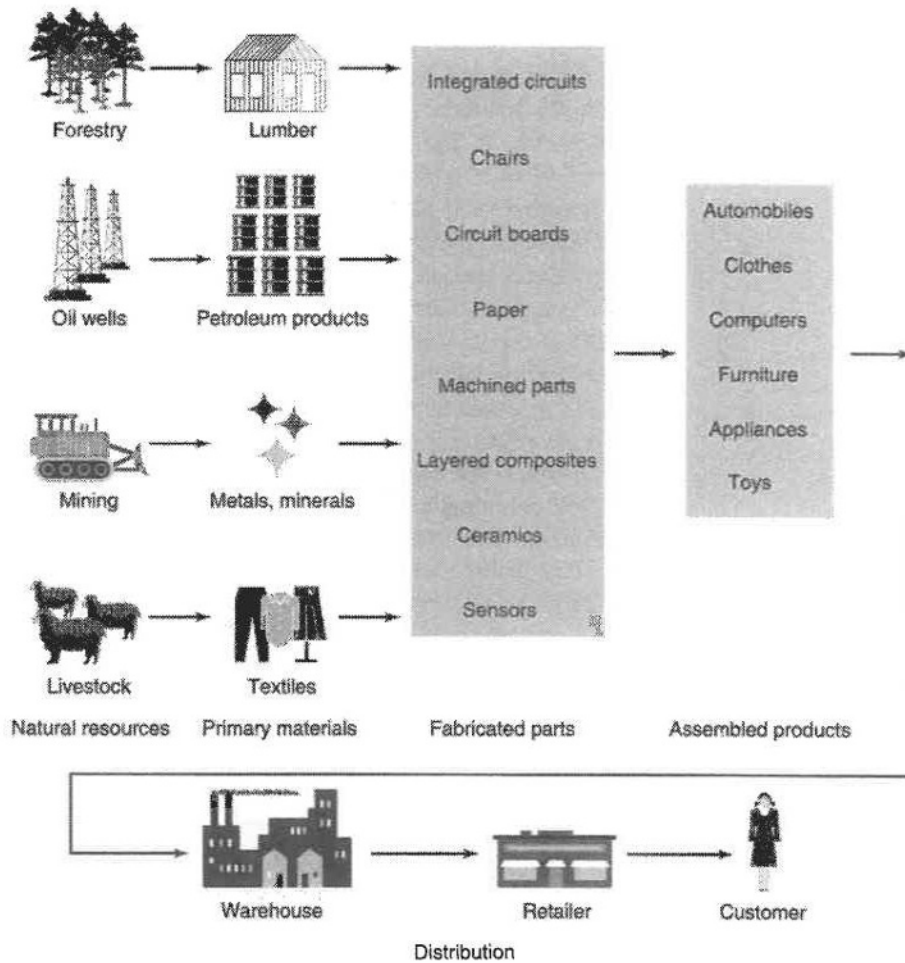
Automobiles, telephones, furniture, clothes, and games. These and all the other products we use in our daily lives are designed, manufactured, and delivered with the intention of making a profit for the producer by enhancing the quality of life of the customer. To achieve this result, entrepreneurs must arrange to bring together the necessary financial, technological, information, and human resources to design, implement, and operate the complete manufacturing system. In this text, we concentrate on one aspect of that total manufacturing spectrum, the production planning and control system. For the most part, we will assume the products have already been designed, and the technologies to be used to make these products have been selected. We will focus on the questions of what to make, how much to make, and when to make it. The associated issues of acquiring raw materials, selecting the most efficient production methods, and deciding how to distribute products (get them to the customers) will also be discussed.

Production system design and operation involve managing production resources to meet customer demand. Managing the system requires the development and execution of production schedules detailing how to use resources to convert raw materials into finished products. In addition to employees, machines, tools, and materials, relevant resources include utilities, information, and established procedures. The physical items used and produced by the system are referred to as **inventory**. Inventories are created during the production process and held in the form of raw materials, component parts, subassemblies, and finished products. The scope of the production system includes long-term **planning**, medium-term production **scheduling**, and short-term **control** (dispatching) decisions. The acquisition of new capacity and development of productive employees require planning months in advance of actual usage of these resources. The interface between long-term planning and medium-term scheduling involves setting production goals for each product over the next several weeks. With these objectives set, short-term schedules must detail the sequence of activities for each worker and machine resource for the current day or week. We may be able to develop a plan for these activities, but the stochastic nature of the world as evidenced by machine breakdowns,

late deliveries, defective parts, and changes in customer orders requires that we be able to react quickly to changing conditions. If we plan wisely, we will have the flexibility to adapt to the random events of the everyday world.

The reader should keep in mind that many steps are involved in converting raw materials into delivered products. We must typically fabricate many component parts, assemble these parts into the final product, and deliver the product to the point of sale. Fabrication and assembly may occur at a single location or may involve facilities spread around the world. Some companies choose to keep as many activities “in-house” as possible, whereas other companies are little more than production managers, subcontracting out most activities. The first approach allows tighter control, but the latter approach allows groups to focus on what they do best and permits the company to remain flexible and constantly seek the best supplier for each activity. The latter situation has become increasingly more common for complex products as companies seek to cope in a dynamic world.

Throughout the system we must ensure conformance to product quality requirements, and execute the necessary administrative support functions. This becomes increasingly complex when dealing with multiple cultures, measurement systems, languages, and standards. Figure 1.1 illustrates the overall production process from “ore to door” for a large product such as an automobile or computer. At each stage of this process, we incur cost and add value to the product. However, the valid criteria deal not with the individual steps, but with the total cost of the system and state of the final delivered product. Thus, we will endeavor to maintain a system-wide perspective on the effects of our planning and control decisions.



**Figure 1.1** The Supply Chain from “Ore to Door”

The industrial firm maintains its existence by providing customers with products whose societal value exceeds their cost of production plus delivery. The product may be a physical good or service.<sup>1</sup> In describing the industrial firm, we will look at the measures that determine the viability of the firm as indicated by its products and/or services, the necessary functional areas of the firm, and the specific activities in the product design, manufacture, and delivery process.

## 1.1 MEASURES OF COMPETITIVENESS

The industrial firm competes in multiple dimensions. When car shopping you will probably buy from the dealer that has the car you want at the lowest **price**. However,

<sup>1</sup> In this text, we will concentrate on physical products produced by manufacturing industries, but much of the discussion herein pertains to service industries as well.

you very likely first limited your choice to a few select models, colors, and optional configurations. Thus, **product features**, both cosmetic and functional, are important. Likewise, you probably stayed clear of any models or dealers with poor **quality** or **service** reputations. And, of course, you restricted yourself to vehicles with **availability** within your time window. Firms compete in all these dimensions. Many firms today perform benchmark analyses of their performance relative to the best in their industry. Such analyses yield information on competitiveness and indicate requirements for success and opportunities for market penetration.

## **1.2 FUNCTIONAL AREAS OF THE FIRM**

Industrial firms vary widely in the products they make and their internal philosophies toward employee development and technology acquisition, but they must all perform the same conceptual functions. Table 1.1 lists the major organizational units commonly found in industrial firms. It is best to view these units as functions instead of departments. Although traditionally each function may have been a separate department, an increasingly popular organizational structure creates employee reporting structures based on product line. Thus, each major product category, such as toasters, microwave ovens, and conventional ovens, would have its own unit to perform each function. This product-based organizational structure causes a greater identification with the product and facilitates cross-disciplinary teamwork. Unfortunately, many of the techniques needed by the individuals relate to their technical discipline and continuing technical education is best accomplished through that discipline. As a result, many companies have found it preferable to use a matrix structure. Individuals reside in an organizational unit based on their technical expertise such as accounting or maintenance, but they are normally on loan and temporarily report to a product-based team. Figure 1.2 illustrates this structure.

## **1.3 PRODUCT DESIGN, MANUFACTURE, AND DELIVERY**

The primary mission of the firm relates to supplying goods and services to satisfy customer needs. Laws governing financial reporting, environmental impact, and product safety; the availability of capital, labor, and materials; customer preferences; and the state of technological knowledge create constraints on how the firm accomplishes this mission. Corporate management strives to maximize profit by determining the optimal targets for the competitive factors discussed above subject to these constraints. The

company must then design and implement systems and procedures to achieve these targets. This leads to the set of functional areas listed in Table 1.1. In addition, management must create an atmosphere conducive to success. Factors such as employee morale, organizational structure, and employee empowerment must be monitored to ensure their support for achieving corporate objectives.

**Table 1.1** Major Functional Units of an Industrial Firm

Functional unit	Activities
Executive Committee	Strategic Planning
Design Engineering	Product Design
Product Engineering	Process Planning
	Test Design
Manufacturing	Production Planning
	Scheduling
	Materials Management
	Material Handling (incl. shipping)
	Tooling
Facilities	Building/Site Layout
	Maintenance
	Equipment Installation
	Utilities
Product Assurance	Quality Assurance
Research and Development	Product Development
	New Technology Evaluation and Implementation
Management Information Systems	Data Processing
	Report Generation
Procurement	Vendor Certification
	Purchasing
Finance	Budgeting
	Cash Flow Management
Accounting	Financial Reporting
	Managerial or Cost Accounting
	Accounts Payable
	Accounts Receivable
Marketing	Sales
	Order Entry
	Forecasting
	Customer Relations
	Advertising

Human Resources

Recruitment

Labor Relations

Wage Administration

Employee Protection (Safety, Equal Opportunity)

Training

Several functions must be executed to create and deliver products. From a chronological perspective, these functions include:

	Project Team (Leader)				
(Manager) Functional Department	(Sanjay) Body frame	(Herbert) Power train	(Kuei) Controls	...	...
(Richard) Mechanical Design	Bill Frank R.	Sam Tom	Samantha Joe		
(Barbara) Electrical Design	Gloria Frank T.	Ron Linda	Ramesh		
(Fang Yu) Test	Fred	Susan Kim	Ralph		
(To be filled) Industrial Design	Sherry	Dave	-		
(Henry) Marketing	Rick		-		
...					

Figure 1.2 Matrix Organization Structure

1. Product, Process, Tooling, and Test Design
2. Manufacturing
3. Distribution
4. Product Support and Maintenance
5. Product and Process Disposal

These activities fall into the phases of product development, production, and usage. Figure 1.3 depicts the product life cycle and the involvement of major functional areas over time. The figure envisions a completely new product being brought to life. The process shown is somewhat simplified. In reality, design engineering stays involved throughout the product's life cycle issuing engineering changes to incorporate improvements in performance and cost reductions. In addition, most new designs represent minor upgrades or modifications of existing products. Eventually, the market

becomes saturated, technological breakthroughs occur, and new creative concepts indicate it is time to develop a new generation of products.

### 1.3.1 Integrated Product, Process, Tooling, and Test Design

Integrated product design begins with collection of customer specification information. Products typically develop from either response to a customer request for quotation or marketing research. The first case occurs with military/government contracts and industrial tooling such as dies. The product idea exists, and the customer is in search of a producer. Alternatively, the producer's marketing department may be surveying potential customers to determine opportunities. Occasionally, the serendipitous discovery of a new technology or product creates a market. The 3M Company's revolutionary Scotchgard developed in this manner. A lab assistant accidentally spilled a chemical mix on a pair of canvas tennis shoes. The shoes then proved to be waterproof and stain-resistant. Most large companies maintain Research and Development groups charged with advancing basic science and finding commercial applications. Breakthroughs in electronics such as the transistor and wafer-fabrication processes have led to new products for computing and telecommunication that have transformed our daily lives.

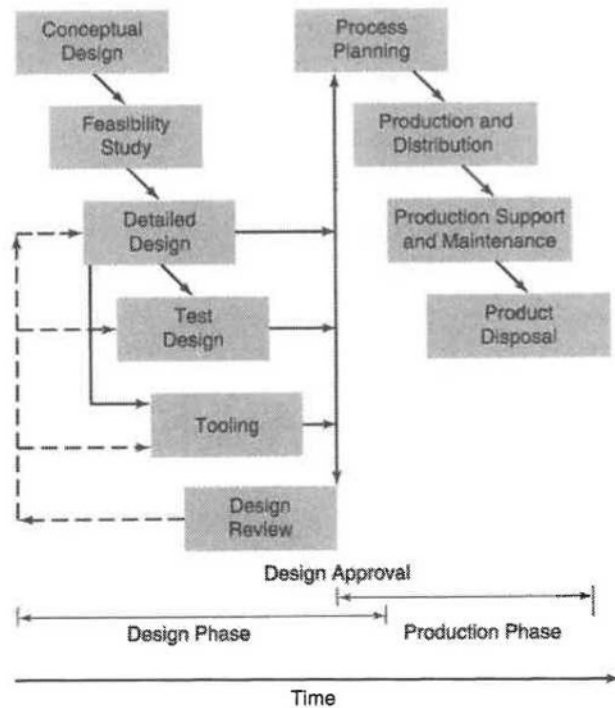


Figure 1.3 The Product Design and Production Process

After collecting customer desires, functional specifications are determined for the product and placed in the internal technical jargon of the firm. Breaking strength in psi and computer storage disk access time in milliseconds are examples. Knowledge on available technology is then synthesized to select the technological approach. Several initial concepts may be generated and compared. This is followed by detailed design and analysis along with formal reviews to accept or reject product designs. In today's rapidly changing technological world, the speed at which new products can be brought to the marketplace often determines the financial success of a company. Current approaches call for simultaneous or concurrent engineering of the product design, manufacturing processes, test equipment, and maintenance plan. Thus, a multidisciplinary team of designers works together to develop the product including its manufacture, test, and service plans. The product design as described in the product definition data must normally be approved by all relevant functional areas of the firm including marketing, purchasing, and finance in addition to the technical areas just noted. Production tooling and test equipment may be designed along with the product. Although this may seem wasteful because not all data necessary for tool and test design will be available until the product design is complete, the integration of these activities frequently reduces the number of iterations required to pass through the design and review cycle. Eliminating costly missteps and design changes in this manner allows the final product to hit the shelves quicker and with lower total cost.

Techniques such as the House of Quality (Clausing [1988]) can be used to guide the acquisition of data and setting of product specifications and to increase the chances of product success. A simplified house is illustrated in Figure 1.4. The **customer attributes** of importance are listed on the left of the house (each level of the house describes "what" the customer wants). A relative measure of importance should be assigned to each customer attribute. Next, the columns are the **engineering characteristics** that will indicate "how" we can measure in technical language whether the attributes are achieved. The elements in the central array indicate the degree of correspondence between each attribute and characteristic. The basement of the house contains an indication of the difficulty in improving each engineering characteristic, a summary of measures for the products of competitors, and our target levels. Product design usually involves breaking down the product into modules. Each module is assigned a subset of functions to perform (engineering characteristics to meet). The design of each module

can be farmed out to the group with expertise in that area. Modules are then fit together with minimal interactions to satisfy all product requirements. For example, one group is responsible for the frame of your computer, another for the power supply. The memory chips and CPU are separate as are the modem and graphics board.

Process planning involves the transformation of part or product definition data (materials, geometry, topology, tolerances, demand volume) into detailed production instructions. Alting and Zhang (1989) summarize this process in ten steps, as shown in Table 1.2. Detailed manufacturing, assembly, test, and service instructions are then generated. An example of a process plan is shown in Figure 1.5.

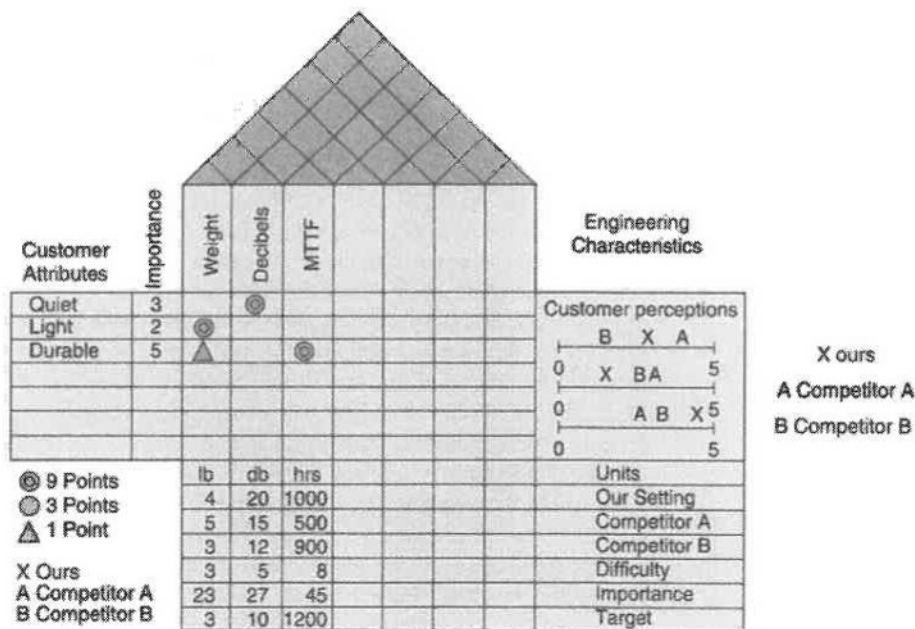


Figure 1.4 Sample House of Quality

Table 1.2 Creation of a Process Plan

1. Interpretation of product design data
2. Selection of machining processes
3. Selection of machine tools
4. Determination of fixtures and datum surfaces
5. Sequencing of operations
6. Selection of inspection devices
7. Determination of production tolerances
8. Determination of the proper cutting conditions
9. Calculation of standard times and costs
10. Generation of process sheets and NC code

A process plan consists of a sequence of **operations** for converting raw material into finished products. (Note that the finished product for one manufacturer may be a component part or bulk product, such as a coil of sheet metal or styrofoam pellets, that becomes the raw material for another manufacturer.) There are several types of operations, and it can be important to distinguish between these when collecting data for modeling the production facility. **Fabrication** involves transforming the raw material such as casting molten metal in a mold, drilling holes, or etching a pattern into the surface of a material. We will include required time-delay processes such as drying, aging, and cooling as a special type of fabrication operation. **Assembly** refers to the action of putting parts together to form a product. Many final products are produced on an assembly line where the various parts are connected by careful positioning, followed by soldering, fastening, or other joining action. We will also refer to **kitting** as an assembly-type operation. Kitting consists of picking from storage the parts needed to make a batch of product and loosely grouping these parts together in a package such as a bag or tote. Kitting frequently precedes assembly. **Separation** operations break a product or material into multiple components. These operations are common in the early stages of processing natural materials such as ore or oil and in the recycling of used products. It may be useful to identify **test** operations because these often have probabilistic outcomes with the subsequent routing of parts being dependent on the results of the test.

Operations possess several attributes in addition to operation type. **Setup** refers to the activity required to begin an operation such as adding tooling on a machine or checkout (running and testing an initial part). The **unit-processing time** indicates the time required per repetition of the operation. This may be a fixed time or a random variable. If parts are processed one at a time, then the batch-processing time is  $S + Qt$ —the sum of setup time ( $S$ ) plus the product of batch size ( $Q$ ) and unit-processing time ( $t$ ). In some operations, units can be processed in parallel, thus reducing the processing time required per batch. Thus, the maximum simultaneous **processing quantity** represents another attribute. Process **yield** denotes the proportion of units that are successfully processed on average. The remaining units are either scrapped or sent for rework. Yield can be multidimensional in the sense that the process may produce product of varying quality. The output of the process may require grading with higher grades bringing higher prices. You have seen this practice when choosing the speed of your computer's microprocessor

or choosing between regular and irregular clothes. Many chemical processes also exhibit this trait.

Operations are normally separated by a material handling activity. For the most part, it is sufficient to consider material handling actions as another operation type. The characteristics of that move are the number of units processed (moved) simultaneously and the move time. We refer to the quantity of units moved per trip as the **unit load**. This may be a single item, a pallet, or tote bin full of material. The number of units processed in immediate succession on a machine is the **process batch**. The process batch normally consists of a single part type. Once the machine is set up, it produces the entire process batch before changing to a different part. The **transfer batch** is the number of units moved at the same time. It will often be the same as the unit load but may consist of several unit loads. The process batch then consists of one or more transfer batches.

If all jobs move through the same sequence of machines we refer to the facility as a **flow shop**. If each job has its own routing through the set of processors then we refer to the production facility as a **job shop**. When operations can be performed in any order, we refer to it as an **open shop**. Some facilities have **re-entrant flow** patterns where jobs repeatedly cycle through the same processors. Semiconductor manufacturing offers the most important example of this flow pattern as each layer of the device requires passing through many of the same processes of masking, photoresist, etching, etc.

The House of Quality can be used in a hierarchical manner for specifying materials and process plans. The engineering characteristics from the conceptual design stage, such as thermal conductivity, become the customer attributes at the detailed design stage. The engineering characteristics from detailed design become the attributes at the process planning stage.



### **1.3.2 Manufacturing**

Manufacturing generates the value added by the industrial firm. It is here that raw materials pass through a series of operations to be converted into finished products for distribution to customers. The production system covered in this text has the responsibility to determine the “what,” “how much,” and “when” of manufacturing. The “how” is determined by process planning. The production system specifies the production rate and corresponding capacity requirements. It then coordinates the flow of materials through the facility. In addition, the production system must specify the levels of support services such as material purchases, inventory, and human resources needed to support this plan.

### **1.3.3 Distribution**

Product value is realized only when the product is delivered to customers in useable condition. Distribution can be a prolonged and expensive activity. The cumulative cost of moving physical goods from the raw material through the finished product stage may account for as much as 50% of the product’s cost. Final goods must often be kept in warehouses near final customers to reduce delivery time. If the final product is available in many variations, we may store generic assemblies and then customize upon receipt of an order to achieve a happy medium between excessive storage costs and instant availability. The combination of purchasing, manufacturing, and distribution is referred to as the **supply chain**.

### **1.3.4 Maintenance and Support**

Rare is the corporate entity that would purchase a computer or duplicating machine without a warranty, on-site maintenance agreement, and, in most cases, on-line support. IBM can attribute much of its historical success to its strong customer support. Products are useless if they do not work and worse than useless if, once put into service, they cannot be counted on in an emergency. Documentation of how your newly purchased VCR operates may not be the most exciting reading, but you certainly expect to be able to find help when needed to ensure you can tape your favorite shows while on vacation.

Customers expect timely delivery of quality products. This requires maintenance of production equipment. The machines must be available for use when needed and must

perform as expected. Preventive maintenance helps ensure that production plans can be met and repair activities help to avoid missing delivery schedules.

### **1.3.5 Disposal**

In recent years, life-cycle management concepts have come to include product disposal and recycling. According to the 1994 General Motors Environmental Report, 94% of cars and trucks in the United States are recycled. Of those, 75% of the vehicle content is recycled (primarily metal). Some manufacturers will now supply customers with written feedback on the ultimate disposition of their vehicles. Environmental rules often require extensive documentation on the disposal of hazardous materials. Within the plant, the use of environmentally safe processes has become increasingly important. In addition to providing a better image, costs are often reduced and safety improved. Capture and reuse of unconsumed chemicals, elimination of unnecessary hazardous materials through better process control, different production methods, or use of cleaner alternatives are all valuable strategies. For instance, water-based solvents are now used in place of many pollutants.

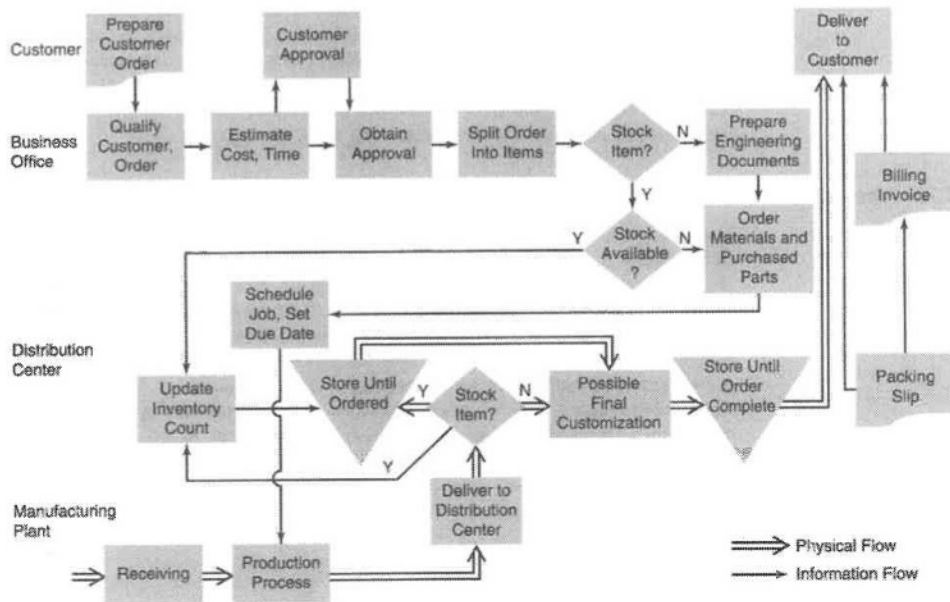
## **1.4 BUSINESS PROCESSES**

Business operations consist of a set of “processes.” A process may be defined as a set of procedures designed to integrate people, knowledge, materials, equipment, energy, and information to accomplish a specific task. Examples of important business processes include:

- Design a product
- Enter a customer order
- Fill a customer order
- Manufacture a product
- Set long-term capacity plans
- Acquire raw materials
- Hire and train workers
- Bill and collect accounts receivable
- Record and reimburse accounts payable
- Develop a proposal for new business

To illustrate how a process can be documented and to familiarize the reader with the basic process of receiving and executing customer orders, Figure 1.6 presents an

aggregate view of the customer order execution process. The figure assumes a producer with a business office, production facility and distribution center from which orders are shipped to customers. The three functions may be at the same or different geographical locations. The first major step is to receive the order and obtain agreement between the customer and supplier on price, delivery date, product quantity, and other attributes of the order. An order will often include multiple items. The production facility must break the order into line items and produce each. Some items may be standard and available off-the-shelf, whereas others may require custom production. Inventory status records must be maintained and production schedules coordinated to blend this order with those of other customers. Eventually, the items are collected and the completed order delivered. In some cases, the customer may be willing to accept partial shipments as items become available. In practice, the order execution process can become far more complex as we need to be able to implement engineering and customer change requests and react to changes in the yields and availability of production equipment.



**Figure 1.6** Overview of Customer Order and Delivery Process

There are three important characteristics for all processes.

1. Processes require resources. This is evident from the list of collected items in the above definition.

2. The process should be derived from the objectives of the firm. It should be possible to trace the justification for the process directly back to satisfaction of some objective of the firm. If the process is not needed for accomplishing the business objectives, it is extraneous. In light of the first characteristic, extraneous processes should be eliminated.
3. Each process must have a product **and** a customer. The customer dictates what the product should be and quality of the process is measured against customer satisfaction and delight. In practice, processes tend to have primary and secondary products and customers. In manufacturing and delivering a physical product such as an automobile or toaster, the primary product is the item itself and the primary customer is the purchaser. However, the employees who made the product and spend much of their lives in the shop, and the service rep who must maintain that product in the field, are also customers.

In evaluating processes, there are several relatively universal measures: cost, quality, and time. Maximizing profit represents a major objective for most private sector entities. This can be accomplished through continually providing to customers products with high perceived value. This perceived value is derived from the functions performed by the product, the timeliness of the product's availability, the aesthetics associated with ownership and use of the product, the quality of its performance, and its cost. Minimizing internal cost to meet a given level of perceived customer value contributes to maximizing profit.

Quality represents several aspects of the overall evaluation process. Design quality refers to the degree of exquisiteness selected for the process (or product). This is closely associated with the market in which we choose to compete. Conformance quality refers to how well the targeted design quality is met. Design quality indicates what we plan to do; conformance quality indicates how well we do it. The quality of a \$50,000 luxury automobile with headlights that are not precisely focused or high internal noise level is poor. This may be attributable to poor design intent or failure to conform to the design. Design for manufacturability bridges the gap between these two concepts to ensure that it is possible with existing human and technological capability to conform to the design.

Processes often cross organizational and functional boundaries. During conversion from raw material to finished product, the material may pass through several process-oriented departments such as receiving, cutting, milling, welding, and assembly.

Designing a product involves marketing, design-engineering, test-engineering, manufacturing, purchasing, finance, and customer-support functions. Processes also are often interconnected. Order entry, purchasing, and production planning are highly interconnected processes. We cannot plan production without the parts being purchased, and we do not know what to produce without order entry.

Advances in information technology support significant improvement in the design of interconnected processes. The time to replenish shelves at the retail level and the cost of inventory can be substantially reduced if retail sales are immediately transmitted back to the order entry and production scheduling system. Electronic checkout systems and the international phone and data communication networks make this a feasible option. Information exchange is important within the production facility as well. When an item is scrapped because of a problem in the manufacturing process, the data should be relayed to related processes such as production scheduling.

## **1.5 ACCOUNTING SYSTEMS: ACQUISITION AND MANAGEMENT OF MODEL DATA**

Accurate, timely, and complete data are essential for good decision making. The models we will be discussing in this text, and, indeed, many of the decisions made in production systems planning and control, depend on the availability of accurate cost data. Whether to use overtime, a second shift, or new labor and machines to meet increasing product demand; whether to make a component or buy it from a supplier; whether to automate an operation or use manual labor. Accounting systems accumulate much of the data necessary to model these problems and make decisions. As part of the process of financial reporting and support of managerial decisions, accounting systems track the cost of materials, labor, factory overhead, and administrative overhead. Labor cost is generally divided into **direct labor** and **indirect labor**. Direct labor includes work performed specifically on the part such as operating a machine while the part is being produced. Activities such as material handling and setup may also be charged to direct labor if the worker's responsibility is restricted to one product type. Usually, however, these are considered indirect labor and allocated to factory overhead.

Indirect labor also includes support activities such as maintenance, supervisors, and quality assurance. Indirect material costs would include general supplies, lubricants, and other materials consumed during operations that do not become part of a finished

product. Other necessary costs that support operations such as utilities, insurance, equipment depreciation, and space rental also are lumped into factory overhead costs in traditional direct cost accounting systems.<sup>2</sup>

Partially completed products that are currently in the shop are referred to as work-in-process (WIP). Accounting systems then use the following relations to accumulate cost for each time period.

$$\text{Total Manufacturing Cost} = \text{Direct Material Cost} + \text{Direct Labor Cost} + \text{Factory Overhead}$$

$$\text{Cost of Goods Manufactured} = \text{Total Mfg. Cost} + \text{Initial WIP Value} - \text{Ending WIP Value}$$

$$\text{Cost of Goods Sold} = \text{Cost of Goods Manufactured} + \text{Initial Finished Goods} - \text{Final Finished Goods}$$

Table 1.3 shows a generic cost of manufactured goods statement.

**Table 1.3** Cost of Manufactured Goods, June, 1999

Direct Materials 5/31/99 Direct	\$25,000
Materials Purchased Direct	\$12,800
Materials 6/30/99	(\$26,500)
Cost of Direct Materials Used	\$11,300
Direct Labor	\$20,000
Indirect Labor	\$8,500
Indirect Materials	\$4,000
Utilities	\$2,500
Insurance	\$800
Rental Space	\$3,000
Depreciation	\$9,600
Misc.	\$1,200
Total Factory Overhead	\$29,600
Work-in-Process 5/31/95	\$53,000
Work-in-Process 6/30/95	(\$52,600)
Cost of WIP Used	\$400
Cost of Goods Manufactured	\$61,300

The objective is to eventually track costs to products. The traditional approach assigned direct material and labor costs to products and then apportioned overhead to products in proportion to their direct costs. As manufacturing systems became more automated

<sup>2</sup> Marketing and administrative offices costs form administrative overhead. These are kept separate from manufacturing costs but are clearly part of the overall business system.

and indirect costs became more dominant, this procedure proved unsatisfactory. **Activity-based costing** (ABC) attempts to first assign all costs to the generating activity. An assembly line, a manufacturing cell of several machines, and an inspection station could each be classified as an activity. The set of products using each activity is recorded. For each activity, a cost driver such as hours on the key machine is identified. The costs for the activity are then assigned to products based on their usage of the cost driver. Quality, equipment depreciation, maintenance, machine setup, and other costs can often be attributed to specific products. This can provide a more accurate picture of product costs. As part of this process, management should consider elimination of activities that are not essential for any product.

### **EXAMPLE 1.1**

A publishing company sells a hardbound and softbound version of a textbook. Publishing requires two steps. First pages are produced and then collated into books and bound. Pages are produced identically for hard-and soft-cover versions. Direct labor is 2.5 hours per 100 books. Indirect cost for page making is \$150,000 per year. The hardback covers are made and the books stitched together by an automated machine. Costs for this process are \$500,000 per year, and the machine can produce 500,000 books per year. Soft covers are produced and glued by hand, taking 7.5 hours per 100 books. Indirect cost for this department is \$100,000 per year (also 500,000 books). Labor costs \$15 per hour and direct material costs are \$4.00 per hardback, \$2.00 per softcover book. Determine costs per 100 books for each version using both traditional and activity-based costing. Assume the facility is fully utilized, making 1,000,000 books per year.

### ***SOLUTION***

Direct costs are the same under both accounting methods. These costs are added for the page making and -binding departments. The activity centers are page-making, hardcover-binding, and softcover-binding. The traditional approach allocates the \$750,000 total annual overhead costs on the basis of direct labor cost. Thus, 80% of this cost is assigned to the soft-cover version because these take 10 direct labor hours per 100 compared with the 2.5 hours for hardback books. Clearly, this is a misleading estimate because page-making costs are the same for both versions, and the labor-intensive softcovers have lower actual overhead cost. This error is corrected by the activity-based estimate where indirect costs at each center are assigned to products. The full cost comparison is shown in Table 1.4. Direct labor and material are the same for both systems. Hardback books require 2.5 labor hours per hundred at the rate of \$15 per hour. Softcover books require a total of 10 labor hours per hundred for page-making and -covering. The difference occurs in allocating the \$750,000 per year of overhead. Because the softcover process uses 80% of the direct labor, it receives 80% of the overhead charge in traditional accounting. With ABC, the overhead costs are apportioned by work center to the products using that center. Page-making and -binding are separated. The full \$500,000 overhead in automated hardcover binding is assigned to the hardcover books at the rate of \$1 per book. Clearly, the two accounting approaches present different pictures of product cost. The traditional accounting approach may

cause us to underprice hardback books and overprice softbacks. Both systems suffer from their inability to estimate cost gradients from attempting to increase or decrease the production rate.

**Table 1.4** Traditional vs. Activity-Based Costing

Traditional cost accounting		
	Hardback	Softcover
Direct Labor	\$37.50	\$150.00
Direct Material	\$400.00	\$200.00
Overhead (Direct Labor Basis)	\$30.00	\$120.00
Total Costs per 100	\$467.50	\$470.00
Activity-based costing		
Direct Labor	\$37.50	\$150.00
Direct Material	\$400.00	\$200.00
Page Dept. Overhead	\$15.00	\$15.00
Binding Dept. Overhead	\$100.00	\$20.00
Total Costs per 100	\$552.50	\$385.00

Of course, some costs are still difficult to assign to specific parts. Also, costs are often random or merely approximations. Suppose, for instance, two identical robots are purchased. In the first case, the robot lasts five years, and product demand runs higher than expected at 20,000 units per year. Each unit of product must be charged 0.0001 of the robot's lifetime cost. On the other hand, if the robot only lasts four years and demand is only 5,000 per year, each unit will be charged for 0.0005 of the robot's cost. Is it fair to charge the product based on the random performance of the robot temporarily assigned to its production? Also, these actual costs are known only after the product and robot's life. At that point, it is too late to change plans. Partly for this reason, **standard costs** are often used instead of actual costs. The use of standard cost rates for resources removes the misleading effect of random events when analyzing cost reports. The standard costs reflect the norm for a particular activity. Variances in labor, material, and other costs are used to indicate the deviation between standard and actual realized costs.<sup>3</sup>

It is important to distinguish variable overhead from fixed overhead. Suppose we are considering producing a new part that was previously purchased. Power to run the machine and materials consumed during production such as cutting tool points are

<sup>3</sup> The accounting use of the term variance refers to a deviation from the standard and differs from the concept of variance in statistics.

clearly variable with the level of production. Their cost, although probably part of overhead, should be included when estimating the cost of producing the part in-house. The salary of the supervisor of the product test department will probably not change and thus can be excluded from the analysis. The accounting system will have one way of compiling costs, yet the factors that are relevant in comparing options often depend on the scale, time frame, and set of alternatives. The experienced decision analyst must extract the appropriate cost data for the problem at hand.

Accounting systems vary widely depending on the type of business. Accumulating costs by process and assigning them to product types seem natural for continuous-flow and high-volume manufacturing. In lower-volume, higher-variety discrete parts manufacturing, the procedure can still be used. As before, costs are allocated to products based on the proportion of time they use each resource. Some businesses operate on a “cost plus” contract basis. This has often been true in the defense industry. In such cases, it may be necessary to directly accumulate costs by specific job or contract instead of by activity. Likewise, actual costs are needed instead of standard costs.

It is important that the builder of production system models understands the components of any accounting figure. In many cases, the data may not be precisely in the form desired for our planning models. We may have a different perspective on fixed vs. variable costs, and direct vs. indirect. Indirect labor may be a direct consequence of our production decisions and relate directly to production levels. If so, the costs of producing products should include this. Storing money in the form of inventory is a real opportunity cost (more about this later) and a necessary part of operating production facilities, but the accounting system may not view cost collection in this manner. We must be cautious in using accounting data without knowing how it was defined and compiled. The cost of a machine hour may seem like a simple request. However, different accounting systems will report different figures. The figure could be standard or actual, may or may not include overhead allocated in one of several ways, and will be based on some assumed utilization when including variable cost.

Beyond this, our desired value will depend on the time frame for the model. In a long-range planning model, selling the machine and reducing the indirect labor force that supports that operation may be relevant costs. In a short-term routing decision, these options do not exist, and their fixed costs should be excluded. As another example, we may wish to know how much we would benefit if we could save an hour of the time

required to change over a machine from producing one product type to another. A simple answer is the accountant's hourly cost basis for the machine (multiplied by the number of changeovers per time period). The actual answer is more complex. As we will see later, such time savings indicate that we should produce fewer units of a product at a time. This in turn will reduce WIP levels and response time to changes in customer demand. If this is a bottleneck machine, time saved in changeovers may allow us to produce more product across the entire factory leading to a significant increase in revenue. Unfortunately, accounting systems are not designed to track these secondary savings or to provide the value of improved customer satisfaction. The accounting system's estimate of the savings from improved changeover efficiency is only a lower bound on the actual benefit.

## 1.6 SUMMARY

The modern industrial firm strives to make a profit by timely delivery of high-quality, low-cost, functional products to customers. Marketing, engineering, and manufacturing work together to design products that will meet customer requirements. Business processes must be developed that receive information from and deliver products to customers while also supporting internal operations. In addition to coordinating the direct flow of materials from suppliers through manufacturing and on to distribution to customers, information must be collected to make sure products satisfy customer needs, meet governmental requirements and execute administrative functions. Employees and suppliers must be paid; equipment must be maintained.

To make appropriate decisions for the firm, it is imperative that accurate data be available and understood. Accounting systems accumulate data and aggregate data into information for financial reporting and managerial decision-making. It is important, therefore, that the accounting data accurately reflect the impact of decisions and that the definitions of accounting parameters are understood by decision-makers. Activity-based cost accounting systems attempt to provide an accurate portrayal of the factors generating all the costs of the firm. Nonetheless, we must be careful when using accounting figures to know precisely what is included and how the figures relate to our engineering choices. Improper classification of costs can distort management's understanding of the production process and lead to poor decision-making.

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## **1.8 PROBLEMS**

- 1.1. List the key resource types required by the firm to produce products.
- 1.2. Describe the key activities for each of the primary functional units of an industrial organization.
- 1.3. What are the primary measures of a firm’s competitiveness? How do you think the relative importance of these will vary from one industry to another? Give examples.
- 1.4. Consider a color printer designed for the home PC market. List the key customer attributes. Define a set of engineering characteristics that could be used to specify product requirements.
- 1.5. What is the purpose of a process plan? List the types of information normally included in the plan.
- 1.6. A furniture shop produces chairs (among other products) with metal arms. The arms are formed from metal blanks in a three-machine cell. This is a make-to-order shop, i.e., the production floor makes a quantity of chairs of a specific type in response to a customer order. The blanks are transported in tubs that hold approximately 50 pieces. The typical order is for about 500 chairs. If tubs are moved in their entirety between machines in the cell, what constitutes the process batch, transfer batch, and unit load? Suppose full tubs are set at the beginning of the cell and empty tubs at the end. Units are paced one at a time between machines and completed units are placed in the “empty” tub. When the empty tub is full, it is moved to the chair assembly line. Now what constitutes the process batch, transfer batch, and unit load?
- 1.7. Define the major types of production operations.
- 1.8. List the important characteristics of a business process.
- 1.9. Visit a local fast food establishment. Observe the process of taking and filling a customer order. Construct a flow diagram of the process for a customer ordering a burger, fries, and shake and paying with a debit card.
- 1.10. Educational institutions produce educated students ready for employment and life-long learning. Consider the process of offering a course for academic credit as part of a degree program. Describe the resources involved, tie this process to the objectives of the firm, and define the product and customer(s) of this process.
- 1.11. Suppose you were considering purchasing a personal computer for use in your educational program. List your key features: price, performance, and delivery requirements.

- 1.12.** Describe the differences between traditional cost accounting systems and activity-based costing. How is activity-based costing more appropriate for modern manufacturing systems?
- 1.13.** Two products are produced in a factory. One thousand units per year of each product are manufactured. Both products have direct material cost of \$10 per unit. Both products visit department A and department B in the plant. Department A is highly automated while B is largely manual operations. A unit of product one requires 0.2 labor hours in department A and 5 hours in department B. Product two takes 1 hour of labor in each department. Annual overhead costs are \$500,000 and \$100,000 respectively for departments A and B. Direct labor costs \$8 per hour. Compute the cost per product for both traditional overhead allocation based on direct labor hours, and activity-based costing.
- 1.14.** What problems can you see happening if the engineering department that finalizes product designs and changes does not communicate well with production planning and purchasing personnel?