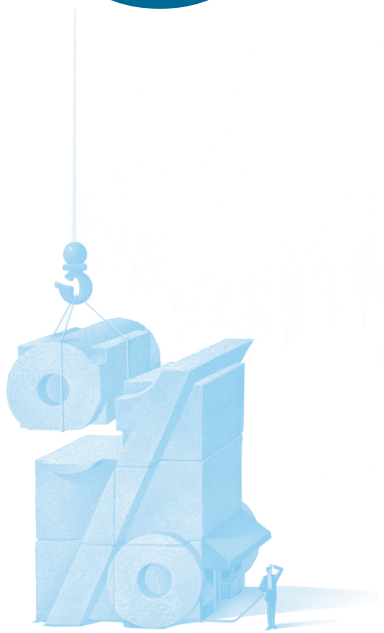
PART

3

Analysis of Project Cash Flows



CHAPTER EIGHT

Cost Concepts Relevant to Decision Making

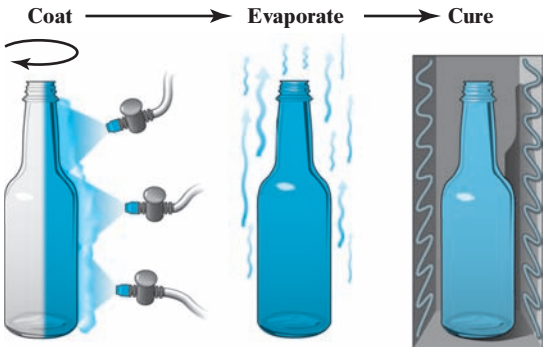
High Hopes for Beer Bottles[1] Three hundred billion beer bottles a year worldwide is a mighty tempting target for the plastics industry. Brewers generally say they need a bottle that provides shelf life of over 120 days with less than 15% loss of CO_2 and admittance of no more than 1 ppm of oxygen. Internal or external coatings, and three- or five-layer polyethylene terephthalate (PET) structures using barrier materials are being evaluated to reach that performance.

What is the least expensive way to make a 0.5L PET barrier bottle? Summit International LLC, Smyrna, GA, which specializes in preform and container development and market research, compared the manufacturing costs of five different barrier technologies against a standard monolayer PET bottle. Summit looked at three-layer and five-layer and at internally and externally coated containers, all of them reheat stretch blow molded. It found the bottle with an external coating to be least costly, while the internally coated bottle was the most expensive.

The firm compared a five-layer structure with an oxygen-scavenger material, a three-layer bottle with a $2.50/lb barrier material, and a second three-layer structure with a $6/lb barrier. Also compared were a bottle coated inside using Sidel's new Actis plasma technology and a bottle coated on the outside.

Capital investment (preform and bottle machines, utilities, downstream equipment, quality control, spare parts, and installation) for producing 20,000 bottles/hr is $10.8 million for the five-layer bottle, $9.9 million for both three-layer structures, $9.2 million for internal coating, $7.5 for external coating, and $6.8 million with no barrier.

[1] "Blow Molding Close-Up: Prospects Brighten for PET Beer Bottles," Mikell Knights, Plastic Technology Online, © copyright 2005, Gardner Publications, Inc.



Spray coating of external PET bottles

Direct manufacturing cost per 1,000 (materials, energy, labor, maintenance, and scrap) amounts to $66.57 for three layers with the expensive barrier, $59.35 for five layers, $55.34 for the external coating, $54.63 for three layers with the low-cost barrier, $46.90 for internal coating, and $44.63 without barrier.

You may be curious how all of those cost data were estimated in the chapter opening story. Before we study the different kinds of engineering economic decision problems, we need to understand the concept of various costs. At the level of plant operations, engineers must make decisions involving materials, plant facilities, and the in-house capabilities of company personnel. Consider, for example, the manufacture of food processors. In terms of selecting materials, several of the parts could be made of plastic, whereas others must be made of metal. Once materials have been chosen, engineers must consider the production methods, the shipping weight, and the method of packaging necessary to protect the different types of materials. In terms of actual production, parts may be made in-house or purchased from an outside vendor, depending on the availability of machinery and labor.

Present economic studies: Various economic analyses for short operating decisions.

All these operational decisions (commonly known as **present economic studies** in traditional engineering economic texts) require estimating the costs associated with various production or manufacturing activities. Because these costs also provide the basis for developing successful business strategies and planning future operations, it is important to understand how various costs respond to changes in levels of business activity. In this chapter, we discuss many of the possible uses of cost data. We also discuss how to define, classify, and estimate costs for each use. Our ultimate task in doing so is to explain how costs are classified in making various engineering economic decisions.

CHAPTER LEARNING OBJECTIVES

After completing this chapter, you should understand the following concepts:

- Various cost terminologies that are common in cost accounting and engineering economic studies.
- How a cost item reacts or responds to changes in the level of production or business activities.
- The types of cost data that management needs in making choice between alternative courses of action.
- The types of present economic studies frequently performed by engineers in manufacturing and business environment.
- How to develop a production budget related to operating activities.

8.1 General Cost Terms

In engineering economics, the term **cost** is used in many different ways. Because there are many types of costs, each is classified differently according to the immediate needs of management. For example, engineers may want cost data to prepare external reports, to prepare planning budgets, or to make decisions. Also, each different use of cost data demands a different classification and definition of *cost*. For example, the preparation of external financial reports requires the use of historical cost data, whereas decision making may require current cost data or estimated future cost data.

Our initial focus in this chapter is on manufacturing companies, because their basic activities (acquiring raw materials, producing finished goods, marketing, etc.) are commonly found in most other businesses. Therefore, the understanding of costs in a manufacturing company can be helpful in understanding costs in other types of business organizations.

8.1.1 Manufacturing Costs

Several types of manufacturing costs incurred by a typical manufacturer are illustrated in Figure 8.1. In converting raw materials into finished goods, a manufacturer incurs various costs associated with operating a factory. Most manufacturing companies divide manufacturing costs into three broad categories: direct raw material costs, direct labor costs, and manufacturing overhead.

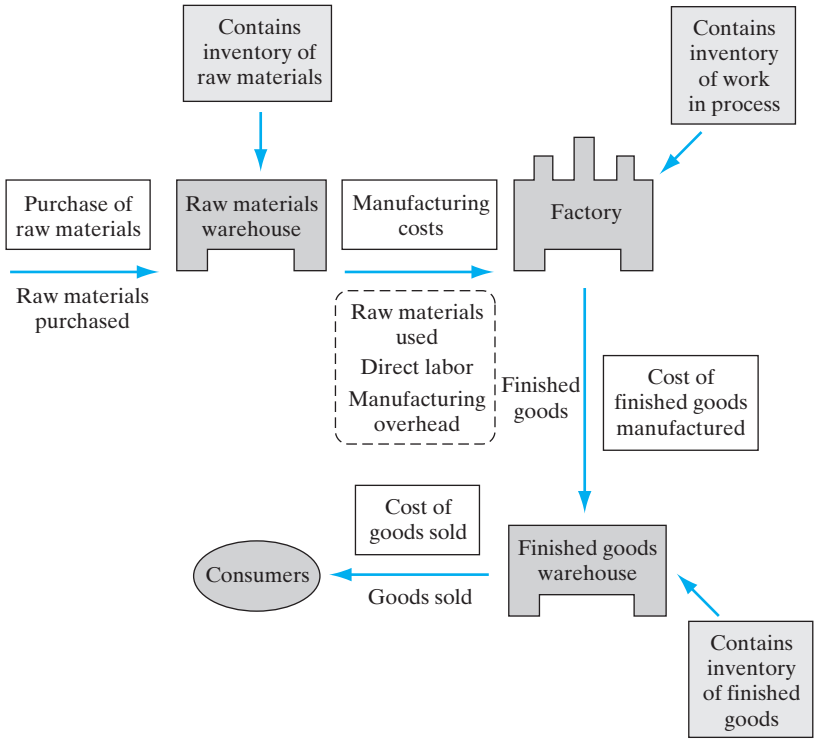


Figure 8.1 Various types of manufacturing costs incurred by a manufacturer.

Direct Raw Materials

Direct raw materials are any materials that are used in the final product and that can be easily traced to it. Some examples are wood in furniture, steel in bridge construction, paper in printing firms, and fabric for clothing manufacturers. It is important to note that the finished product of one company can become the raw materials of another company. For example, the computer chips produced by Intel are a raw material used by Dell in its personal computers.

Direct cost: A cost that can be directly traced to producing specific goods or services.

Direct Labor

Like direct raw materials, direct labor incurs costs that go into the production of a product. The labor costs of assembly-line workers, for example, would be direct labor costs, as would the labor costs of welders in metal-fabricating industries, carpenters or bricklayers in home building, and machine operators in various manufacturing operations.

Overhead: A reference in accounting to all costs not including or related to direct labor, materials, or administration costs.

Manufacturing Overhead

Manufacturing overhead, the third element of manufacturing cost, includes all costs of manufacturing except the costs of direct materials and direct labor. In particular, manufacturing overhead includes such items as the costs of indirect materials; indirect labor; maintenance and repairs on production equipment; heat and light, property taxes, depreciation, and insurance on manufacturing facilities; and overtime premiums. The most

important thing to note about manufacturing overhead is the fact that, unlike direct materials and direct labor, it is not easily traceable to specific units of output. In addition, many manufacturing overhead costs do not change as output changes, as long as the production volume stays within the capacity of the plant. For example, depreciation of factory buildings is unaffected by the amount of production during any particular period. If, however, a new building is required to meet any increased production, manufacturing overhead will certainly increase.

- Sometimes it may not be worth the effort to trace the costs of materials that are relatively insignificant in the finished products. Such minor items include the solder used to make electrical connections in a computer circuit board and the glue used to bind this textbook. Materials such as solder and glue are called *indirect materials* and are included as part of manufacturing overhead.
- Sometimes we may not be able to trace some of the labor costs to the creation of a product. We treat this type of labor cost as a part of manufacturing overhead, along with indirect materials. *Indirect labor* includes the wages of janitors, supervisors, material handlers, and night security guards. Although the efforts of these workers are essential to production, it would be either impractical or impossible to trace their costs to specific units of product. Therefore, we treat such labor costs as indirect labor costs.

8.1.2 Nonmanufacturing Costs

Two additional costs incurred in supporting any manufacturing operation are (1) marketing or selling costs and (2) administrative costs. Marketing or selling costs include all costs necessary to secure customer orders and get the finished product or service into the hands of the customer. Breakdowns of these types of costs provide data for control over selling and administrative functions in the same way that manufacturing cost breakdowns provide data for control over manufacturing functions. For example, a company incurs costs for

- **Overhead.** Heat and light, property taxes, and depreciation or similar items associated with the company's selling and administrative functions.
- **Marketing.** Advertising, shipping, sales travel, sales commissions, and sales salaries. Marketing costs include all executive, organizational, and clerical costs associated with sales activities.
- **Administrative functions.** Executive compensation, general accounting, public relations, and secretarial support, associated with the general management of an organization.

Matching concept: The accounting principle that requires the recognition of all costs that are associated with the generation of the revenue reported in the income statement.

8.2 Classifying Costs for Financial Statements

For purposes of preparing financial statements, we often classify costs as either period costs or product costs. To understand the difference between them, we must introduce the matching concept essential to any accounting studies. In financial accounting, the **matching principle** states that *the costs incurred in generating a certain amount of revenue should be recognized as expenses in the same period that the revenue is recognized*. This matching principle is the key to distinguishing between period costs and product costs. Some costs are matched against periods and become expenses immediately. Other costs are matched

against products and do not become expenses until the products are sold, which may be in the next accounting period.

8.2.1 Period Costs

Period costs are costs charged to expenses in the period in which they are incurred. The underlying assumption is that the associated benefits are received in the same period the cost is incurred. Some specific examples are all general and administrative expenses, selling expenses, and insurance and income tax expenses. Therefore, advertising costs, executives' salaries, sales commissions, public-relations costs, and other nonmanufacturing costs discussed earlier would all be period costs. Such costs are not related to the production and flow of manufactured goods, but are deducted from revenue in the income statement. In other words, period costs will appear on the income statement as expenses during the time in which they occur.

8.2.2 Product Costs

Some costs are better matched against products than they are against periods. Costs of this type—called **product costs**—consist of the costs involved in the purchase or manufacture of goods. In the case of manufactured goods, product costs are the costs of direct materials, direct labor costs, and manufacturing overhead. Product costs are not viewed as expenses; rather, they are the cost of creating inventory. Thus, product costs are considered an asset until the associated goods are sold. At the time they are sold, the costs are released from inventory as expenses (typically called cost of goods sold) and matched against sales revenue. Since product costs are assigned to inventories, they are also known as *inventory costs*. In theory, product costs include all manufacturing costs—that is, all costs relating to the manufacturing process. As shown in Figure 8.2, product costs appear on financial statements when the inventory, or final goods, is sold, not when the product is manufactured.

To understand product costs more fully, let us look briefly at the flow of costs in a manufacturing company. By doing so, we will be able to see how product costs move

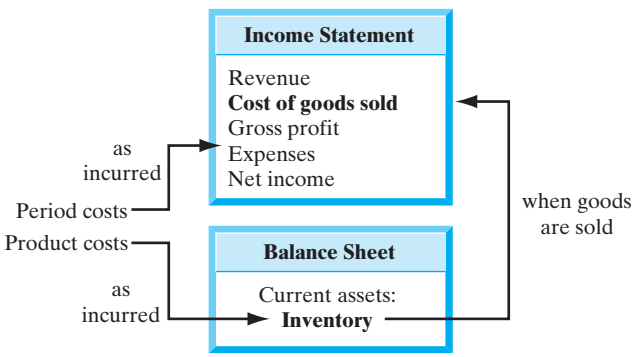


Figure 8.2 How the period costs and product costs flow through financial statements from the manufacturing floor to sales.

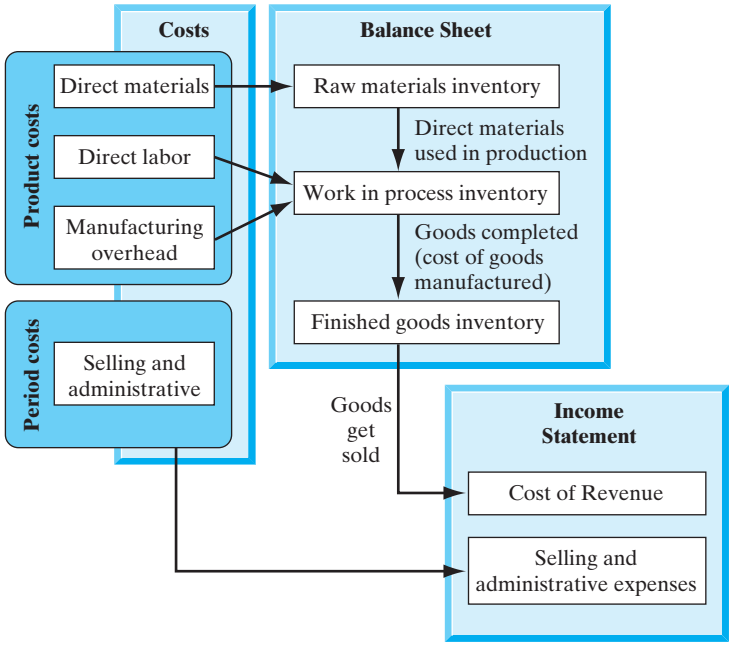


Figure 8.3 Cost flows and classifications in a manufacturing company.

through the various accounts and affect the balance sheet and the income statement in the course of the manufacture and sale of goods. The flows of period costs and product costs through the financial statements are illustrated in Figure 8.3. All product costs filter through the balance-sheet statement as "inventory cost." If the product gets sold, the inventory costs in the balance-sheet statement are transferred to the income statement under the head "cost of goods sold."

- **Raw-materials inventory.** This account in the balance-sheet statement represents the unused portion of the raw materials on hand at the end of the fiscal year.
- **Work-in-process inventory.** This balance-sheet entry consists of the partially completed goods on hand in the factory at year-end. When raw materials are used in production, their costs are transferred to the work-in-process inventory account as direct materials. Note that direct labor cost and manufacturing overhead cost are also added directly to work-in-process, which can be viewed as the assembly line in a manufacturing plant, where workers are stationed and where products slowly take shape as they move from one end of the line to the other.
- **Finished-goods inventory.** This account shows the cost of finished goods that are on hand and awaiting sale to customers at year-end. As the goods are completed, accountants transfer the cost from the work-in-process account into the finished-goods account. At this stage, the goods await sale to a customer. As the goods are sold, their cost is transferred from the finished-goods account into the cost-of-goods-sold (or cost-of-revenue) account. At this point, we finally treat the various material, labor, and overhead costs that were involved in the manufacture of the units being sold as *expenses* in the income statement.

Example 8.1 serves to explain the classification scheme for financial statements.

EXAMPLE 8.1 Classifying Costs for Uptown Ice Cream Shop

Here is a look at why it costs $2.50 for a single-dip ice cream cone at a typical store in Washington, DC. The annual sales volume (the number of ice cream cones sold) averages around 185,000 cones, bringing in revenue of $462,500. This is equivalent to selling more than 500 cones a day, assuming a seven-day operation. The following table shows the unit price of an ice cream cone and the costs that go into producing the product:

Items	Total Cost	Unit Price*	% of Price
Ice cream (cream, sugar, milk, and milk solids)	$120,250	$0.65	26%
Cone	9,250	0.05	2
Rent	112,850	0.61	24
Wages	46,250	0.25	10
Payroll taxes	9,250	0.05	2
Sales taxes	42,550	0.23	9
Business taxes	14,800	0.08	3
Debt service	42,550	0.23	9
Supplies	16,650	0.09	4
Utilities	14,800	0.08	3
Other expenses (insurance, advertising, fees, and heating and lighting for shop)	9,250	0.05	2
Profit	24,050	0.13	5
Total	**$462,500**	**$2.50**	**100**

*Based on an annual volume of 185,000 cones.

If you were to classify the operating costs into either product costs or period costs, how would you do it?

SOLUTION:

Given: Financial data just described.

Find: Classify the cost elements into product costs and period costs.

The following is a breakdown of the two kinds of costs:

- **Product costs:** Costs incurred in preparing 185,000 ice cream cones per year.

Raw materials:	
Ice cream @ $0.65	$120,250
Cone @ $0.05	9,250
Labor:	
Wages @ $0.25	46,250
Overhead:	
Supplies @ $0.09	16,650
Utilities @ $0.08	14,800
Total product cost	$207,200

- **Period costs:** Costs incurred in running the shop regardless of sales volume.

Business taxes:	
Payroll taxes @ $0.05	$ 9,250
Sales taxes @ $0.23	42,550
Business taxes @ $0.08	14,800
Operating expenses:	
Rent @ $0.61	112,850
Debt service @ $0.23	42,550
Other @ $0.05	9,250
Total period cost	$231,250

8.3 Cost Classification for Predicting Cost Behavior

In engineering economic analysis, we need to predict how a certain cost will behave in response to a change in activity. For example, a manager will want to estimate the impact a 5% increase in production will have on the company's total wages before he or she decides whether to alter production. **Cost behavior** describes how a cost item will react or respond to changes in the level of business activity.

8.3.1 Volume Index

In general, the operating costs of any company are likely to respond in some way to changes in the company's operating volume. In studying cost behavior, we need to determine some measurable volume or activity that has a strong influence on the amount of cost incurred. The unit of measure used to define volume is called a **volume index**. A volume index may be based on production inputs, such as tons of coal processed, direct labor hours used, or machine-hours worked; or it may be based on production outputs, such as the number of kilowatt-hours generated. For a vehicle, the number of miles driven per year may be used as a volume index. Once we identify a volume index, we try to find out how costs change in response to changes in the index.

8.3.2 Cost Behaviors

Accounting systems typically record the cost of resources acquired and track their subsequent usage. Fixed costs and variable costs are the two most common cost behavior patterns. An additional category known as "mixed costs" contains two parts, the first of which is fixed and the other of which varies with the volume of output.

Fixed Costs

The costs of providing a company's basic operating capacity are known as the company's **fixed cost** or **capacity cost**. For a cost item to be classified as fixed, it must have a relatively wide span of output over which costs are expected to remain constant. This span is called the **relevant range**. In other words, fixed costs do not change within a given period, although volume may change. In the case of an automobile, for example, the annual insurance premium, property tax, and license fee are fixed costs, since they are independent of the number of miles driven per year. Some other typical examples are building rents; depreciation of buildings, machinery, and equipment; and salaries of administrative and production personnel. In our Uptown Scoop Ice Cream Store example, we may classify expenses such as rent, business taxes, debt service, and other (insurance, advertising, professional fees) as fixed costs (costs that are fixed in total for a given period of time and for given production levels).

Fixed cost: A cost that remains constant, regardless of any change in a company's activity.

Variable Costs

In contrast to fixed operating costs, **variable operating costs** have a close relationship to the level of volume of a business. If, for example, volume increases 10%, a total variable cost will also increase by approximately 10%. Gasoline is a good example of a variable automobile cost, because fuel consumption is directly related to miles driven. Similarly, the cost of replacing tires will increase as a vehicle is driven more.

In a typical manufacturing environment, direct labor and material costs are major variable costs. In our Uptown Scoop example, the variable costs would include the cost of the ice cream and cone (direct materials), wages, payroll taxes, sales taxes, and supplies. Both payroll and sales taxes are related to sales volume. In other words, if the store becomes busy, more servers are needed, which will increase the payroll as well as taxes.

Variable cost: A cost that changes in proportion to a change in a company's activity or business.

Mixed Costs

Some costs do not fall precisely into either the fixed or the variable category, but contain elements of both. We refer to these as mixed costs (or **semivariable costs**). In our automobile example, **depreciation** (loss of value) is a mixed cost. On the one hand, some depreciation occurs simply from the passage of time, regardless of how many miles a car is driven, and this represents the fixed portion of depreciation. On the other hand, the more miles an automobile is driven a year, the faster it loses its market value, and this represents the variable portion of depreciation. A typical example of a mixed cost in manufacturing is the cost of electric power. Some components of power consumption, such as lighting, are independent of the operating volume, while other components (e.g., the number of machine-hours equipment is operated) may vary directly with volume. In our Uptown Scoop example, the utility cost can be a mixed cost item: Some lighting and heating requirements might stay the same, but the use of power mixers will be in proportion to sales volume.

Mixed cost: Costs are fixed for a set level of production or consumption, becoming variable after the level is exceeded.

Average Unit Cost

The foregoing description of fixed, variable, and mixed costs was expressed in terms of total volume over a given period. We often use the term **average cost** to express

activity cost on a per unit basis. In terms of unit costs, the description of cost is quite different:

- The variable cost per unit of volume is a constant.
- Fixed cost per unit varies with changes in volume: As the volume increases, the fixed cost per unit decreases.
- The mixed cost per unit also changes as volume changes, but the amount of change is smaller than that for fixed costs.

To explain the behavior of the fixed, variable, mixed, and average costs in relation to volume, let's consider a medium-size car, say, the 2005 Ford Taurus SEL Deluxe six-cylinder (3.0-liter) four-door sedan. In calculating the vehicle's operating costs, we may use the procedure outlined by the American Automobile Association (AAA) as shown in Table 8.1.

On the basis of the assumptions in Table 8.1, the operating and ownership costs of our Ford vehicle are estimated as follows:

Operating costs:	
• Gas and oil	8.5 cents
• Maintenance	5.8 cents
• Tires	0.7 cent
Cost per mile	15.0 cents

TABLE 8.1 **Assumptions Used in Calculating the Average Cost of Owning and Operating a New Vehicle**

What's Covered	Costs Base
Fuel	U.S. price of unleaded gasoline from AAA's *Fuel Gauge Report*, weighted 60% city and 40% highway driving.
Maintenance	Costs of retail parts and labor for normal, routine maintenance, as specified by the vehicle manufacturer.
Tires	Costs are based on the price of one set of replacement tires of the same quality, size, and ratings as those which came with the vehicle.
Insurance	A full-coverage policy for a married 47-year-old male with a good driving record living a small city and commuting 3 to 10 miles daily to work.
License, Registration, and Taxes	All government taxes and fees payable at time of purchase, as well as fees due each year to keep the vehicle licensed and registered.
Depreciation	Based on the difference between the new-vehicle purchase price and the estimated trade-in value at the end of five years.
Finance	Based on a five-year loan at 6% interest with a 10% down payment.

Source: American Automobile Association (AAA).

Ownership costs:	
• Comprehensive insurance ($250 deductible)	$1,195
• License, registration, taxes	$390
• Depreciation (15,000 miles annually)	$4,005
• Finance charge (20% down, loan @8.5%/4 years)	$740
Cost per year	$6,330
Cost per day	$17.34
Added depreciation costs (per 1,000 miles over 15,000 miles annually)	$185
Total cost per mile:	
• Cost per mile × 15,000 miles	$2,250
• Cost per day × 365 days per year	$6,330
Total cost per year	$8,580
Average cost per mile ($8,580/15,000)	57.2 cents

Now, if you drive the same vehicle for 20,000 miles instead of 15,000 miles, you may be interested in knowing how the average cost per mile would change. Example 8.2 illustrates how you determine the average cost as a function of mileage.

EXAMPLE 8.2 Calculating Average Cost per Mile as a Function of Mileage

Table 8.2 itemizes the operating and ownership costs associated with driving a passenger car by fixed, variable, and mixed classes. Note that the only change from the preceding list is in the depreciation amount. Using the given data, develop a cost–volume chart and calculate the average cost per mile as a function of the annual mileage.

DISCUSSION: First we may examine the effect of driving an additional 1,000 miles over the 15,000 allotted miles. Since the loss in the car's value due to driving an additional 1,000 miles over 15,000 miles is estimated to be $185, the total cost per year and the average cost per mile, based on 16,000 miles, can be recalculated as follows:

- Added depreciation cost: $185.
- Added operating cost: 1,000 miles × 15 cents = $150.
- Total cost per year: $8,580 + $185 + $150 = $8,915.
- Average cost per mile ($8,915/16,000 miles): 55.72 cents.

Note that the average cost comes down as you drive more, as the ownership cost per mile is further reduced.

SOLUTION

Given: Financial data.

Find: The average cost per mile at an annual operating volume between 15,000 and 20,000 miles.

TABLE 8.2 Cost Classification of Owning and Operating a Passenger Car

Cost Classification	Reference	Cost
Variable costs:		
Standard miles per gallon	20 miles/gallon	
Average fuel price per gallon	$1.939/gallon	
Fuel and oil per mile		$0.085
Maintenance per mile		$0.058
Tires per mile		$0.007
Annual fixed costs:		
Insurance (comprehensive)		$1,195
License, registration, taxes		$390
Finance charge		$740
Mixed costs: Depreciation		
Fixed portion per year (15,000 miles)		$4,005
Variable portion per mile (above 15,000 miles)		$0.185

In Table 8.3, we summarize the costs of owning and operating the automobile at various annual operating volumes from 15,000 to 20,000 miles. Once the total cost figures are available at specific volumes, we can calculate the effect of volume on unit (per mile) costs by converting the total cost figures to average unit costs.

TABLE 8.3 Operating Costs as a Function of Mileage Driven

Volume Index (miles)	15,000	16,000	17,000	18,000	19,000	20,000
Variable costs (15¢ per mile)	$ 2,250	$ 2,400	$ 2,550	$ 2,700	$ 2,850	$ 3,000
Fixed costs	2,325	2,325	2,325	2,325	2,325	2,325
Mixed costs (depreciation):						
Variable portion	0	185	370	555	740	925
Fixed portion	4,005	4,005	4,005	4,005	4,005	4,005
Total variable cost	2,250	2,585	2,920	3,255	3,590	3,925
Total fixed cost	6,330	6,330	6,330	6,330	6,330	6,330
Total costs	$ 8,580	$ 8,915	$ 9,250	$ 9,585	$ 9,920	$10,255
Cost per mile	$0.5720	$0.5572	$0.5441	$0.5325	$0.5221	$0.5128

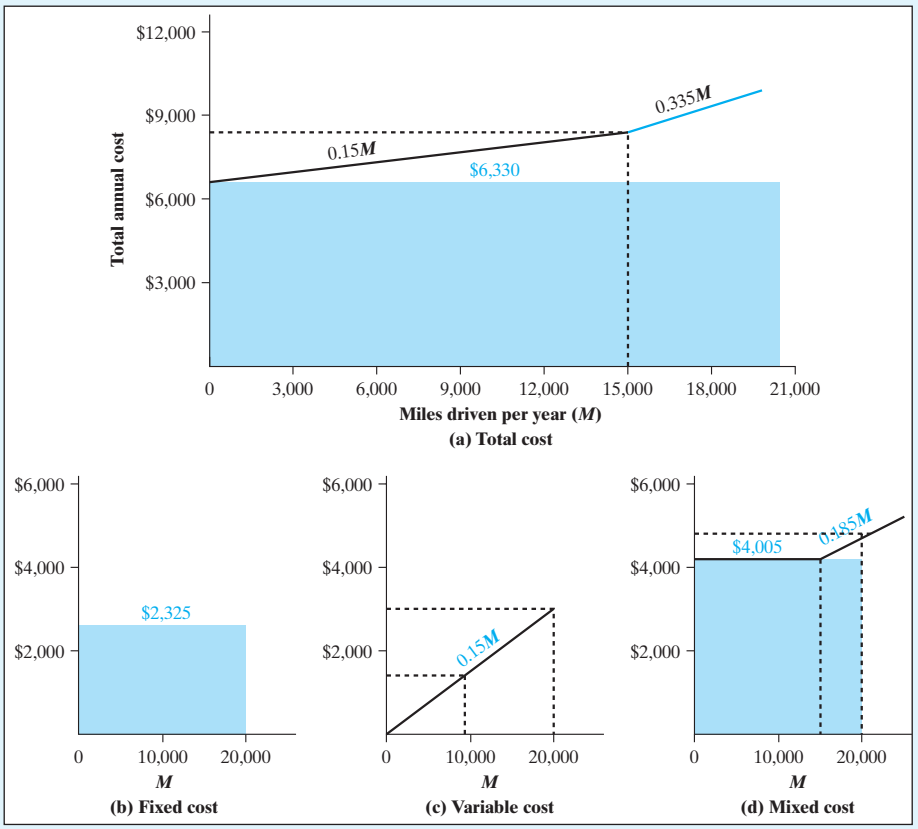


Figure 8.4 Cost–volume relationships pertaining to annual automobile costs (Example 8.2).

To estimate annual costs for any assumed mileage, we construct a **cost–volume diagram** as shown in Figure 8.4(a). Further, we can show the relation between volume (miles driven per year) and the three cost classes separately, as in Figure 8.4(b) through (d). We can use these cost–volume graphs to estimate both the separate and combined costs of operating the car at other possible volumes. For example, an owner who expects to drive 16,500 miles in a given year may estimate the total cost at $9,082.50, or 55.05 cents per mile. In Figure 8.4, all costs more than those necessary to operate at the zero level are known as variable costs. Since the fixed cost is $6,330 a year, the remaining $2,752.50 is variable cost. By combining all the fixed and variable elements of cost, we can state simply that the cost of owning and operating an automobile is $6,330 per year, plus 16.68 cents per mile driven during the year.

Figure 8.5 illustrates graphically the average unit cost of operating the automobile. The average fixed unit cost, represented by the height of the middle curve in the figure, declines steadily as the volume increases. The average unit cost is high when volume is low because the total fixed cost is spread over a relatively few units

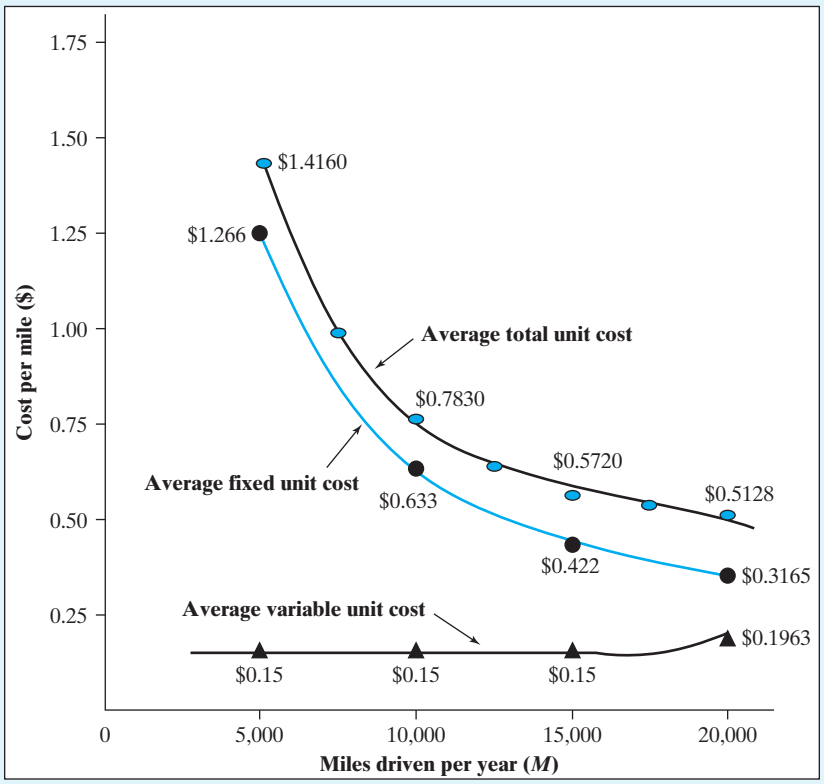


Figure 8.5 Average cost per mile of owning and operating a car (Example 8.2).

of volume. In other words, the total fixed costs remain the same regardless of the number of miles driven, but the average fixed cost decreases on a per mile basis as the number of miles driven increases.

8.4 Future Costs for Business Decisions

In the previous sections, our focus has been on classifying cost data that serve management's need to control and evaluate the operations of a firm. However, these data are historical in nature; they may not be suitable for management's planning future business operations. We are not saying that historical cost data are of no use in making decisions about the future. In fact, they serve primarily as the first step in predicting the uncertain future. However, the types of cost data that management needs in making choices between alternative courses of action are different from historical cost data.

8.4.1 Differential Cost and Revenue

As we have seen throughout the text, decisions involve choosing among alternatives. In business decisions, each alternative has certain costs and benefits that must be compared with the costs and benefits of the other available alternatives. A difference in cost between any two alternatives is known as a **differential cost**. Similarly, a difference in revenue

between any two alternatives is known as **differential revenue**. A differential cost is also known as an incremental cost, although, technically, an incremental cost should refer only to an increase in cost from one alternative to another.

Cost–volume relationships based on differential costs find many engineering applications. In particular, they are useful in making a variety of short-term operational decisions. Many short-run problems have the following characteristics:

- The base case is the status quo (the current operation or existing method), and we propose an alternative to the base case. If we find the alternative to have lower costs than the base case, we accept the alternative, assuming that nonquantitative factors do not offset the cost advantage. The **differential (incremental) cost** is the difference in total cost that results from selecting one alternative instead of another. If several alternatives are possible, we select the one with the maximum savings from the base. Problems of this type are often called trade-off problems, because one type of cost is traded off for another.
- New investments in physical assets are not required.
- The planning horizon is relatively short (a week or a month—certainly less than a year).
- Relatively few cost items are subject to change by management decision.

Incremental cost is the overall change that a company experiences by producing one additional unit of good.

Some common examples of short-run problems are method changes, operations planning, and make-or-buy decisions.

Method Changes

Often, we may derive the best information about future costs from an analysis of historical costs. Suppose the proposed alternative is to consider some new method of performing an activity. Then, as Example 8.3 shows, if the differential costs of the proposed method are significantly lower than the current method, we adopt the new method.

EXAMPLE 8.3 Differential Cost Associated with Adopting a New Production Method

The engineering department at an auto-parts manufacturer recommends that the current dies (the base case) be replaced with higher quality dies (the alternative), which would result in substantial savings in manufacturing one of the company's products. The higher cost of materials would be more than offset by the savings in machining time and electricity. If estimated monthly costs of the two alternatives are as shown in the accompanying table, what is the differential cost for going with better dies?

SOLUTION

Given: Financial data.

Find: Which production method is preferred.

In this problem, the differential cost is −$5,000 a month. The differential cost's being negative indicates a saving, rather than an addition to total cost. An important point to remember is that differential costs usually include variable costs, but fixed costs are affected only if the decision involves going outside of the relevant range. Although the production volume remains unchanged in our example, the slight increase

	Current Dies	Better Dies	Differential Cost
Variable costs:			
Materials	$150,000	$170,000	+$20,000
Machining labor	85,000	64,000	−21,000
Electricity	73,000	66,000	−7,000
Fixed costs:			
Supervision	25,000	25,000	0
Taxes	16,000	16,000	0
Depreciation	40,000	43,000	+3,000
Total	$392,000	$387,000	−$5,000

in depreciation expense is due to the acquisition of new machine tools (dies). All other items of fixed cost remained within their relevant ranges.

Operations Planning

In a typical manufacturing environment, when demand is high, managers are interested in whether to use a one-shift-plus-overtime operation or to add a second shift. When demand is low, it is equally possible to explore whether to operate temporarily at very low volume or to shut down until operations at normal volume become economical. In a chemical plant, several routes exist for scheduling products through the plant. The problem is which route provides the lowest cost. Example 8.4 illustrates how engineers may use cost–volume relationships in a typical operational analysis.

Break-even analysis: An analysis of the level of sales at which a project would make zero profit.

EXAMPLE 8.4 Break-Even Volume Analysis

Sandstone Corporation has one of its manufacturing plants operating on a single-shift five-day week. The plant is operating at its full capacity (24,000 units of output per week) without the use of overtime or extra shifts. Fixed costs for single-shift operation amount to $90,000 per week. The average variable cost is a constant $30 per unit, at all output rates, up to 24,000 units per week. The company has received an order to produce an extra 4,000 units per week beyond the current single-shift maximum capacity. Two options are being considered to fill the new order:

- **Option 1.** Increase the plant's output to 36,000 units a week by adding overtime, by adding Saturday operations, or both. No increase in fixed costs is entailed, but the variable cost is $36 per unit for any output in excess of 24,000 units per week, up to a 36,000-unit capacity.
- **Option 2.** Operate a second shift. The maximum capacity of the second shift is 21,000 units per week. The variable cost of the second shift is $31.50 per unit, and the operation of a second shift entails additional fixed costs of $13,500 per week.

Determine the range of operating volume that will make Option 2 profitable.

SOLUTION

Given: Financial data.

Find: The break-even volume that will make both options indifferent.

In this example, the operating costs related to the first-shift operation will remain unchanged if one alternative is chosen instead of another. Therefore, those costs are irrelevant to the current decision and can safely be left out of the analysis. Consequently, we need to examine only the increased total cost due to the additional operating volume under each option. (This kind of study is known as *incremental analysis*.) Let Q denote the additional operating volume. Then we have

- **Option 1.** Overtime and Saturday operation: $\$36Q$.
- **Option 2.** Second-shift operation: $\$13{,}500 + \$31.50Q$.

We can find the break-even volume (Q_b) by equating the incremental cost functions and solving for Q:

$$\begin{aligned} 36Q &= 13{,}500 + 31.5Q, \\ 4.5Q &= 13{,}500, \\ Q_b &= 3{,}000 \text{ units}. \end{aligned}$$

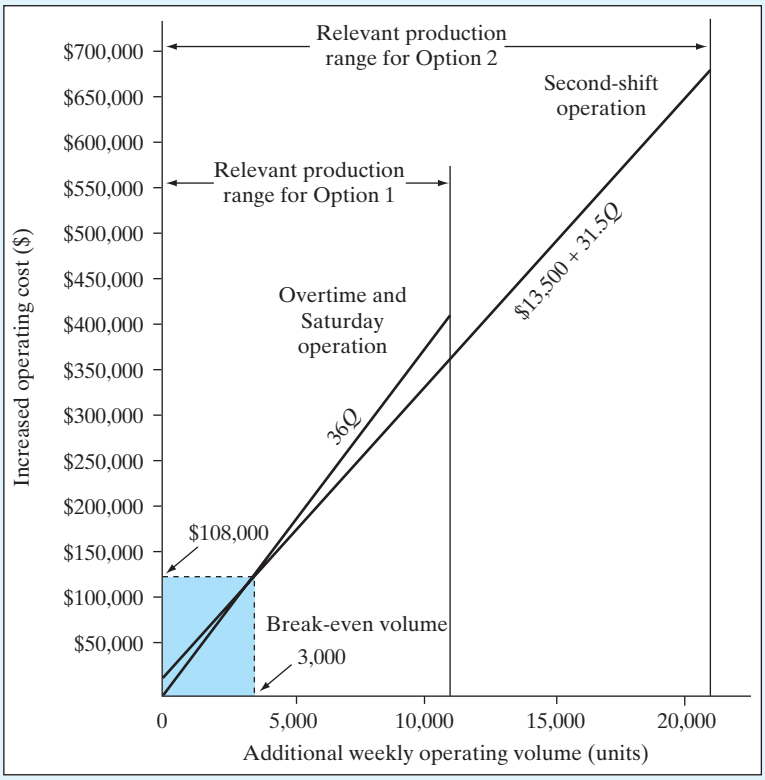


Figure 8.6 Cost–volume relationships of operating overtime and a Saturday operation versus second-shift operation beyond 24,000 units (Example 8.4).

If the additional volume exceeds 3,000 units, the second-shift operation becomes more efficient than overtime or Saturday operation. A break-even (or cost–volume) graph based on the foregoing data is shown in Figure 8.6. The horizontal scale represents additional volume per week. The upper limit of the relevant volume range for Option 1 is 12,000 units, whereas the upper limit for Option 2 is 21,000 units. The vertical scale is in dollars of cost. The operating savings expected at any volume may be read from the cost–volume graph. For example, the break-even point (zero savings) is 3,000 units per week. Option 2 is a better choice, since the additional weekly volume from the new order exceeds 3,000 units.

Make-or-Buy (Outsourcing) Decision

In business, the make-or-buy decision arises on a fairly frequent basis. Many firms perform certain activities using their own resources and pay outside firms to perform certain other activities. It is a good policy to constantly seek to improve the balance between these two types of activities by asking whether we should outsource some function that we are now performing ourselves or vice versa. Make-or-buy decisions are often grounded in the concept of *opportunity cost*.

Opportunity cost: The benefits you could have received by taking an alternative action.

8.4.2 Opportunity Cost

Opportunity cost may be defined as the potential benefit that is given up as you seek an alternative course of action. In fact, virtually every alternative has some opportunity cost associated with it. For example, suppose you have a part-time job while attending college that pays you $200 per week. You would like to spend a week at the beach during spring break, and your employer has agreed to give you the week off. What would be the opportunity cost of taking the time off to be at the beach? The $200 in lost wages would be an opportunity cost.

In an economic sense, opportunity cost could mean the contribution to income that is forgone by not using a limited resource in the best way possible. Or we may view opportunity costs as cash flows that could be generated from an asset the firm already owns, provided that such flows are not used for the alternative in question. In general, *accountants do not post opportunity cost in the accounting records of an organization. However, this cost must be explicitly considered in every decision.* In sum,

- An opportunity cost arises when a project uses a resource that may already have been paid for by the firm.
- When a resource that is already owned by a firm is being considered for use in a project, that resource has to be priced on its next-best alternative use, which may be
  1. A sale of the asset, in which case the opportunity cost is the expected proceeds from the sale, net of any taxes on gains.
  2. Renting or leasing the asset out, in which case the opportunity cost is the expected present value of the after-tax revenue from the rental or lease.
  3. Some use elsewhere in the business, in which case the opportunity cost is the cost of replacing the resource.
  4. That the asset has been abandoned or is of no use. Then the opportunity cost is zero.

EXAMPLE 8.5 Opportunity Cost: Lost Rental Income (Opportunity Cost)

Benson Company is a farm equipment manufacturer that currently produces 20,000 units of gas filters annually for use in its lawn-mower production. The expected annual production cost of the gas filters is summarized as follows:

Variable costs:	
Direct materials	$100,000
Direct labor	190,000
Power and water	35,000
Fixed costs:	
Heating and light	20,000
Depreciation	100,000
Total cost	$445,000

Tompkins Company has offered to sell Benson 20,000 units of gas filters for $17.00 per unit. If Benson accepts the offer, some of the manufacturing facilities currently used to manufacture the filters could be rented to a third party at an annual rent of $35,000. Should Benson accept Tompkins's offer, and why?

SOLUTION

Given: Financial data; production volume = 20,000 units.

Find: Whether Benson should outsource the gas filter operation.

	Make Option	Buy Option	Differential Cost (Make-Buy)
Variable costs:			
Direct materials	$100,000		$100,000
Direct labor	190,000		190,000
Power and water	35,000		35,000
Gas filters		340,000	−340,000
Fixed costs:			
Heating and light	20,000	20,000	0
Depreciation	100,000	100,000	0
Rental income lost	35,000		35,000
Total cost	$480,000	$460,000	$20,000
Unit cost	$24.00	$23.00	$1.00

This problem is unusual in the sense that the buy option would generate a rental fee of $35,000. In other words, Benson could rent out the current manufacturing facilities if it were to purchase the gas filters from Tompkins. To compare the two options, we need to examine the cost of each option.

The buy option has a lower unit cost and saves $1 for each use of a gas filter. If the lost rental income (opportunity cost) were not considered, however, the decision would favor the make option.

Sunk cost: A cost that has been incurred and cannot be reversed

8.4.3 Sunk Costs

A sunk cost is a cost that has already been incurred by past actions. Sunk costs are not relevant to decisions, because they cannot be changed regardless of what decision is made now or in the future. The only costs relevant to a decision are costs that vary among the alternative courses of action being considered. To illustrate a sunk cost, suppose you have a very old car that requires frequent repairs. You want to sell the car, and you figure that the current market value would be about $1,200 at best. While you are in the process of advertising the car, you find that the car's water pump is leaking. You decided to have the pump repaired, which cost you $200. A friend of yours is interested in buying your car and has offered $1,300 for it. Would you take the offer, or would you decline it simply because you cannot recoup the repair cost with that offer? In this example, the $200 repair cost is a sunk cost. You cannot change this repair cost, regardless of whether you keep or sell the car. Since your friend's offer is $100 more than the best market value, it would be better to accept the offer.

8.4.4 Marginal Cost

We make decisions every day, as entrepreneurs, professionals, executives, investors, and consumers, with little thought as to where our motivations come from or how our assumptions of logic fit a particular academic regimen. As you have seen, the engineering economic decisions that we describe throughout this text owe much to English economist Alfred Marshall (1842–1924) and his concepts of **marginalism**. In our daily quest for material gain, rarely do we recall the precepts of microeconomics or marginal utility, yet the ideas articulated by Marshall remain some of the most useful core principles guiding economic decision making.

Definition

Marginal cost: The cost associated with one additional unit of production.

Another cost term useful in cost–volume analysis is marginal cost. We define **marginal cost** as the added cost that would result from increasing the rate of output by a single unit. The accountant's differential-cost concept can be compared to the economist's marginal-cost concept. In speaking of changes in cost and revenue, the economist employs the terms *marginal cost* and *marginal revenue*. The revenue that can be obtained from selling one more unit of product is called **marginal revenue**. The cost involved in producing one more unit of product is called **marginal cost**.

EXAMPLE 8.6 Marginal Costs versus Average Costs

Consider a company that has an available electric load of 37 horsepower and that purchases its electricity at the following rates:

kWh/Month	@$/kWh	Average Cost ($/kWh)
First 1,500	$0.050	$0.050
Next 1,250	0.035	$\frac{\$75 + 0.0350(X - 1{,}500)}{X}$
Next 3,000	0.020	$\frac{\$118.75 + 0.020(X - 2{,}750)}{X}$
All over 5,750	0.010	$\frac{\$178.25 + 0.010(X - 5{,}750)}{X}$

According to this rate schedule, the unit variable cost in each rate class represents the marginal cost per kilowatt-hours (kWh). Alternatively, we may determine the average costs in the third column by finding the cumulative total cost and dividing it by the total number of kWh (X). Suppose that the current monthly consumption of electric power averages 3,200 kWh. On the basis of this rate schedule, determine the marginal cost of adding one more kWh and, for a given operating volume (3,200 kWh), the average cost per kWh.

SOLUTION

Given: Marginal cost schedule for electricity; operating volume = 3,200 kWh.

Find: Marginal and average cost per kWh.

The marginal cost of adding one more kWh is $0.020. The average variable cost per kWh is calculated as follows:

kWh	Rate ($/kWh)	Cost
First 1,500	0.050	$75.00
Next 1,250	0.035	43.75
Remaining 450	0.020	9.00
Total		$127.75

The average variable cost per kWh is $127.75/3,200 kWh = $0.0399 kWh. Or we can find the value by using the formulas in the third column of the rate schedule:

$$\frac{\$118.75 + 0.020(3{,}200 - 2{,}750)}{3{,}200} = \frac{\$127.75}{3{,}200\ \text{kWh}} = \$0.0399\ \text{kWh}.$$

Changes in the average variable cost per unit are the result of changes in the marginal cost. As shown in Figure 8.7, the average variable cost continues to fall because the marginal cost is lower than the average variable cost over the entire volume.

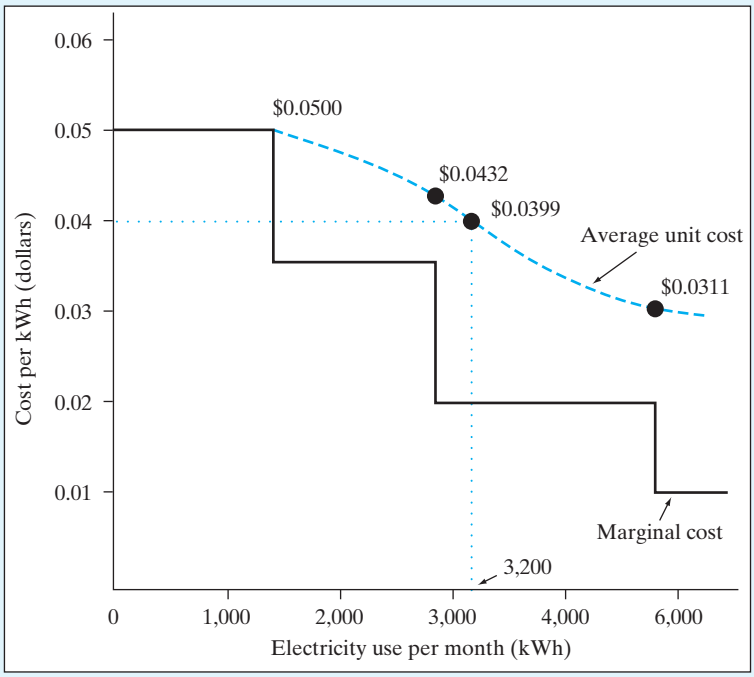


Figure 8.7 Marginal versus average cost per kWh (Example 8.6).

Marginal analysis: A technique used in microeconomics by which very small changes in specific variables are studied in terms of the effect on related variables and the system as a whole.

Marginal Analysis

The fundamental concept of marginal thinking is that you are where you are, and what is past is irrelevant. (This means that we should ignore the sunk cost.) The point is whether you move forward, and you will do so if the benefits outweigh the costs, even if they do so by a smaller margin than before. You will continue to produce a product or service until the cost of doing so equals the revenue derived. Microeconomics suggests that businesspersons and consumers measure progress not in great leaps, but in small incremental steps. Rational persons will reevaluate strategies and take new actions if benefits exceed costs on a marginal basis. If there is more than one alternative to choose, do so always with the alternative with greatest marginal benefit.

As we have mentioned, the economist's marginal-cost concept is the same as the accountant's differential-cost concept. For a business problem on maximization of profit, economists place a great deal of emphasis on the importance of marginal analysis: Rational individuals and institutions should perform the most cost-effective activities first. Specifically,

- When you examine marginal costs, you want to use the least expensive methods first and the most expensive last (if at all).

- Similarly, when you examine marginal revenue (or demand) the most revenue-enhancing methods should be used first, the least revenue enhancing last.
- If we need to consider the revenue along with the cost, the volume at which the total revenue and total cost are the same is known as the *break-even point*. If the cost and revenue function are assumed to be linear, this point may also be calculated, by means of the following formula:

$$\text{Break-even volume} = \frac{\text{Fixed costs}}{\text{Sales price per unit} - \text{Variable cost per unit}}$$

$$= \frac{\text{Fixed costs}}{\text{Marginal contribution per unit}} \tag{8.1}$$

The difference between the unit sales price and the unit variable cost is the producer's **marginal contribution**, also known as **marginal income**. This means that each unit sold contributes toward absorbing the company's fixed costs.

EXAMPLE 8.7 Profit-Maximization Problem: Marginal Analysis[2]

Suppose you are a chief executive officer (CEO) of a small pharmaceutical company that manufactures generic aspirin. You want the company to maximize its profits. You can sell as many aspirins as you make at the prevailing market price. You have only one manufacturing plant, which is the constraint. You have the plant working at full capacity Monday through Saturday, but you close the plant on Sunday because on Sundays you have to pay workers overtime rates, and it is not worth it. The marginal costs of production are constant Monday through Saturday. Marginal costs are higher on Sundays, only because labor costs are higher.

Now you obtain a long-term contract to manufacture a brand-name aspirin. The costs of making the generic aspirin or the brand-name aspirin are identical. In fact, there is no cost or time involved in switching from the manufacture of one to the other. You will make much larger profits from the brand-name aspirin, but the demand is limited. One day of manufacturing each week will permit you to fulfill the contract. You can manufacture both the brand-name and the generic aspirin. Compared with the situation before you obtained the contract, your profits will be much higher if you now begin to manufacture on Sundays—even if you have to pay overtime wages.

- *Generic aspirin*. Each day, you can make 1,000 cases of generic aspirin. You can sell as many as you make, for the market price of $10 per case. Every week you have fixed costs of $5,000 (land tax and insurance). No matter how many cases you manufacture, the cost of materials and supplies is $2 per case; the cost of labor is $5 per case, except on Sundays, when it is $10 per case.
- *Brand-name aspirin*. Your order for the brand-name aspirin requires that you manufacture 1,000 cases per week, which you sell for $30 per case. The cost for the brand-name aspirin is identical to the cost of the generic aspirin.

What do you do?

[2] *Source:* "Profit Maximization Problem," by David Hemenway and Elon Kohlberg, *Economic Inquiry,* October 1, 1997, Page 862, Copyright 1997 Western Economic Association International.

SOLUTION

Given: Sales price, \$10 per case for generic aspirin, \$30 per case for band aspirin; fixed cost, \$5,000; variable cost, \$7 per case during weekdays, \$12 per case on Sunday operation; weekly production, 6,000 cases of generic aspirin, 1,000 cases of brand-name aspirin.

Find: (a) Optimal production mix and (b) break-even volume.

(a) Optimal production mix: The marginal costs of manufacturing brand-name aspirin are constant Monday through Saturday; they rise substantially on Sunday and are above the marginal revenue from manufacturing generic aspirin. In other words, your company should manufacture the brand-name aspirin first. Your marginal revenue is the highest the "first" day, when you manufacture the brand-name aspirin. It then falls and remains constant for the rest of the week. On the seventh day (Sunday), the marginal revenue from manufacturing the generic aspirin is still below the marginal cost. You should manufacture brand-name aspirin one day a week and generic aspirin five days a week. On Sundays, the plant should close.

- The marginal revenue from manufacturing on Sunday is \$10,000 (1,000 cases times \$10 per case).
- The marginal cost from manufacturing on Sunday is \$12,000 (1,000 cases times \$12 per case—\$10 labor + \$2 materials).
- Profits will be \$2,000 lower than revenue if the plant operates on Sunday.

(b) Break-even volume: The total revenue and cost functions can be represented as follows:

$$\text{Total revenue function: } \begin{cases} 30Q & \text{for } \quad 0 \le Q \le 1{,}000 \\ 30{,}000 + 10Q & \text{for } 1{,}000 < Q \le 6{,}000, \end{cases}$$

$$\text{Total cost function: } \begin{cases} 5{,}000 + 7Q & \text{for } 0 \le Q \le 6{,}000 \\ 47{,}000 + 12Q & \text{for } 6{,}000 \le Q \le 7{,}000. \end{cases}$$

Table 8.4 shows the various factors involved in the production of the brand-name and the generic aspirin.

- If you produce the brand-name aspirin first, the break-even volume is

$$30Q - 7Q - 5{,}000 = 0,$$
$$Q_b = 217.39.$$

- If you produce the generic aspirin first, the break-even volume is

$$10Q - 7Q - 5{,}000 = 0,$$
$$Q_b = 1{,}666.67.$$

Clearly, scheduling the production of the brand-name aspirin first is the better strategy, as you can recover the fixed cost (\$5,000) much faster by selling just 217.39 cases of brand-name aspirin. Also, Sunday operation is not economical, as the marginal cost exceeds the marginal revenue by \$2,000, as shown in Figure 8.8.

TABLE 8.4 Net Profit Calculation as a Function of Production Volume

	Production Volume (Q)	Product Mix	Revenue	Total Revenue	Variable Cost	Fixed Cost	Total Cost	Net Profit
	0		0	0	0	$5,000	$5,000	−$5,000
Mon	1,000	Brand name	$30,000	$30,000	$7,000	0	12,000	18,000
Tue	2,000	Generic	10,000	40,000	7,000	0	19,000	21,000
Wed	3,000	Generic	10,000	50,000	7,000	0	26,000	24,000
Thu	4,000	Generic	10,000	60,000	7,000	0	33,000	27,000
Fri	5,000	Generic	10,000	70,000	7,000	0	40,000	30,000
Sat	6,000	Generic	10,000	80,000	7,000	0	47,000	33,000
Sun	7,000	Generic	10,000	90,000	12,000	0	59,000	31,000

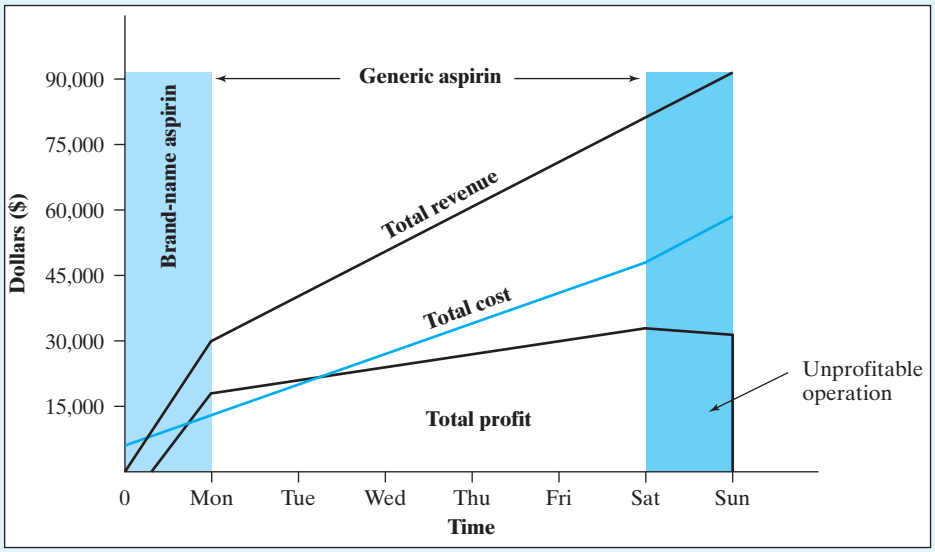


Figure 8.8 Weekly profits as a function of time. Sunday operation becomes unprofitable, because the marginal revenue stays at $10 per case whereas the marginal cost increases to $12 per case (Example 8.7).

8.5 Estimating Profit from Production

Up to this point, we have defined various cost elements and their behaviors in a manufacturing environment. Our ultimate objective is to develop a project's cash flows; we do so in Chapter 10, where the first step is to formulate the budget associated with the sales and production of the product. As we will explain in that chapter, the income statement developed in the current chapter will be the focal point for laying out the project's cash flows.

8.5.1 Calculation of Operating Income

Accountants measure the net income of a specified operating period by subtracting expenses from revenues for that period. These terms can be defined as follows:

1. The **project revenue** is the income earned[3] by a business as a result of providing products or services to customers. Revenue comes from sales of merchandise to customers and from fees earned by services performed for clients or others.
2. The **project expenses** that are incurred[4] are the cost of doing business to generate the revenues of the specified operating period. Some common expenses are the cost of the goods sold (labor, material, inventory, and supplies), depreciation, the cost of employees' salaries, the business's operating costs (such as the cost of renting buildings and the cost of insurance coverage), and income taxes.

The business expenses just listed are accounted for in a straightforward fashion on a company's income statement and balance sheet: The amount paid by the organization for each item would translate, dollar for dollar, into expenses in financial reports for the period. One additional category of expenses—the purchase of new assets—is treated by depreciating the total cost gradually over time. Because capital goods are given this unique accounting treatment, depreciation is accounted for as a separate expense in financial reports. Because of its significance in engineering economic analysis, we will treat depreciation accounting in a separate chapter.

Figure 8.9 will be used as a road map to construct the income statement related to the proposed manufacturing activities.

8.5.2 Sales Budget for a Manufacturing Business

The first step in laying out a sales budget for a manufacturing business is to predict the dollar sales, which is the key to the entire process. The estimates are typically expressed in both dollars and units of the product. Using the expected selling price, we can easily extend unit sales

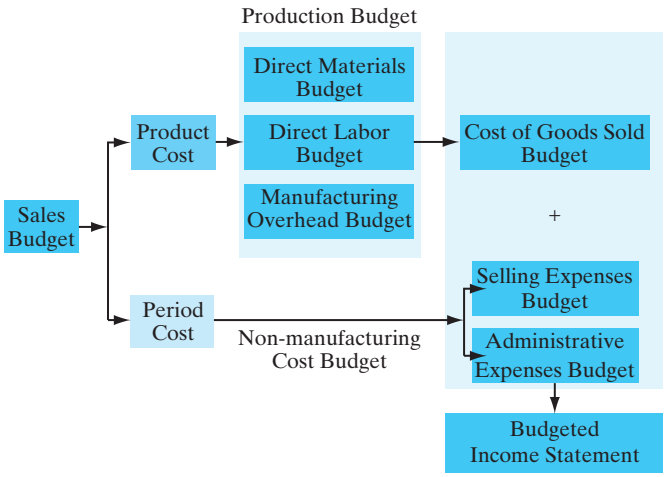


Figure 8.9 Process of creating a master production budget.

[3] Note that the cash may be received in a different accounting period.
[4] Note that the cash may be paid in a different accounting period.

to revenues. Often, the process is initiated by individual salespersons or managers predicting sales in their own area for the budget period. Of course, an aggregate sales budget is influenced by economic conditions, pricing decisions, competition, marketing programs, etc. To illustrate, suppose that you want to create a sales budget schedule on a quarterly basis. Projected sales units are 1,000 units during the first quarter, 1,200 units during the second quarter, 1,300 units during the third quarter, and 1,500 units during the fourth quarter. The projected sales price is $15 per unit. Then an estimated sales schedule looks like the following:

Sales Budget Schedule (Year 2006)—Product X					
	1Q	2Q	3Q	4Q	Annual Total
Budgeted units	1,000	1,200	1,300	1,500	5,000
Sales price	$ 15	$ 15	$ 15	$ 15	$ 15
Estimated sales	$ 15,000	$ 18,000	$ 19,500	$ 22,500	$ 75,000

8.5.3 Preparing the Production Budget

Once the sales budget is known, we can prepare the production activities. Using the sales budget for the number of project units needed, we prepare an estimate of the number of units to be produced in the budget period. Note that the production budget is the basis for projecting the cost-of-goods-manufactured budget, which we will discuss subsequently. To illustrate, we may use the following steps:

1. From the sales budget, record the projected number of units to be sold.
2. Determine the desired number of units to carry in the ending inventory; usually, that number is a percentage of next quarter's needs. In our example, we will assume that 20% of the budgeted units will be the desirable ending inventory position in each quarter.
3. *Add* to determine the total number of units needed each period.
4. Determine the projected number of units in the beginning inventory. Note that the beginning inventory is last quarter's ending inventory. In our example, we will assume that the first quarter's beginning inventory is 100 units.
5. *Subtract* to determine the projected production budget.

Then a typical production budget may look like the following:

Production Budget (Year 2006)—Product X					
	1Q	2Q	3Q	4Q	Annual Total
Budgeted units to be produced	1,000	1,200	1,300	1,500	5,000
Desired ending inventory	200	240	260	300	1,000
Total units needed	1,200	1,440	1,560	1,800	6,000
Less beginning inventory	100	200	240	260	800
Units to produce	1,100	1,240	1,320	1,540	5,200

Materials Budgets

Once we know how many units we need to produce, we are ready to develop direct materials budgets. We may use the following steps:

1. From the production budget, copy the projected number of units to be produced.
2. *Multiply* by the amount of raw materials needed per unit to calculate the amount of materials needed. In our example, we will assume that each production unit consumes $4 of materials.
3. Calculate the desired ending inventory (the number of units required in the ending inventory × $4).
4. *Add* to calculate the total amount of materials needed.
5. *Subtract* the beginning inventory, which is last quarter's ending inventory, to calculate the amount of raw materials needed to be purchased.
6. Calculate the net cost of raw materials.

Then a typical direct materials budget may look like the following:

Direct Materials Budget (Year 2006)—Product X

	1Q	2Q	3Q	4Q	Annual Total
Units to produce	1,100	1,240	1,320	1,540	5,200
Unit cost of materials	$ 4	$ 4	$ 4	$ 4	
Cost of materials for units to be produced	$ 4,400	$ 4,960	$ 5,280	$ 6,160	$ 20,800
Plus cost of materials in ending inventory	$ 800	$ 960	$ 1,040	$ 1,200	$ 4,000
Total cost of materials needed	$ 5,200	$ 5,920	$ 6,320	$ 7,360	$ 24,800
Less cost of materials in beginning inventory	$ 400	$ 800	$ 960	$ 1,040	$ 3,200
Cost of materials to purchase	$ 4,800	$ 5,120	$ 5,360	$ 6,320	$ 21,600

Direct Labor Budget for a Manufacturing Business

As with the materials budgets, once the production budget has been completed, we can easily prepare the direct labor budget. This budget allows the firm to estimate labor requirements—both labor hours and dollars—in advance. To illustrate, use the following steps:

1. From the production budget, copy the projected number of units to be produced.
2. *Multiply* by the direct labor cost per unit to calculate the total direct labor cost. In our example, we will assume that the direct labor cost is $3 per unit.

Then a typical direct labor budget may look like the following:

Direct Labor Budget (Year 2006)—Product X					
	1Q	2Q	3Q	4Q	Annual Total
Units to produce	1,100	1,240	1,320	1,540	5,200
× Direct labor cost per unit	$ 3.00	$ 3.00	$ 3.00	$ 3.00	
Total direct labor cost ($)	$ 3,300	$ 3,720	$ 3,960	$ 4,620	$ 15,600

Overhead Budget for a Manufacturing Business

The overhead budget should provide a schedule of all costs of production other than direct materials and direct labor. Typically, the overhead budget is expressed in dollars, based on a predetermined overhead rate. In preparing a manufacturing overhead budget, we may take the following steps:

1. From the production budget, copy the projected number of units to be produced.
2. *Multiply* by the variable overhead rate to calculate the budgeted variable overhead. In our example, we will assume the variable overhead rate to be $1.50 per unit. There are several ways to determine this overhead rate. One common approach (known as traditional standard costing) is to divide the expected total overhead cost by the budgeted number of direct labor hours (or units). Another approach is to adopt an **activity-based costing** concept, allocating indirect costs against the activities that caused them. We will not review this accounting method here, but it can more accurately reflect indirect cost improvement than traditional standard costing can.
3. *Add* any budgeted fixed overhead to calculate the total budgeted overhead. In our example, we will assume the fixed overhead to be $230 each quarter.

Activity-based costing (ABC) identifies opportunities to improve business process effectiveness and efficiency by determining the "true" cost of a product or service.

Then a typical manufacturing overhead budget may look like the following:

Manufacturing Overhead Budget (Year 2006)—Product X					
	1Q	2Q	3Q	4Q	Annual Total
Units to produce	1,100	1,240	1,320	1,540	5,200
Variable mfg overhead rate per unit ($1.50)	$ 1,650	$ 1,860	$ 1,980	$ 2,310	$ 7,800
Fixed mfg overhead	$ 230	$ 230	$ 230	$ 230	$ 920
Total overhead	$ 1,880	$ 2,090	$ 2,210	$ 2,540	$ 8,720

8.5.4 Preparing the Cost-of-Goods-Sold Budget

The production budget developed in the previous section shows how much it would cost to produce the required production volume. Note that the number of units to be produced includes both the anticipated number of sales units and the number of units in inventory.

The cost-of-goods-sold budget is different from the production budget, because we do not count the costs incurred to carry the inventory. Therefore, we need to prepare a budget that details the costs related to the sales, not the inventory. Typical steps in preparing a cost-of-goods-sold budget are as follows:

1. From the sales budget, and not the production budget, copy the budgeted number of sales units.
2. *Multiply* by the direct material cost per unit to estimate the amount of direct materials.
3. *Multiply* by the direct labor cost per unit to estimate the direct labor.
4. *Multiply* by the manufacturing overhead per unit to estimate the overhead.

Then a typical cost-of-goods-sold budget may look like the following:

Cost of goods sold: A figure reflecting the cost of the product or good that a company sells to generate revenue.

Cost of Goods Sold (Year 2006)—Product X					
	1Q	2Q	3Q	4Q	Annual Total
Budgeted sales units	1,000	1,200	1,300	1,500	5,000
Direct materials ($4/unit)	$ 4,000	$ 4,800	$ 5,200	$ 6,000	$ 20,000
Direct labor ($3/unit)	$ 3,000	$ 3,600	$ 3,900	$ 4,500	$ 15,000
Mfg overhead:					
Variable ($1.50 per unit)	$ 1,500	$ 1,800	$ 1,950	$ 2,250	$ 7,500
Fixed	$ 230	$ 230	$ 230	$ 230	$ 920
Cost of goods sold	$ 7,000	$ 8,400	$ 9,100	$ 10,500	$ 35,000

8.5.5 Preparing the Nonmanufacturing Cost Budget

To complete the entire production budget, we need to add two more items related to production: the selling expenses and the administrative expenses.

Selling Expenses Budget for a Manufacturing Business

Since we know the sales volume, we can develop a selling expenses budget by considering the budgets of various individuals involved in marketing the products. The budget includes both variable cost items (shipping, handling, and sales commission) and fixed items, such as advertising and salaries for marketing personnel. To prepare the selling expenses budget, we may take the following steps:

1. From the sales budget, copy the projected number of unit sales.
2. List the variable selling expenses, such as the sales commission. In our example, we will assume that the sales commission is calculated at 5% of unit sales.
3. List the fixed selling expenses, typically rent, depreciation expenses, advertising, and other office expenses. In our example, we will assume the following: rent, $500 per quarter; advertising, $300 per quarter; office expense, $200 per quarter.
4. *Add* to calculate the total budgeted selling expenses.

Then a typical selling expenses budget may look like the following:

Selling Expenses (Year 2006)—Product X					
	1Q	2Q	3Q	4Q	Annual Total
Budgeted unit sales ($)	$ 15,000	$ 18,000	$ 19,500	$ 22,500	$ 75,000
Variable expenses:					
Commission	$ 750	$ 900	$ 975	$ 1,125	$ 3,750
Fixed expenses:					
Rent	$ 500	$ 500	$ 500	$ 500	$ 2,000
Advertising	$ 300	$ 300	$ 300	$ 300	$ 1,200
Office expenses	$ 200	$ 200	$ 200	$ 200	$ 800
Total selling expenses	$ 1,750	$ 1,900	$ 1,975	$ 2,125	$ 7,750

Administrative Expenses Budget for a Manufacturing Business

Another nonmanufacturing expense category to consider is administrative expenses, a category that contains mostly fixed-cost items such as executive salaries and the depreciation of administrative buildings and office furniture. To prepare an administrative expense budget, we may take the following steps:

1. List the variable administrative expenses, if any.
2. List the fixed administrative expenses, which include salaries, insurance, office supplies, and utilities. We will assume the following quarterly expenses: salaries, $1,400; insurance, $135; office supplies, $300; other office expenses, $150.
3. *Add* to calculate the total administrative expenses.

Then a typical administrative expenses budget may look like the following:

Administrative Expenses (Year 2006)—Product X					
	1Q	2Q	3Q	4Q	Annual Total
Variable expenses:					
Fixed expenses:					
Salaries	$ 1,400	$ 1,400	$ 1,400	$ 1,400	$ 5,600
Insurance	$ 135	$ 135	$ 135	$ 135	$ 540
Office supplies	$ 300	$ 300	$ 300	$ 300	$ 1,200
Utilities (phone, power, water, etc.)	$ 500	$ 500	$ 500	$ 500	$ 2,000
Other office expenses	$ 150	$ 150	$ 150	$ 150	$ 600
Total administrative expenses	$ 2,485	$ 2,485	$ 2,485	$ 2,485	$ 9,940

8.5.6 Putting It All Together: The Budgeted Income Statement

Now we are ready to develop a consolidated budget that details a company's projected sales, costs, expenses, and net income. To determine the net income, we need to include any other operating expenses, such as interest expenses and renting or leasing expenses. Once we calculate the taxable income, we can determine the federal taxes to pay. The procedure to follow is

1. Copy the net sales from the sales budget.
2. Copy the cost of goods sold.
3. Copy both the selling and administrative expenses.
4. Gross income = Sales − Cost of goods sold.
5. Operating income = Sales − (Cost of goods sold + Operating expenses).
6. Determine any interest expense incurred during the budget period.
7. Calculate the federal income tax at a percentage of taxable income. In our example, let's assume a 35% tax rate.
8. Net income = Income from operations − Federal income tax, which summarizes the projected profit from the budgeted sales units.

Then the budgeted income statement would look like the format shown in Table 8.5.

Once you have developed a budgeted income statement, you may be able to examine the profitability of the manufacturing operation. Three margin figures are commonly used to quickly assess the profitability of the operation: gross margin, operating margin, and net profit margin.

TABLE 8.5 Budgeted Income Statement

Budgeted Income Statement (Year 2006)—Product X					
	1Q	2Q	3Q	4Q	Annual Total
Sales	$ 15,000	$ 18,000	$ 19,500	$ 22,500	$ 75,000
Cost of goods sold	$ 7,000	$ 8,400	$ 9,100	$ 10,500	$ 35,000
Gross income	$ 8,000	$ 9,600	$ 10,400	$ 12,000	$ 40,000
Operating expenses:					
Selling expenses	$ 1,750	$ 1,900	$ 1,975	$ 2,125	$ 7,750
Administrative expenses	$ 2,485	$ 2,485	$ 2,485	$ 2,485	$ 9,940
Operating income	$ 3,765	$ 5,215	$ 5,940	$ 7,390	$ 22,310
Interest expenses	$ —	$ —	$ —	$ —	$ —
Net income before taxes	$ 3,765	$ 5,215	$ 5,940	$ 7,390	$ 22,310
Income taxes (35%)	$ 1,318	$ 1,825	$ 2,079	$ 2,587	$ 7,809
Net income	$ 2,447	$ 3,390	$ 3,861	$ 4,804	$ 14,502

Gross Margin

The gross margin reveals how much a company earns, taking into consideration the costs that it incurs for producing its products or services. In other words, gross margin is equal to gross income divided by net sales and is expressed as a percentage:

$$\text{Gross margin} = \frac{\text{Gross income}}{\text{Net sales}}. \tag{8.2}$$

In our example, gross margin = \$40,000/\$75,000 = 53%. Gross margin indicates how profitable a company is at the most fundamental level. Companies with higher gross margins will have more money left over to spend on other business operations, such as research and development or marketing.

Operating Margin

Operating margin gives analysts an idea of how much a company makes (before interest and taxes) on each dollar of sales.

The operating margin is defined as the operating profit for a certain period, divided by revenues for that period:

$$\text{Operating margin} = \frac{\text{Operating income}}{\text{Net sales}}. \tag{8.3}$$

In our example, operating margin = \$22,310/\$75,000 = 30%. Operating *profit margin* indicates how effective a company is at controlling the costs and expenses associated with its normal business operations.

Net Profit Margin

As we defined the term in Chapter 2, the net profit margin is obtained by dividing net profit by net revenues, often expressed as a percentage:

$$\text{Net profit margin} = \frac{\text{Net income}}{\text{Net sales}}. \tag{8.4}$$

This number is an indication of how effective a company is at cost control. The higher the net profit margin, the more effective the company is at converting revenue into actual profit. In our example, the net profit margin = \$14,502/\$75,000 = 19%. The net profit margin is a good way of comparing companies in the same industry, since such companies are generally subject to similar business conditions.

8.5.7 Looking Ahead

The operational decision problem described in this chapter tends to have a relatively short-term horizon (weekly or monthly). That is, such decisions do not commit a firm to a certain course of action over a relatively long period. If operational decision problems significantly affect the amount of funds that must be invested in a firm, fixed costs will have to increase. In Example 8.7, if the daily aspirin production increases to 10,000 cases per day, exceeding the current production capacity, the firm must make new investments in plant and equipment. Since the benefits of the expansion will continue to occur over an extended period, we need to consider the economic effects of the fixed costs over the life of the assets. Also, we have not discussed how we actually calculate the depreciation amount related to production or the amount of income taxes to be paid from profits generated from the operation. Doing so requires an understanding the concepts of **capital investment**, **depreciation**, **and income taxes**, which we will discuss in the next chapter.

SUMMARY

In this chapter, we examined several ways in which managers classify costs. How the costs will be used dictates how they will be classified:

- Most manufacturing companies divide **manufacturing costs** into three broad categories: *direct materials*, *direct labor*, and *manufacturing overhead*. **Nonmanufacturing costs** are classified into two categories: *marketing* or *selling costs* and *administrative costs*.
- For the purpose of valuing inventories and determining expenses for the balance sheet and income statement, costs are classified as either **product costs** or **period costs**.
- For the purpose of predicting **cost behavior**—how costs will react to changes in activity—managers commonly classify costs into two categories: variable costs and fixed costs.
- An understanding of the following **cost–volume relationships** is essential to developing successful business strategies and to planning future operations:

  Fixed operating costs: Costs that do not vary with production volume.

  Variable operating costs: Costs that vary with the level of production or sales.

  Average costs: Costs expressed in terms of units obtained by dividing total costs by total volumes.

  Differential (incremental) costs: Costs that represent differences in total costs, which result from selecting one alternative instead of another.

  Opportunity costs: Benefits that could have been obtained by taking an alternative action.

  Sunk costs: Past costs not relevant to decisions because they cannot be changed no matter what actions are taken.

  Marginal costs: Added costs that result from increasing rates of outputs, usually by single units.

  Marginal analysis: In economic analysis, we need to answer the apparently trivial question, "Is it worthwhile?"—whether the action in question will add sufficiently to the benefits enjoyed by the decision maker to make performing the action worth the cost. This is the heart of marginal-decision making—the statement that an action merits performance if, and only if, as a result, we can expect to be better off than we were before.

- At the level of plant operations, engineers must make decisions involving materials, production processes, and the in-house capabilities of company personnel. Most of these operating decisions do not require any investments in physical assets; therefore, they depend solely on the cost and volume of business activity, without any consideration of the time value of money.
- Engineers are often asked to prepare the production budgets related to their operating division. Doing this requires a knowledge of budgeting scarce resources, such as labor and materials, and an understanding of the overhead cost. The same budgeting practice will be needed in preparing the estimates of costs and revenues associated with undertaking a new project.

PROBLEMS

Classifying Costs

8.1 Identify which of the following transactions and events are product costs and which are period costs:

- Storage and material handling costs for raw materials.
- Gains or losses on the disposal of factory equipment.
- Lubricants for machinery and equipment used in production.
- Depreciation of a factory building.
- Depreciation of manufacturing equipment.
- Depreciation of the company president's automobile.
- Leasehold costs for land on which factory buildings stand.
- Inspection costs of finished goods.
- Direct labor cost.
- Raw-materials cost.
- Advertising expenses.

Cost Behavior

8.2 Identify which of the following costs are fixed and which are variable:

- Wages paid to temporary workers.
- Property taxes on a factory building.
- Property taxes on an administrative building.
- Sales commission.
- Electricity for machinery and equipment in the plant.
- Heating and air-conditioning for the plant.
- Salaries paid to design engineers.
- Regular maintenance on machinery and equipment.
- Basic raw materials used in production.
- Factory fire insurance.

8.3 The accompanying figures are a number of cost behavior patterns that might be found in a company's cost structure. The vertical axis on each graph represents total cost, and the horizontal axis on each graph represents level of activity (volume). For each of the situations that follow, identify the graph that illustrates the cost pattern involved. Any graph may be used more than once[5].

(a) Electricity bill—a flat-rate fixed charge, plus a variable cost after a certain number of kilowatt-hours are used.

(b) City water bill, which is computed as follows:

First 1,000,000 gallons $1,000 flat or less rate

Next 10,000 gallons $0.003 per gallon used

Next 10,000 gallons $0.006 per gallon used

Next 10,000 gallons $0.009 per gallon used

Etc. etc.

[5] Adapted originally from a CPA exam, and the same materials are also found in R. H. Garrison and E. W. Noreen, *Managerial Accounting*, 8th ed. Irwin, 1997, copyright © Richard D. Irwin, p. 271.

(c) Depreciation of equipment, where the amount is computed by the straight-line method. When the depreciation rate was established, it was anticipated that the obsolescence factor would be greater than the wear-and-tear factor.

(d) Rent on a factory building donated by the city, where the agreement calls for a fixed fee payment unless 200,000 labor-hours or more are worked, in which case no rent need be paid.

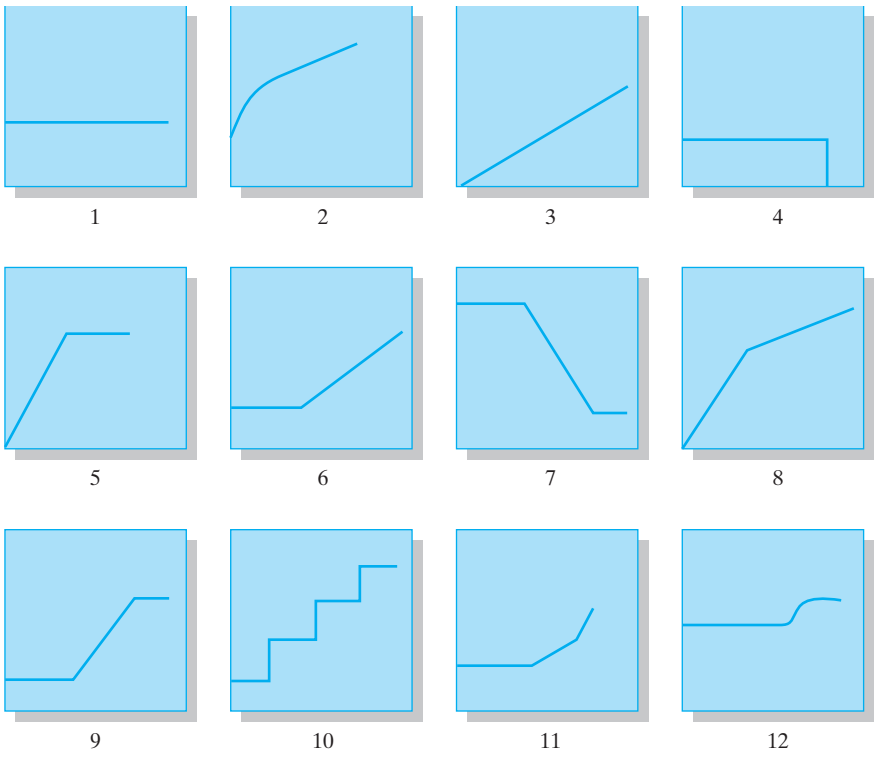
(e) Cost of raw materials, where the cost decreases by 5 cents per unit for each of the first 100 units purchased, after which it remains constant at $2.50 per unit.

(f) Salaries of maintenance workers, where one maintenance worker is needed for every 1,000 machine-hours or less (that is, 0 to 1,000 hours requires one maintenance worker, 1,001 to 2,000 hours requires two maintenance workers, etc.).

(g) Cost of raw materials used.

(h) Rent on a factory building donated by the county, where the agreement calls for rent of $100,000, less $1 for each direct labor-hour worked in excess of 200,000 hours, but a minimum rental payment of $20,000 must be paid.

(i) Use of a machine under a lease, where a minimum charge of $1,000 must be paid for up to 400 hours of machine time. After 400 hours of machine time, an additional charge of $2 per hour is paid, up to a maximum charge of $2,000 per period.



8.4 Harris Company manufactures a single product. Costs for the year 2001 for output levels of 1,000 and 2,000 units are as follows:

Units produced	1,000	2,000
Direct labor	$30,000	$30,000
Direct materials	20,000	40,000
Overhead:		
Variable portion	12,000	24,000
Fixed portion	36,000	36,000
Selling and administrative costs:		
Variable portion	5,000	10,000
Fixed portion	22,000	22,000

At each level of output, compute the following:
(a) Total manufacturing costs.
(b) Manufacturing costs per unit.
(c) Total variable costs.
(d) Total variable costs per unit.
(e) Total costs that have to be recovered if the firm is to make a profit.

Cost–Volume–Profit Relationships

8.5 Bragg & Stratton Company manufactures a specialized motor for chain saws. The company expects to manufacture and sell 30,000 motors in year 2001. It can manufacture an additional 10,000 motors without adding new machinery and equipment. Bragg & Stratton's projected total costs for the 30,000 units are as follows:

Direct Materials	$150,000
Direct labor	300,000
Manufacturing overhead:	
Variable portion	100,000
Fixed portion	80,000
Selling and administrative costs:	
Variable portion	180,000
Fixed portion	70,000

The selling price for the motor is $80.

(a) What is the total manufacturing cost per unit if 30,000 motors are produced?

(b) What is the total manufacturing cost per unit if 40,000 motors are produced?

(c) What is the break-even price on the motors?

8.6 The accompanying chart shows the expected monthly profit or loss of Cypress Manufacturing Company within the range of its monthly practical operating capacity. Using the information provided in the chart, answer the following questions:

(a) What is the company's break-even sales volume?

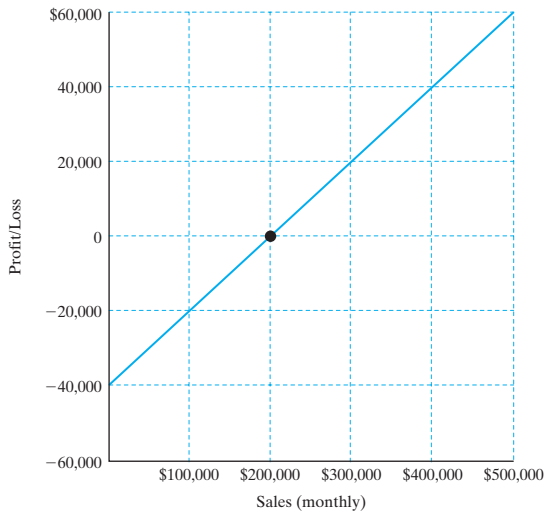
(b) What is the company's marginal contribution rate?

(c) What effect would a 5% decrease in selling price have on the break-even point in (a)?

(d) What effect would a 10% increase in fixed costs have on the marginal contribution rate in (b)?

(e) What effect would a 6% increase in variable costs have on the break-even point in (a)?

(f) If the chart also reflects $20,000 monthly depreciation expenses, compute the sale at the break-even point for cash costs.



8.7 The accompanying graph is a cost–volume–profit graph. In the graph, identify the following line segments or points:

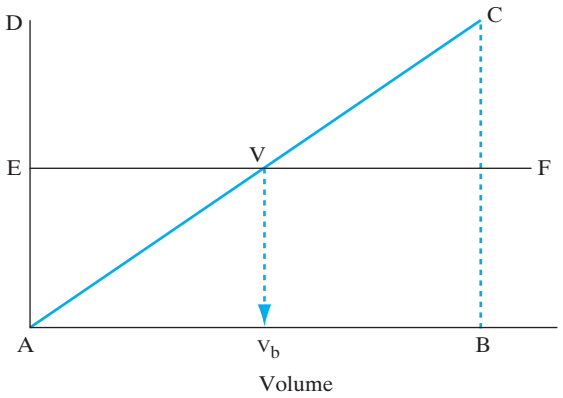
(a) Line EF represents _____.

(b) The horizontal axis AB represents _____, and the vertical axis AD represents _____.

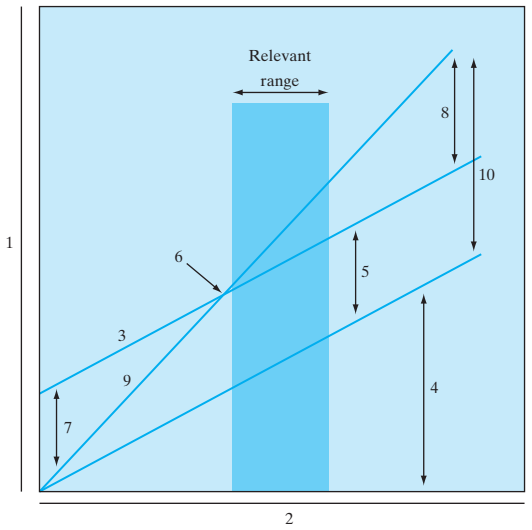
(c) Point V represents _____.

(d) The distance CB divided by the distance AB is _____.

(e) The point V_b is a break-even _____.



8.8 A cost–volume–profit (CVP) graph is a useful technique for showing relationships between costs, volume, and profits in an organization.



(a) Identify the numbered components in the accompanying CVP graph.

No.	Description	No.	Description
1		6	
2		7	
3		8	
4		9	
5		10	

(b) Using the typical CVP relationship shown, fill in the missing amounts in each of the following four situations (each case is independent of the others):

Case	Units Sold	Sales	Variable Expenses	Contribution Margin per Unit	Fixed Expenses	Net Income (Loss)
A	9,000	$270,000	$162,000		$ 90,000	
B		$350,000		$15	$170,000	$ 40,000
C	20,000		$280,000	$ 6		$ 35,000
D	5,000	$100,000			$ 82,000	($12,000)

Cost Concepts Relevant to Decision Making

8.9 An executive from a large merchandising firm has called your vice-president for production to get a price quote for an additional 100 units of a given product. The vice-president has asked you to prepare a cost estimate. The number of hours required to produce a unit is 5. The average labor rate is $12 per hour. The materials cost $14 per unit. Overhead for an additional 100 units is estimated at 50% of the direct labor cost. If the company wants to have a 30% profit margin, what should be the unit price to quote?

8.10 The Morton Company produces and sells two products: A and B. Financial data related to producing these two products are summarized as follows:

	Product A	Product B
Selling price	$ 10.00	$12.00
Variable costs	$ 5.00	$10.00
Fixed costs	$ 2,000	$ 600

(a) If these products are sold in the ratio of 4A for 3B, what is the break-even point?

(b) If the product mix has changed to 5A for 5B, what would happen to the break-even point?

(c) In order to maximize the profit, which product mix should be pushed?

(d) If both products must go through the same manufacturing machine and there are only 30,000 machine hours available per period, which product should be pushed? Assume that product A requires 0.5 hour per unit and B requires 0.25 hour per unit.

8.11 Pearson Company manufactures a variety of electronic printed circuit boards (PCBs) that go into cellular phones. The company has just received an offer from an outside supplier to provide the electrical soldering for Pearson's Motorola product line (Z-7 PCB, slimline). The quoted price is $4.80 per unit. Pearson is interested in this offer, since its own soldering operation of the PCB is at its peak capacity.

- **Outsourcing option.** The company estimates that if the supplier's offer were accepted, the direct labor and variable overhead costs of the Z-7 slimline would be reduced by 15% and the direct material cost would be reduced by 20%.
- **In-house production option.** Under the present operations, Pearson manufactures all of its own PCBs from start to finish. The Z-7 slimlines are sold through Motorola at $20 per unit. Fixed overhead charges to the Z-7 slimline total $20,000 each year. The further breakdown of producing one unit is as follows:

Direct materials	$ 7.50
Direct labor	5.00
Manufacturing overhead	4.00
Total cost	$16.00

The manufacturing overhead of $4.00 per unit includes both variable and fixed manufacturing overhead, based on a production of 100,000 units each year.

(a) Should Pearson Company accept the outside supplier's offer?

(b) What is the maximum unit price that Pearson Company should be willing to pay the outside supplier?

Short Case Study

ST8.1 The Hamilton Flour Company is currently operating its mill six days a week, 24 hours a day, on three shifts. At current prices, the company could easily obtain a sufficient volume of sales to take the entire output of a seventh day of operation each week. The mill's practical capacity is 6,000 hundredweight of flour per day. Note that

- Flour sells for $12.40 a hundredweight (cwt.) and the price of wheat is $4.34 a bushel. About 2.35 bushels of wheat are required per cwt. of flour. Fixed costs now average $4,200 a day, or $0.70 per cwt. The average variable cost of mill operation, almost entirely wages, is $0.34 per cwt.
- With Sunday operation, wages would be doubled for Sunday work, which would bring the variable cost of Sunday operation to $0.66 per cwt. Total fixed costs per week would increase by $420 (or $29,820) if the mill were to operate on Sunday.

(a) Using the information provided, compute the break-even volumes for six-day and seven-day operation.

(b) What are the marginal contribution rates for six-day and seven-day operation?

(c) Compute the average total cost per cwt. for six-day operation and the net profit margin per cwt. before taxes.

(d) Would it be economical for the mill to operate on Sundays? (Justify your answer numerically.)