After Completing This Chapter...

The student should be able to:

- Define various cost concepts.
- Provide specific examples of how and why these engineering cost concepts are important.
- Define engineering cost estimating.
- Explain the three types of engineering estimate, as well as common difficulties encountered in making engineering cost estimates.
- Use several common mathematical estimating models in cost estimating.
- Discuss the impact of the *learning curve* on cost estimates.
- State the relationship between cost estimating and estimating project benefits.
- Draw *cash flow diagrams* to show project costs and benefits.

Questions to Consider

1. By investing heavily in warehouses and other infrastructure, Webvan incurred large "fixed costs" that it would have to pay regardless of whether it attracted customers. By contrast, Tesco invested a more modest sum up front and hired employees only when customer orders increased enough to warrant it. How might these choices have affected the financial fates of the two companies?
2. In most cases, businesses that are seeking financing for start-up or expansion must develop detailed estimates of their likely costs and future earnings. But Webvan convinced investors that it was operating in a "new world" of Internet commerce, to which the old rules did not apply. How did this affect investors' willingness to accept Webvan's estimates of its financial prospects?
3. Generally, businesses view cost considerations as a constraint. In this case, however, the dotcom boom of the 1990s stood that rule on its head: the more Webvan spent, the more money investors seemed willing to give the company—at least until the boom ran its course. Would Webvan have been better off with investors who asked more questions and imposed more limits? Why or why not?

CHAPTER 2

Engineering Costs and Cost Estimating

Webvan Hits the Skids

Webvan, an on-line supermarket, aimed to revolutionize the humdrum business of selling groceries. Consumers could order their weekly provisions with a few clicks and have the goods delivered right to their door. It sounded like a great business plan, and the company had no trouble attracting capital during the dotcom boom of the late 1990s. Eager investors happily poured hundreds of millions into the company.

With that kind of money to spend, Webvan invested lavishly in building infrastructure, including large warehouses capable of filling 8000 orders a day. The firm rapidly expanded to serve multiple cities nationwide and even acquired a competing on-line company, Home Grocer.

But the hoped-for volume of customers never materialized. By early 2000, Internet grocers had managed to capture only a small part of the food sales market—far short of the 20% they had anticipated. When the dotcom boom went bust, Webvan suddenly looked much less attractive to investors, who quickly snapped their wallets shut.

Without new money coming in, Webvan suddenly had to face an uncomfortable fact: it was spending far more than it was earning. Finally, in 2001, Webvan went bankrupt. A rival on-line grocer, Peapod, narrowly escaped the same fate—but only because a Dutch retailer was willing to buy the company and continue pumping money into it.

Interestingly, at the same time Webvan was burning through millions in dotcom cash, a bricks-and-mortar supermarket chain in Britain called Tesco also decided to get into the on-line grocery business. Tesco invested around $56 million in a computerized processing system and, instead of building warehouses, had employees in each store walk the aisles filling orders. Unlike Webvan, Tesco made a profit.

This chapter defines fundamental cost concepts. These include fixed and variable costs, marginal and average costs, sunk and opportunity costs, recurring and nonrecurring costs, incremental cash costs, book costs, and life-cycle costs. We then describe the various types of estimates and difficulties sometimes encountered. The models that are described include unit factor, segmenting, cost indexes, power sizing, triangulation, and learning curves. The chapter discusses estimating benefits, developing cash flow diagrams, and drawing these diagrams with spreadsheets.

Understanding engineering costs is fundamental to the engineering economic analysis process, and therefore this chapter addresses an important question: Where do the numbers come from?

ENGINEERING COSTS

Evaluating a set of feasible alternatives requires that many costs be analyzed. Examples include costs for initial investment, new construction, facility modification, general labor, parts and materials, inspection and quality, contractor and subcontractor labor, training, computer hardware and software, material handling, fixtures and tooling, data management, and technical support, as well as general support costs (overhead). In this section we describe several concepts for classifying and understanding these costs.

Fixed, Variable, Marginal, and Average Costs

Fixed costs are constant or unchanging regardless of the level of output or activity. In contrast, **variable** costs depend on the level of output or activity. A **marginal** cost is the variable cost for one more unit, while the **average** cost is the total cost divided by the number of units.

For example, in a production environment fixed costs, such as those for factory floor space and equipment, remain the same even though production quantity, number of employees, and level of work-in-process may vary. Labor costs are classified as a *variable* cost because they depend on the number of employees in the factory. Thus *fixed* costs are level or constant regardless of output or activity, and *variable* costs are changing and related to the level of output or activity.

As another example, many universities charge full-time students a fixed cost for 12 to 18 hours and a cost per credit hour for each credit hour over 18. Thus for full-time students who are taking an overload (>18 hours), there is a variable cost that depends on the level of activity.

This example can also be used to distinguish between *marginal* and *average* costs. A marginal cost is the cost of one more unit. This will depend on how many credit hours the student is taking. If currently enrolled for 12 to 17 hours, adding one more is free. The marginal cost of an additional credit hour is $0. However, if the student is taking 18 or more hours, then the marginal cost equals the variable cost of one more hour.

To illustrate average costs, the fixed and variable costs need to be specified. Suppose the cost of 12 to 18 hours is $1800 per term and overload credits are $120/hour. If a student takes 12 hours, the *average* cost is $\$1800/12 = \$150$ per credit hour. If the student were to take 18 hours, the *average* cost decreases to $\$1800/18 = \$100$ per credit hour. If the student takes 21 hours, the *average* cost is $102.86 per credit hour [$\$1800 + (3 \times \$120)/21$].

Average cost is thus calculated by dividing the total cost for all units by the total number of units. Decision makers use **average** cost to attain an overall cost picture of the investment on a per unit basis.

Marginal cost is used to decide whether the additional unit should be made, purchased, or enrolled in. For the full-time student at our example university, the marginal cost of another credit is $0 or $120 depending on how many credits the student has already signed up for.

EXAMPLE 2-1

An entrepreneur named DK was considering the money-making potential of chartering a bus to take people from his hometown to an event in a larger city. DK planned to provide transportation, tickets to the event, and refreshments on the bus for his customers. He gathered data and categorized the predicted expenses as either fixed or variable.

DK's Fixed Costs		DK's Variable Costs	
Bus rental	$80	Event ticket	$12.50 per person
Gas expense	75	Refreshments	7.50 per person
Other fuels	20		
Bus driver	50		

Develop an expression of DK's total fixed and total variable costs for chartering this trip.

SOLUTION

DK's fixed costs will be incurred regardless of how many people sign up for the trip (even if only one person signs up!). These costs include bus rental, gas and fuel expense, and the cost to hire a driver:

$$\text{Total fixed costs} = 80 + 75 + 20 + 50 = \$225$$

DK's variable costs depend on how many people sign up for the charter, which is the level of activity. Thus for event tickets and refreshments, we would write

$$\text{Total variable costs} = 12.50 + 7.50 = \$20 \text{ per person}$$

From Example 2-1 we see how it is possible to calculate total fixed and total variable costs. Furthermore, these values can be combined into a single **total** cost equation as follows:

$$\textbf{Total cost} = \textbf{Total fixed cost} + \textbf{Total variable cost} \qquad (2\text{-}1)$$

The relationship between total cost and fixed and variable costs are shown in Figure 2-1. The fixed-cost portion of $3000 is the same across the entire range of the output variable x. Often, the variable costs are *linear* (y equals a constant times x); however, the variable costs can be nonlinear. For example, employees are often paid at 150% of their hourly rate for overtime hours, so that production levels requiring overtime have higher variable costs.

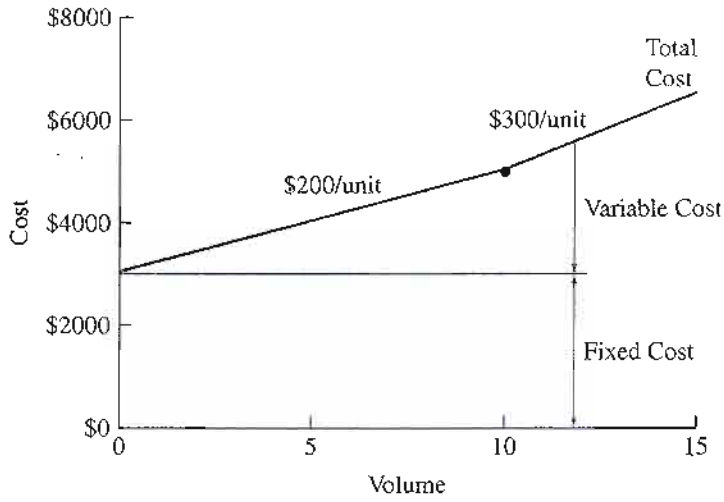


FIGURE 2-1 Fixed, variable, and total costs.

Total cost in Figure 2-1 is a fixed cost of \$3000 plus a variable cost of \$200 per unit for straight-time production of up to 10 units and \$300 per unit for overtime production of up to 5 more units.

Figure 2-1 can also be used to illustrate marginal and average costs. At a volume of 5 units the marginal cost is \$200 per unit, while at a volume of 12 units the marginal cost is \$300 per unit. The respective average costs are \$800 per unit, or $(3000 + 200 \times 5)/5$, and \$467 per unit, or $(3000 + 200 \times 10 + 300 \times 2)/12$.

EXAMPLE 2-2

In Example 2-1, DK developed an overall total cost equation for his business expenses. Now he wants to evaluate the potential to make money from this chartered bus trip.

SOLUTION

We use Equation 2-1 to find DK's total cost equation:

$$\text{Total cost} = \text{total fixed cost} + \text{total variable cost}$$
$$= \$225 + (\$20)(\text{number of people on the trip})$$

where number of people on the trip $= x$. Thus,

$$\text{Total cost} = 225 + 20x$$

Using this relationship, DK can calculate the total cost for any number of people—up to the capacity of the bus. What he lacks is a *revenue equation* to offset his costs. DK's total revenue from this trip can be expressed as:

$$\text{Total revenue} = (\text{Charter ticket price})(\text{Number of people on the trip}) = (\text{Ticket price})(x)$$

DK believes that he could attract 30 people at a charter ticket price of \$35. Thus

$$\text{Total profit} = (\text{Total revenue}) - (\text{Total costs}) = (35x) - (225 + 20x) = 15x - 225$$

At $x = 30$,

$$\text{Total profit} = 35 \times 30 - (225 + 20 \times 30) = \$225$$

So, if 30 people take the charter, DK will net a profit of \$225. This somewhat simplistic analysis ignores the value of DK's time—he would have to "pay himself" out of his \$225 profit.

In Examples 2-1 and 2-2 DK developed *total cost* and *total revenue* equations to describe the charter bus proposal. These equations can be used to create what is called a *profit–loss breakeven chart* (see Figure 2-2). Both the *costs* and *revenues* associated with various levels of output (activity) are placed on the same set of x–y axes. This allows one to illustrate a *breakeven point* (in terms of costs and revenue) and regions of *profit* and *loss* for some business activity. These terms can be defined as follows.

Breakeven point: The level of business activity at which the total costs to provide the product, good, or service are *equal to* the revenue (or savings) generated by providing the service. This is the level at which one "just breaks even."

Profit region: The output level of the variable x greater than the breakeven point, where total revenue is greater than total costs.

Loss region: The output level of the variable x less than the breakeven point, where total costs are greater than total revenue.

Notice in Figure 2-2 that the *breakeven* point for the number of persons on the charter trip is 15 people. For more than 15 people, DK will make a profit. If fewer than 15 sign up

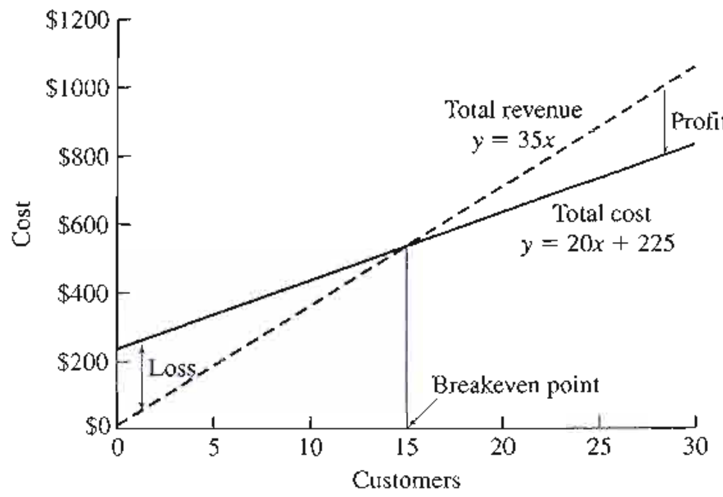


FIGURE 2-2 Profit–loss breakeven chart for Examples 2-1 and 2-2.

there will be a net loss. At the breakeven level the total cost to provide the charter equals the revenue received from the 15 passengers. We can solve for the *breakeven point* by setting the *total costs* and *total revenue* expressions equal to each other and solving for the unknown value of x. From Examples 2-1 and 2-2:

$$\text{Total cost} = \text{Total revenue}$$
$$\$225 + 20x = 35x$$
$$x = 15 \text{ people}$$

Sunk Costs

A **sunk cost** is money already spent as a result of a *past* decision. Sunk costs should be disregarded in our engineering economic analysis because current decisions cannot change the past. For example, dollars spent last year to purchase new production machinery is money that is *sunk:* the money allocated to purchase the production machinery has already been spent—there is nothing that can be done now to change that action. As engineering economists we deal with present and future opportunities.

Many times it is difficult not to be influenced by sunk costs. Consider 100 shares of stock in XYZ, Inc., purchased for $15 per share last year. The share price has steadily declined over the past 12 months to a price of $10 per share today. Current decisions must focus on the $10 per share that could be attained today (as well as future price potential), not the $15 per share that was paid last year. The $15 per share paid last year is a *sunk cost* and has no influence on present opportunities.

As another example, when Regina was a sophomore, she purchased a newest-generation laptop from the college bookstore for $2000. By the time she graduated, the most anyone would pay her for the computer was $400 because the newest models were faster, cheaper and had more capabilities. For Regina the original purchase price was a *sunk cost* that has no influence on her present opportunity to sell the laptop at its current market value ($400).

Opportunity Costs

An **opportunity cost** is associated with using a resource in one activity instead of another. Every time we use a business resource (equipment, dollars, manpower, etc.) in one activity, we give up the opportunity to use the same resources at that time in some other activity.

Every day businesses use resources to accomplish various tasks—forklifts are used to transport materials, engineers are used to design products and processes, assembly lines are used to make a product, and parking lots are used to provide parking for employees' vehicles. Each of these resources costs the company money to maintain for those intended purposes. However, that cost is not just made up of the dollar cost, it also includes the opportunity cost. Each resource that a firm owns can feasibly be used in several alternative ways. For instance, the assembly line could produce a different product, and the parking lot could be rented out, used as a building site, or converted into a small airstrip. Each of these alternative uses would provide some benefit to the company.

A firm that chooses to use the resource in one way is giving up the benefits that would be derived from using it in those other ways. The benefit that would be derived by using the resource in this "other activity" is the **opportunity cost** for using it in the chosen activity. Opportunity cost may also be considered a **forgone opportunity cost** because we are forgoing the benefit that could have been realized. A formal definition of opportunity cost might be:

> An *opportunity cost* is the benefit that is *forgone* by engaging a business resource in a chosen activity instead of engaging that same resource in the forgone activity.

As an example, suppose that friends invite a college student to travel through Europe over the summer break. In considering the offer, the student might calculate all the *out-of-pocket* cash costs that would be incurred. Cost estimates might be made for items such as air travel, lodging, meals, entertainment, and train passes. Suppose this amounts to $3000 for a 10-week period. After checking his bank account, the student reports that indeed he can afford the $3000 trip. However, the *true* cost to the student includes not only his *out-of-pocket* cash costs but also his *opportunity cost.* By taking the trip, the student is giving up the *opportunity* to earn $5000 as a summer intern at a local business. The student's total cost will comprise the $3000 cash cost as well as the $5000 opportunity cost (wages forgone)—the total cost to our traveler is thus $8000.

EXAMPLE 2-3

A distributor of electric pumps must decide what to do with a "lot" of old electric pumps purchased 3 years ago. Soon after the distributor purchased the lot, technology advances made the old pumps less desirable to customers. The pumps are becoming more obsolescent as they sit in inventory. The pricing manager has the following information.

Distributor's purchase price 3 years ago	$ 7,000
Distributor's storage costs to date	1,000
Distributor's list price 3 years ago	9,500
Current list price of the same number of new pumps	12,000
Amount offered for the old pumps from a buyer 2 years ago	5,000
Current price the lot of old pumps would bring	3,000

Looking at the data, the pricing manager has concluded that the price should be set at $8000. This is the money that the firm has "tied up" in the lot of old pumps ($7000 purchase and $1000 storage), and it was reasoned that the company should at least recover this cost. Furthermore, the pricing manager has argued that an $8000 price would be $1500 less than the list price from 3 years ago, and it would be $4000 less than what a lot of new pumps would cost ($12,000 − $8000). What would be your advice on price?

SOLUTION

Let's look more closely at each of the data items.

Distributor's purchase price 3 years ago: This is a sunk cost that should not be considered in setting the price today.

Distributor's storage costs to date: The storage costs for keeping the pumps in inventory are sunk costs; that is, they have been paid. Hence they should not influence the pricing decision.

Distributor's list price 3 years ago: If there have been no willing buyers in the past 3 years at this price, it is unlikely that a buyer will emerge in the future. This past list price should have no influence on the current pricing decision.

Current list price of newer pumps: Newer pumps now include technology and features that have made the older pumps less valuable. Directly comparing the older pumps to those with new technology is misleading. However, the price of the new pumps and the value of the new features help determine the market value of the old pumps.

Amount offered from a buyer 2 years ago: This is a forgone opportunity. At the time of the offer, the company chose to keep the lot and thus the $5000 offered became an opportunity cost for keeping the pumps. This amount should not influence the current pricing decision.

Current price the lot could bring: The price a willing buyer in the marketplace offers is called the asset's *market value*. The lot of old pumps in question is believed to have a current market value of $3000.

From this analysis, it is easy to see the flaw in the pricing manager's reasoning. In an engineering economist analysis we deal only with *today's* and prospective *future* opportunities. It is impossible to go back in time and change decisions that have been made. Thus, the pricing manager should recommend to the distributor that the price be set at the current value that a buyer assigns to the item: $3000.

Recurring and Nonrecurring Costs

Recurring costs refer to any expense that is known, anticipated, and occurs at regular intervals. **Nonrecurring costs** are one-of-a-kind expenses that occur at irregular intervals and thus are sometimes difficult to plan for or anticipate from a budgeting perspective.

Examples of recurring costs include those for resurfacing a highway and reshingling a roof. Annual expenses for maintenance and operation are also recurring expenses. Examples of nonrecurring costs include the cost of installing a new machine (including any facility modifications required), the cost of augmenting equipment based on older technology to restore its usefulness, emergency maintenance expenses, and the disposal or close-down costs associated with ending operations.

In engineering economic analyses *recurring costs* are modeled as cash flows that occur at regular intervals (such as every year or every 5 years.) Their magnitude can be estimated, and they can be included in the overall analysis. *Nonrecurring costs* can be handled easily in our analysis if we are able to anticipate their timing and size. However, this is not always so easy to do.

Incremental Costs

One of the fundamental principles in engineering economic analysis is that in making a choice among a set of competing alternatives, focus should be placed on the *differences* between those alternatives. This is the concept of **incremental costs.** For instance, one may be interested in comparing two options to lease a vehicle for personal use. The two lease options may have several specifics for which costs are the same. However, there may be incremental costs associated with one option not required or stipulated by the other. In comparing the two leases, the focus should be on the differences between the alternatives, not on the costs that are the same.

EXAMPLE 2-4

Philip is choosing between model *A* (a budget model) and model *B* (with more features and a higher purchase price). What *incremental costs* would Philip incur if he chose model *B* instead of the less expensive model *A*?

Cost Items	Model *A*	Model *B*
Purchase price	$10,000	$17,500
Installation costs	3,500	5,000
Annual maintenance costs	2,500	750
Annual utility expenses	1,200	2,000
Disposal costs after useful life	700	500

SOLUTION

We are interested in the incremental or *extra* costs that are associated with choosing model *B* instead of model *A*. To obtain these we subtract model *A* costs from model *B* costs for each category (cost item) with the following results.

Cost Items	(Model *B* Cost − *A* Cost)	Incremental Cost of *B*
Purchase price	17,500 − 10,000	$7500
Installation costs	5,000 − 3,500	1500
Annual maintenance costs	750 − 2,500	−1750/yr
Annual utility expenses	2,000 − 1,200	800/yr
Disposal costs after useful life	500 − 700	−200

Notice that for the cost categories given, the incremental costs of model *B* are both positive and negative. Positive incremental costs mean that model *B* costs more than model *A*, and negative incremental costs indicate that there would be a *savings* (reduction in cost) if model *B* where chosen instead.

Because model *B* has more features, a decision would also have to reflect consideration the incremental benefits offered by that model.

Cash Costs Versus Book Costs

A *cash cost* requires the cash transaction of dollars "out of one person's pocket" into "the pocket of someone else." When you buy dinner for your friends or make your monthly automobile payment you are incurring a **cash cost** or **cash flow.** Cash costs and cash flows are the basis for engineering economic analysis.

Book costs do not require the transaction of dollars "from one pocket to another." Rather, **book costs** are cost effects from past decisions that are recorded "in the books" (accounting books) of a firm. In one common book cost, asset depreciation (which we discuss in Chapter 11), the expense paid for a particular business asset is "written off" on a company's accounting system over a number of periods. Book costs do not ordinarily represent cash flows and thus are not included in engineering economic analysis. One exception to this is the impact of asset depreciation on tax payments—which are cash flows and are included in after-tax analyses.

Life-Cycle Costs

The products, goods, and services designed by engineers all progress through a **life cycle** very much like the human life cycle. People are conceived, go through a growth phase, reach their peak during maturity, and then gradually decline and expire. The same general pattern holds for products, goods, and services. As with humans, the duration of the different phases, the height of the peak at maturity, and the time of the onset of decline and termination all vary depending on the individual product, good, or service. Figure 2-3 illustrates the typical phases that a product, good or service progresses through over its life cycle.

Life-cycle costing refers to the concept of designing products, goods, and services with a full and explicit recognition of the associated costs over the various phases of their life cycles. Two key concepts in life-cycle costing are that the later design changes are made, the higher the costs, and that decisions made early in the life cycle tend to "lock in" costs that are incurred later. Figure 2-4 illustrates how costs are committed early in the product

Beginning ——— Time ———→ End

Needs Assessment and Justification Phase	Conceptual or Preliminary Design Phase	Detailed Design Phase	Production or Construction Phase	Operational Use Phase	Decline and Retirement Phase
Requirements	Impact Analysis	Allocation of Resources	Product, Goods & Services Built	Operational Use	Declining Use
Overall Feasibility	Proof of Concept	Detailed Specifications	All Supporting Facilities Built	Use by Ultimate Customer	Phase Out
Conceptual Design Planning	Prototype/ Breadboard	Component and Supplier Selection	Operational Use Planning	Maintenance and Support	Retirement
	Development and Testing	Production or Construction Phase		Processes, Materials and Methods Use	Responsible Disposal
	Detailed Design Planning			Decline and Retirement Planning	

FIGURE 2-3 Typical life cycle for products, goods and services.

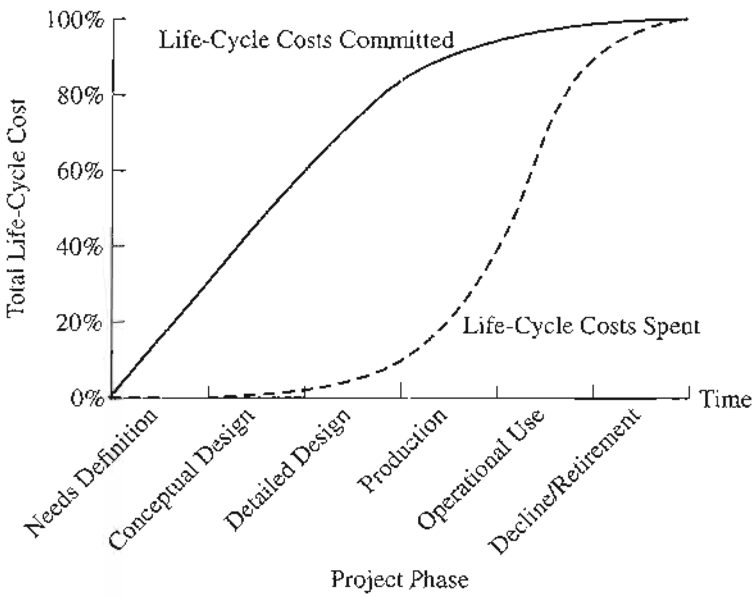


FIGURE 2-4 Cumulative life-cycle costs committed and dollars spent.

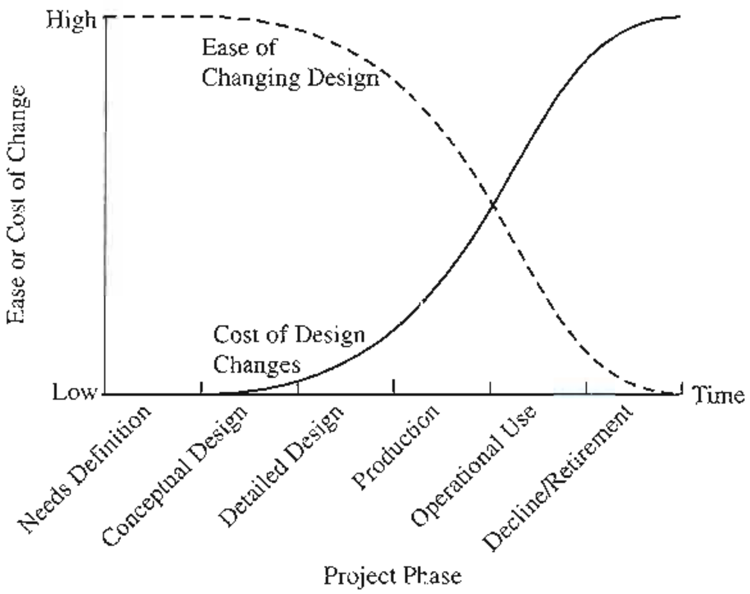


FIGURE 2-5 Life-cycle design change costs and ease of change.

life cycle—nearly 70–90% of all costs are set during the design phases. At the same time, as the figure shows, only 10–30% of cumulative life-cycle costs have been spent.

Figure 2-5 reinforces these concepts by illustrating that downstream product changes are more costly and that upstream changes are easier (and less costly) to make. When planners try to save money at an early design stage, the result is often a poor design, calling for change orders during construction and prototype development. These changes, in turn, are more costly than working out a better design would have been.

From Figures 2-4 and 2-5 we see that the time to consider all life-cycle effects, and make design changes, is during the needs and conceptual/preliminary design phases—before a lot of dollars are committed. Some of the life-cycle effects that engineers should consider at design time include product costs for liability, production, material, testing and quality assurance, and maintenance and warranty. Other life-cycle effects include product features based on customer input and product disposal effects on the environment. The key point is that engineers who design products and the systems that produce them should consider all life-cycle costs.

COST ESTIMATING

Engineering economic analysis focuses on the future consequences of current decisions. Because these consequences are in the future, usually they must be estimated and cannot be known with certainty. Examples of the estimates that may be needed in engineering economic analysis include purchase costs, annual revenue, yearly maintenance, interest rates for investments, annual labor and insurance costs, equipment salvage values, and tax rates.

Estimating is the foundation of economic analysis. As is the case in any analysis procedure, the outcome is only as good as the quality of the numbers used to reach the decision. For example, a person who wants to estimate her federal income taxes for a given year could do a very detailed analysis, including social security deductions, retirement savings deductions, itemized personal deductions, exemption calculations, and estimates of likely changes to the tax code. However, this very technical and detailed analysis will be grossly inaccurate if poor data are used to predict the next year's income. Thus, to ensure that an analysis is a reasonable evaluation of future events, it is very important to make careful estimates.

Types of Estimate

The American poet and novelist Gertrude Stein wrote in *The Making of Americans* in 1925 that "a rose is a rose is a rose is a rose." However, what holds for roses does not necessarily hold for estimates because "an estimate is not an estimate." Ms. Stein was not suggesting that all roses are the same, but it *is* true that all estimates *are not* the same. Rather, we can define three general types of estimate whose purposes, accuracies, and underlying methods are quite different.

Rough estimates: Order-of-magnitude estimates used for high-level planning, for determining macrofeasibility, and in a project's initial planning and evaluation phases. Rough estimates tend to involve back-of-the-envelope numbers with little detail or accuracy. The intent is to quantify and consider the order of magnitude of the numbers involved. These estimates require minimum resources to develop, and their accuracy is generally −30% to +60%.

Notice the nonsymmetry in the estimating error. This is because decision makers tend to underestimate the magnitude of costs (negative economic effects). Also as Murphy's law predicts, there seem to be more ways for results to be worse than expected than there are for the results to be better than expected.

Semidetailed estimates: Used for budgeting purposes at a project's conceptual or preliminary design stages. These estimates are more detailed, and they require additional time and resources to develop. Greater sophistication is used in developing semidetailed estimates than the rough-order type, and their accuracy is generally −15 to +20%.

Detailed estimates: Used during a project's detailed design and contract bidding phases. These estimates are made from detailed quantitative models, blueprints, product specification sheets, and vendor quotes. Detailed estimates involve the most time and resources to develop and thus are much more accurate than rough or semi-detailed estimates. The accuracy of these estimates is generally −3 to +5%.

The upper limits of +60% for rough order, +20% for semi-detailed, and +5% for detailed estimates are based on construction data for plants and infrastructure. Final costs for software, research and development, and new military weapons often correspond to much higher percentages.

In considering the three types of estimate it is important to recognize that each has its unique purpose, place, and function in a project's life. Rough estimates are used for general feasibility activities, semidetailed estimates support budgeting and preliminary design decisions, and detailed estimates are used for establishing design details and contracts. As one moves from rough to detailed design, one moves from less to much more accurate estimates.

However, this increased accuracy requires added time and resources. Figure 2-6 illustrates the trade-off between accuracy and cost. In engineering economic analysis, the resources spent must be justified by the need for detail in the estimate. As an illustration, during the project feasibility stages we would not want to use our resources (people, time, and money) to develop detailed estimates for unfeasible alternatives that will be quickly eliminated from further consideration. However, regardless of how accurate an estimate is assumed to be, it only an estimate of what the future will be. There will be some error even if ample resources and sophisticated methods are used.

Difficulties in Estimation

Estimating is difficult because the future is unknown. With few exceptions (such as with legal contracts) it is difficult to anticipate future economic consequences exactly. In this section we discuss several aspects of estimating that make it a difficult task.

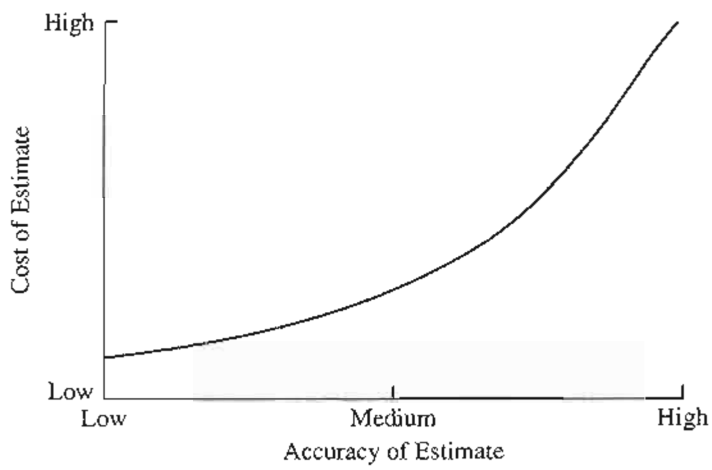


FIGURE 2-6 Accuracy versus cost trade-off in estimating.

One-of-a-Kind Estimates

Estimated parameters can be for one-of-a-kind or first-run projects. The first time something is done, it is difficult to estimate costs required to design, produce, and maintain a product over its life cycle. Consider the projected cost estimates that were developed for the first NASA missions. The U.S. space program initially had no experience with human flight in outer space; thus the development of the cost estimates for design, production, launch, and recovery of the astronauts, flight hardware, and payloads was a "first-time experience." The same is true for any endeavor lacking local or global historical cost data. New products or processes that are unique and fundamentally different make estimating costs difficult.

The good news is that there are very few one-of-a-kind estimates to be made in engineering design and analysis. Nearly all new technologies, products, and processes have "close cousins" that have led to their development. The concept of **estimation by analogy** allows one to use knowledge about well-understood activities to anticipate costs for new activities. In the 1950s, at the start of the military missile program, aircraft companies drew on their in-depth knowledge of designing and producing aircraft when they bid on missile contracts. As another example, consider the problem of estimating the production labor requirements for a brand new product, X. A company may use its labor knowledge about Product Y, a similar type product, to build up the estimate for X. Thus, although "first-run" estimates are difficult to make, estimation by analogy can be an effective tool.

Time and Effort Available

Our ability to develop engineering estimates is constrained by time and person-power availability. In an ideal world, it would *cost nothing* to use *unlimited resources* over an *extended period of time*. However, reality requires the use of limited resources in fixed intervals of time. Thus for a rough estimate only limited effort is used.

Constraints on time and person-power can make the overall estimating task more difficult. If the estimate does not require as much detail (such as when a rough estimate is the goal), then time and personnel constraints may not be a factor. When detail is necessary and critical (such as in legal contracts), however, requirements must be anticipated and resource use planned.

Estimator Expertise

Consider two common phrases: *The past is our greatest teacher* and *knowledge is power*. These simple axioms hold true for much of what we encounter during life, and they are true in engineering estimating as well. The more experienced and knowledgeable the engineering estimator is, the less difficult the estimating process will be, the more accurate the estimate will be, the less likely it is that a major error will occur, and the more likely it is that the estimate will be of high quality.

How is experience acquired in industry? One approach is to assign inexperienced engineers relatively smaller jobs, to create expertise and build familiarity with products and processes. Another strategy used is to pair inexperienced engineers with mentors who have vast technical experience. Technical boards and review meetings conducted to "justify the numbers" also are used to build knowledge and experience. Finally, many firms maintain databases of their past estimates and the costs that were actually incurred.

ESTIMATING MODELS

This section develops several estimating models that can be used at the rough, semidetailed, or detailed design levels. For rough estimates the models are used with rough data, likewise for detailed design estimates they are used with detailed data. The level of detail will depend upon the accuracy of the model's data.

Per-Unit Model

The **per-unit model** uses a "per unit" factor, such as cost per square foot, to develop the estimate desired. This is a very simplistic yet useful technique, especially for developing estimates of the rough or order-of-magnitude type. The per unit model is commonly used in the construction industry. As an example, you may be interested in a new home that is constructed with a certain type of material and has a specific construction style. Based on this information a contractor may quote a cost of \$65 per square foot for your home. If you are interested in a 2000 square foot floor plan, your cost would thus be: $2000 \times 65 = \$130{,}000$. Other examples where per unit factors are utilized include

- Service cost per customer
- Safety cost per employee
- Gasoline cost per mile
- Cost of defects per batch
- Maintenance cost per window
- Mileage cost per vehicle
- Utility cost per square foot of floor space
- Housing cost per student

It is important to note that the per-unit model does not make allowances for economies of scale (the fact that higher quantities usually cost less on a per-unit basis). In most cases, however, the model can be effective at getting the decision maker "in the ballpark" of likely costs, and it can be very accurate if accurate data are used.

EXAMPLE 2-5

Use the per-unit model to estimate the cost per student that you will incur for hosting 24 foreign exchange students at a local island campground for 10 days. During camp you are planning the following activities:

- 2 days of canoeing
- 3 campsite-sponsored day hikes
- 3 days at the lake beach (swimming, volleyball, etc.)
- Nightly entertainment

After calling the campground and collecting other information, you have accumulated the following data:

- Van rental from your city to the camp (one way) is \$50 per 15 person van plus gas.
- Camp is 50 miles away, the van gets 10 miles per gallon, and gas is \$1 per gallon.

- Each cabin at the camp holds 4 campers, and rent is $10 per day per cabin.
- Meals are $10 per day per camper; no outside food is allowed.
- Boat transportation to the island is $2 per camper (one way).
- Insurance/grounds fee/overhead is $1 per day per camper.
- Canoe rentals are $5 per day per canoe, canoes hold 3 campers.
- Day hikes are $2.50 per camper (plus the cost for meals).
- Beach rental is $25 per group per half-day.
- Nightly entertainment is free.

SOLUTION

You are asked to use the per unit factor to estimate the cost per student on this trip. For planning purposes we assume that there will be 100% participation in all activities. We will break the total cost down into categories of transportation, living, and entertainment.

Transportation Costs

Van travel to and from camp: 2 vans × 2 trips × ($50/van + 50 miles × 1 gal/10 miles × $1/gal) = $220

Boat travel to and from island: 2 trips × $2/camper × 24 campers = $96

Transportation costs = 220 + 96 = $316

Living Costs

Meals for the 10-day period: 24 campers × $10/camper/day × 10 days = $2400

Cabin rental for the 10-day period: 24 campers × 1 cabin/4 campers × $10/day/cabin × 10 days = $600

Insurance/Overhad expense for the 10-day period: 24 campers × $1/day/camper × 10 days = $240

Living costs = 2400 + 600 + 240 = $3240

Entertainment Costs

Canoe rental costs: 2 canoe days × 24 campers × 1 canoe/3 campers × $5/day/canoe = $80

Beach rental costs: 3 days × 2 half-days/day × $25/half-day = $150

Day hike costs: 24 campers × 3 day hikes × $2.50/camper/day hike = $180

Nightly entertainment: This is free! Can you believe it?

Entertainment costs = 80 + 150 + 180 + 0 = $410

Total cost

$$\text{Total cost for 10-day period} = \text{Transportation costs} + \text{Living costs} + \text{Entertainment costs}$$
$$= 316 + 3240 + 410 = \$3966$$

Thus, the cost per student would be $3966/24 = $165.25.

Thus, it would cost you $165.25 per student to host the students at the island campground for the 10-day period. In this case the per-unit model gives you a very detailed cost estimate (although its accuracy depends on the accuracy of your data and assumptions you've made).

Segmenting Model

The **segmenting model** can be described as "divide and conquer." An estimate is decomposed into its individual components, estimates are made at those lower levels, and then the estimates are aggregated (added) back together. It is much easier to estimate at the lower levels because they are more readily understood. This approach is common in engineering estimating in many applications and for any level of accuracy needed. In planning the camp trip of Example 2-5, the overall estimate was **segmented** into the costs for travel, living, and entertainment. The example illustrated the segmenting model (division of the overall estimate into the various categories) together with the unit factor model to make the subestimates for each category. Example 2-6 provides another example of the segmenting approach.

EXAMPLE 2-6

Clean Lawn Corp. a manufacturer of yard equipment is planning to introduce a new high-end industrial-use lawn mower called the Grass Grabber. The Grass Grabber is designed as a walk-behind self-propelled mower. Clean Lawn engineers have been asked by the accounting department to estimate the material costs that will make up the new mower. The material cost estimate will be used, along with estimates for labor and overhead to evaluate the potential of this new model.

SOLUTION

The engineers decide to decompose the design specifications for the Grass Grabber into its subcomponents, estimate the material costs for each of the subcomponents, and then sum these costs up to obtain their overall estimate. The engineers are using a segmenting approach to build up their estimate. After careful consideration, the engineers have divided the mower into the following major subsystems: chassis, drive train, controls, and cutting/collection system. Each of these is further divided as appropriate, and unit material costs were estimated at this lowest of levels as follows:

Cost Item	Unit Material Cost Estimate	Cost Item	Unit Material Cost Estimate
A. Chassis		**C. Controls**	
A.1 Deck	$ 7.40	C.1 Handle assembly	$ 3.85
A.2 Wheels	10.20	C.2 Engine linkage	8.55
A.3 Axles	4.85	C.3 Blade linkage	4.70
	$22.45	C.4 Speed control linkage	21.50
B. Drive train		C.5 Drive control assembly	6.70
B.1 Engine	$38.50	C.6 Cutting height adjuster	7.40
B.2 Starter assembly	5.90		$52.70
B.3 Transmission	5.45	**D. Cutting/Collection system**	
B.4 Drive disc assembly	10.00	D.1 Blade assembly	$10.80
B.5 Clutch linkage	5.15	D.2 Side chute	7.05
B.6 Belt assemblies	7.70	D.3 Grass bag and adapter	7.75
	$72.70		$25.60

The total material cost estimate of $173.45 was calculated by summing up the estimates for each of the four major subsystem levels (chassis, drive train, controls, and cutting/collection system). It should be noted that this cost represents only the material portion of the overall cost to produce the mowers. Other costs would include labor and overhead items.

In Example 2-6 the engineers at Clean Lawn Corp. decomposed the cost estimation problem into logical elements. The scheme they used of decomposing cost items and numbering the material components (A.1, A.1, A.2, etc.) is known as a **work breakdown structure.** This technique is commonly used in engineering cost estimating and project management of large products, processes, or projects. A work breakdown structure decomposes a large "work package" into its constituent parts which can then be estimated or managed individually. In Example 2-6 the work breakdown structure of the Grass Grabber has three levels. At the top level is the product itself, at the second level are the four major subsystems, and at the third level are the individual cost items. Imagine what the product work breakdown structure for a Boeing 777 looks like. Then imagine trying to manage the 777's design, engineering, construction, and costing without a tool like the work breakdown structure.

Cost Indexes

Cost indexes are numerical values that reflect historical change in engineering (and other) costs. The cost index numbers are dimensionless, and reflect relative price change in either individual cost items (labor, material, utilities) or groups of costs (consumer prices, producer prices). Indexes can be used to update historical costs with the basic ratio relationship given in Equation 2-2.

$$\frac{\text{Cost at time } A}{\text{Cost at time } B} = \frac{\text{Index value at time } A}{\text{Index value at time } B} \tag{2-2}$$

Equation 2-2 states that the ratio of the cost index numbers at two points in time (A and B) is equivalent to the dollar cost ratio of the item at the same times (see Example 2-7).

EXAMPLE 2-7

Miriam is interested in estimating the annual labor and material costs for a new production facility. She was able to obtain the following labor and material cost data:

Labor costs

- Labor cost index value was at 124 ten years ago and is 188 today.
- Annual labor costs for a similar facility were $575,500 ten years ago.

Material Costs

- Material cost index value was at 544 three years ago and is 715 today.
- Annual material costs for a similar facility were $2,455,000 three years ago.

SOLUTION

Miriam will use Equation 2-2 to develop her cost estimates for annual labor and material costs.

Labor

$$\frac{\text{Annual cost today}}{\text{Annual cost 10 years ago}} = \frac{\text{Index value today}}{\text{Index value 10 years ago}}$$

$$\text{Annual cost today} = \frac{188}{124} \times \$575{,}500 = \$871{,}800$$

Materials

$$\frac{\text{Annual cost today}}{\text{Annual cost 3 years ago}} = \frac{\text{Index value today}}{\text{Index value 3 years ago}}$$

$$\text{Annual cost today} = \frac{715}{544} \times \$2{,}455{,}000 = \$3{,}227{,}000$$

Cost index data are collected and published by several private and public sources in the United States (and world). The U.S. government publishes data through the Bureau of Labor Statistics of the Department of Commerce. The *Statistical Abstract of the United States* publishes cost indexes for labor, construction, and materials. Another useful source for engineering cost index data is the *Engineering News Record*.

Power-Sizing Model

The **power-sizing model** is used to estimate the costs of industrial plants and equipment. The model "scales up" or "scales down" known costs, thereby accounting for economies of scale that are common in industrial plant and equipment costs. Consider the cost to build a refinery. Would it cost twice as much to build the same facility with double the capacity? It is unlikely. The *power-sizing model* uses the exponent (x), called the *power-sizing exponent,* to reflect economies of scale in the size or capacity:

$$\frac{\text{Cost of equipment } A}{\text{Cost of equipment } B} = \left(\frac{\text{Size(capacity) of equipment } A}{\text{Size(capacity) of } B}\right)^x \tag{2-3}$$

where x is the power-sizing exponent, costs of A and B are at the same point in time (same dollar basis), and size or capacity is in the same physical units for both A and B.

The power-sizing exponent (x) can be 1.0 (indicating a linear cost-versus-size/capacity relationship) or greater than 1.0 (indicating *dis*economies of scale), but it is usually less than 1.0 (indicating economies of scale). Generally the ratio should be less than 2, and it should never exceed 5. This model works best in a "middle" range—not very small or very large size.

Exponent values for plants and equipment of many types may be found in several sources, including industry reference books, research reports, and technical journals. Such exponent values may be found in *Perry's Chemical Engineers' Handbook, Plant Design and Economics for Chemical Engineers,* and *Preliminary Plant Design in Chemical Engineering.* Table 2-1 gives power sizing exponent values for several types of industrial facilities and equipment. The exponent given applies only to equipment within the size range specified.

In Equation 2-3 equipment costs for both A and B occur at the same point in time. This equation is useful for scaling equipment costs but *not* for updating those costs. When the time of the desired cost estimate is different from the time in which the scaling occurs (per Equation 2-3) cost indexes accomplish the time updating. Thus, in cases like Example 2-8 involving both scaling and updating, we use the power sizing model together with cost indexes.

TABLE 2-1 Example Power-Sizing Exponent Values

Equipment/Facility	Size Range	Power-Sizing Exponent
Blower, centrifugal	10,000–100,000 ft^3/min	0.59
Compressor	200–2100 hp	0.32
Crystallizer, vacuum batch	500–7000 ft^2	0.37
Dryer, drum, single atmospheric	10–100 ft^2	0.40
Fan, centrifugal	20,000–70,000 ft^2/min	1.17
Filter, vacuum rotary drum	10–1500 ft^2	0.48
Lagoon, aerated	0.05–20 million gal/day	1.13
Motor	5–20 hp	0.69
Reactor, 300 psi	100–1000 gal	0.56
Tank, atmospheric, horizontal	100–40,000 gal	0.57

EXAMPLE 2-8

Based on her work in Example 2-7, Miriam has been asked to estimate the cost today of a 2500 ft^2 heat exchange system for the new plant being analyzed. She has the following data.

- Her company paid $50,000 for a 1000 ft^2 heat exchanger 5 years ago.
- Heat exchangers within this range of capacity have a power sizing exponent (x) of 0.55.
- Five years ago the Heat Exchanger Cost Index (HECI) was 1306; it is 1487 today.

SOLUTION

Miriam will first use Equation 2-3 to scale up the cost of the 1000 ft^2 exchanger to one that is 2500 ft^2 using the 0.55 power-sizing exponent.

$$\frac{\text{Cost of 2500 ft}^2\text{ equipment}}{\text{Cost of 1000 ft}^2\text{ equipment}} = \left(\frac{\text{2500 ft}^2\text{ equipment}}{\text{1000 ft}^2\text{ equipment}}\right)^{0.55}$$

$$\text{Cost of 2500 ft}^2\text{ equipment} = \left(\frac{2500}{1000}\right)^{0.55} \times 50{,}000 = \$82{,}800$$

Miriam knows that the $82,800 reflects only the scaling up of the cost of the 1000 ft^2 model to a 2500 ft^2 model. Now she will use Equation 2-2 and the HECI data to estimate the cost of a 2500 ft^2 exchanger today. Miriam's cost estimate would be:

$$\frac{\text{Equipment cost today}}{\text{Equipment cost 5 years ago}} = \frac{\text{Index value today}}{\text{Index value 5 years ago}}$$

$$\text{Equipment cost today} = \frac{1487}{1306} \times \$82{,}800 = \$94{,}300$$

Triangulation

Triangulation is used in engineering surveying. A geographical area is divided into triangles from which the surveyor is able to map points within that region by using three fixed points and horizontal angular distances to locate fixed points of interest (e.g., property line reference points). Since any point can be located with two lines, the third line represents an extra perspective and check. We will not use trigonometry to arrive at our cost estimates, but we can utilize the concept of triangulation. We should approach our economic estimate from different perspectives because such varied perspectives add richness, confidence, and quality to the estimate. **Triangulation** in cost estimating might involve using different sources of data or using different quantitative models to arrive at the value being estimated. As decision makers we should always seek out varied perspectives.

Improvement and the Learning Curve

One common phenomenon observed, regardless of the task being performed, is that as the number of repetitions increases, performance becomes faster and more accurate. This is the concept of learning and improvement in the activities that people perform. From our own experience we all know that our fiftieth repetition is completed in much less time than we needed to accomplish the task the first time.

The **learning curve** captures the relationship between task performance and task repetition. In general, as output *doubles* the unit production time will be reduced to some fixed percentage, the **learning curve percentage** or **learning curve rate.** For example, it may take 300 minutes to produce the third unit in a production run involving a task with a 95% learning time curve. In this case the sixth (2 × 3) unit will take 300(0.95) = 285 minutes to produce. Sometimes the learning curve is also known as the progress curve, improvement curve, experience curve, or manufacturing progress function.

Equation 2-4 gives an expression that can be used for time estimating in repetitive tasks.

$$T_N = T_{\text{initial}} \times N^b \tag{2-4}$$

where T_N = time requirement for the Nth unit of production
T_{initial} = time requirement for the first (initial) unit of production
N = number of completed units (cumulative production)
b = learning curve exponent (slope of the learning curve on a log–log plot)

As just given, a learning curve is often referred to by its percentage learning slope. Thus, a curve with $b = -0.074$ is a 95% learning curve because $2^{-0.074} = 0.95$. This equation uses 2 because the learning curve percentage applies for doubling cumulative production. The learning curve exponent is calculated using Equation 2-5.

$$b = \frac{\log\text{ (learning curve expressed as a decimal)}}{\log 2.0} \tag{2-5}$$

EXAMPLE 2-9

Calculate the time required to produce the hundredth unit of a production run if the first unit took 32.0 minutes to produce and the learning curve rate for production is 80%.

SOLUTION

$$T_{100} = T_1 \times 100^{\log 0.80/\log 2.0}$$

$$T_{100} = 32.0 \times 100^{-0.3219}$$

$$T_{100} = 7.27\text{ minutes}$$

It is particularly important to account for the learning-curve effect if the production run involves a small number of units instead of a large number. When thousands or even millions of units are being produced, early inefficiencies tend to be "averaged out" because of the larger batch sizes. However, in the short run, inefficiencies of the same magnitude can lead to rather poor estimates of production time requirements, and thus production cost estimates may be understated. Consider Example 2-10 and the results that might be observed if the learning-curve effect is ignored. Notice in this example that a "steady state" time is given. Steady state is the time at which the physical constraints of performing the task prevent the achievement of any more learning or improvement.

EXAMPLE 2-10

Estimate the overall labor cost portion due to a task that has a learning-curve rate of 85% and reaches a steady state value after 16 units of 5.0 minutes per unit. Labor and benefits are \$22 per hour, and the task requires two skilled workers. The overall production run is 20 units.

SOLUTION

Because we know the time required for the 16th unit, we can use Equation 2-4 to calculate the time required to produce the first unit.

$$T_{16} = T_1 \times 16^{\log 0.85/\log 2.0}$$

$$5.0 = T_1 \times 16^{-0.2345}$$

$$T_1 = 9.6 \text{ minutes}$$

Now we use Equation 2-4 to calculate the time requirements for each unit in the production run as well as the total production time required.

$$T_N = 9.6 \times N^{-0.2345}$$

Unit Number, N	Time (min) to produce N^{th} Unit	Cumulative Time from 1 to N	Unit Number, N	Time (min) to produce N^{th} Unit	Cumulative Time from 1 to N
1	9.6	9.6	11	5.5	74.0
2	8.2	17.8	12	5.4	79.2
3	7.4	24.2	13	5.3	84.5
4	6.9	32.1	14	5.2	89.7
5	6.6	38.7	15	5.1	94.8
6	6.3	45.0	16	5.0	99.8
7	6.1	51.1	17	5.0	104.8
8	5.9	57.0	18	5.0	109.8
9	5.7	62.7	19	5.0	114.8
10	5.6	68.3	20	5.0	119.8

The total cumulative time of the production run is 119.8 minutes (2.0 hours). Thus the total labor cost estimate would be:

$$2.0 \text{ hours} \times \$22\text{/hour per worker} \times 2 \text{ workers} = \$88$$

If we ignore the learning-curve effect and calculate the labor cost portion based only on the steady state labor rate, the estimate would be

$$0.083 \text{ hours/unit} \times 20 \text{ units} \times \$22\text{/hour per worker} \times 2 \text{ workers} = \$73.04$$

This estimate is understated by about 20% from what the true cost would be.

Estimating Benefits

This chapter has focused on cost terms and cost estimating. However, engineering economists must often also estimate benefits. Example benefits include sales of products, revenues from bridge tolls and electric power sales, cost reductions from reduced material or labor costs, reduced time spent in traffic jams, and reduced risk of flooding. Many engineering projects are undertaken precisely to secure these benefits.

The cost concepts and cost estimating models can also be applied to economic benefits. Fixed and variable benefits, recurring and nonrecurring benefits, incremental benefits, and life-cycle benefits all have meaning. Also, issues regarding the type of estimate (rough, semidetailed, and detailed) as well as difficulties in estimation (one of a kind, time and effort, and estimator expertise) all apply directly to estimating benefits. Last, per unit, segmented, and indexed models are used to estimate benefits. The concept of triangulation is particularly important for estimating benefits.

The uncertainty in benefit estimates is also typically asymmetric, with a broader limit for negative outcomes. Benefits are more likely to be overestimated than underestimated, so an example set of limits might be (–50%, +20%). One difference between cost and benefit estimation is that many costs of engineering projects occur in the near future (for design and construction), but the benefits are further in the future. Because benefits are often further in the future, they are more difficult to estimate accurately, and more uncertainty is typical.

The estimation of economic benefits for inclusion in our analysis is an important step that should not be overlooked. Many of the models, concepts, and issues that apply in the estimation of costs also apply in the estimation of economic benefits.

Cash Flow Diagrams

The costs and benefits of engineering projects occur over time and are summarized on a cash flow diagram (CFD). Specifically, a CFD illustrates the size, sign, and timing of individual cash flows. In this way the CFD is the basis for engineering economic analysis.

A **cash flow diagram** is created by first drawing a segmented time-based horizontal line, divided into appropriate time units. The time units on the CFD can be years, months, quarters, or any other consistent time unit. Then at each time at which a cash flow will occur, a vertical arrow is added—pointing down for costs and up for revenues or benefits. These cash flows are drawn to relative scale.

The cash flows are **assumed** to occur at time 0 or at the **end** of each period. Consider Figure 2-7, the CFD for a specific investment opportunity whose cash flows are described as follows:

Timing of Cash Flow	Size of Cash Flow
At time zero (now or today)	A positive cash flow of \$100
1 time period from today	A negative cash flow of \$100
2 time periods from today	A positive cash flow of \$100
3 time periods from today	A negative cash flow of \$150
4 time periods from today	A negative cash flow of \$150
5 time periods from today	A positive cash flow of \$50

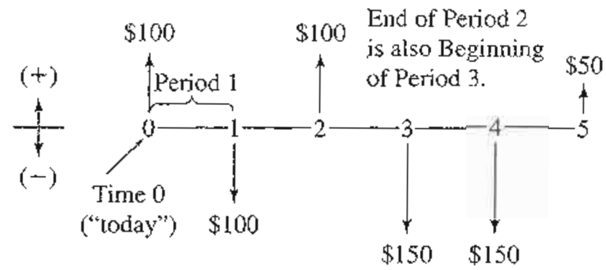


FIGURE 2-7 An example cash flow diagram (CFD).

Categories of Cash Flows

The expenses and receipts due to engineering projects usually fall into one of the following categories.

First cost ≡ expense to build or to buy and install

Operations and maintenance (O&M) ≡ annual expense, such as electricity, labor, and minor repairs

Salvage value ≡ receipt at project termination for sale or transfer of the equipment (can be a salvage cost)

Revenues ≡ annual receipts due to sale of products or services

Overhaul ≡ major capital expenditure that occurs during the asset's life

Individual projects will often have specific costs, revenues, or user benefits. For example, annual operations and maintenance (O&M) expenses on an assembly line might be divided into direct labor, power, and other. Similarly, a public-sector dam project might have its annual benefits divided into flood control, agricultural irrigation, and recreation.

Drawing a Cash Flow Diagram

The cash flow diagram shows when all cash flows occur. Look at Figure 2-7 and the $100 positive cash flow at the end of period 2. From the time line one can see that this cash flow can also be described as occurring at the *beginning* of period 3. Thus, in a CFD the end of *period* t is the same time as the beginning of *period* $t + 1$. Beginning-of-period cash flows (such as rent, lease, and insurance payments) are thus easy to handle: just draw your CFD and put them in where they occur. Thus O&M, salvages, revenues, and overhauls are assumed to be end-of-period cash flows.

The choice of time 0 is arbitrary. For example, it can be when a project is analyzed, when funding is approved, or when construction begins. When construction periods are assumed to be short; first costs are assumed to occur at time 0, and the first annual revenues and costs start at the end of the first period. When construction periods are long, time 0 is usually the date of commissioning—when the facility comes on stream.

Perspective is also important when one is drawing a CFD. Consider the simple transaction of paying $5000 for some equipment. To the firm buying the equipment, the cash flow is a cost and hence negative in sign. To the firm selling the equipment, the cash flow is a revenue and positive in sign. This simple example shows that a consistent perspective is required when one is using a CFD to model the cash flows of a problem. One person's cash outflow is another person's inflow.

Often two or more cash flows occur in the same year, such as an overhaul and an O&M expense or the salvage value and the last year's O&M expense. Combining these into one total cash flow per year would simplify the cash flow diagram. However, it is better to show each individually, to ensure a clear connection from the problem statement to each cash flow in the diagram.

Drawing Cash Flow Diagrams with a Spreadsheet

One simple way to draw cash flow diagrams with "arrows" proportional to the size of the cash flows is to use a spreadsheet to draw a stacked bar chart. The data for the cash flows is entered, as shown in the table part of Figure 2-8. To make a quick graph, select cells B1 to D8, which are the three columns of the cash flow. Then select the graph menu and choose column chart and select the stack option. Except for labeling axes (using the cells for year 0 to year 6), choosing the scale for the y axis, and adding titles, the cash flow diagram is done. Refer to the appendix for a review of basic spreadsheet use. (*Note:* a bar chart labels periods rather than using an x axis with arrows at times 0, 1, 2 . . . .)

	A	B	C	D	E	F
1	Year	Capital Costs	O&M	Overhaul		
2	0	−80000				
3	1		−12000			
4	2		−12000			
5	3		−12000	−25000		
6	4		−12000			
7	5		−12000			
8	6	10000	−12000			
9						

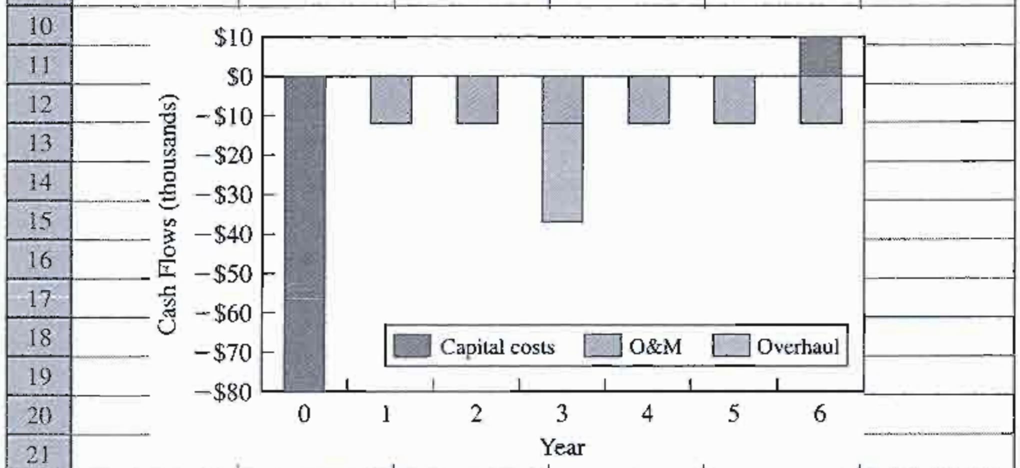


FIGURE 2-8 Example of cash flow diagram in spreadsheets.

SUMMARY

This chapter has introduced the following cost concepts: fixed and variable, marginal and average, sunk, opportunity, recurring and nonrecurring, incremental, cash and book, and life-cycle. **Fixed costs** are constant and unchanging as volumes change, while **variable**

costs change as output changes. Fixed and variable costs are used to find a breakeven value between costs and revenues, as well as the regions of net profit and loss. A **marginal cost** is for one more unit, while the **average cost** is the total cost divided by the number of units.

Sunk costs result from past decisions and should not influence our attitude toward current and future opportunities. Remember, "sunk costs are sunk." **Opportunity costs** involve the benefit that is forgone when we choose to use a resource in one activity instead of another. **Recurring costs** can be planned and anticipated expenses; **nonrecurring costs** are one-of-a-kind costs that are often more difficult to anticipate.

Incremental costs are economic consequences associated with the differences between two choices of action. **Cash costs** are also known as **out-of-pocket costs** that represent actual cash flows. **Book costs** do not result in the exchange of money, but rather are costs listed in a firm's accounting books. **Life-cycle costs** are all costs that are incurred over the life of a product, process, or service. Thus engineering designers must consider life-cycle costs when choosing materials and components, tolerances, processes, testing, safety, service and warranty, and disposal.

Cost estimating is the process of "developing the numbers" for engineering economic analysis. Unlike a textbook, the real world does not present its challenges with neat problem statements that provide all the data. **Rough estimates** give us order-of-magnitude numbers and are useful for high-level and initial planning as well as judging the feasibility of alternatives. **Semidetailed estimates** are more accurate than rough-order estimates, thus requiring more resources (people, time, and money) to develop. These estimates are used in preliminary design and budgeting activities. **Detailed estimates** generally have an accuracy of ± 3–5%. They are used during the detailed design and contract bidding phases of a project.

Difficulties are common in developing estimates. **One-of-a-kind estimates** will have no basis in earlier work, but this disadvantage can be addressed through **estimation by analogy.** Lack of time available is best addressed by planning and by matching the estimate's detail to the purpose—one should not spend money developing a detailed estimate when only a rough estimate is needed. **Estimator expertise** must be developed through work experiences and mentors.

Several general models and techniques for developing cost estimates were discussed. The **per-unit** and **segmenting models** use different levels of detail and costs per square foot or other unit. **Cost index data** are useful for updating historical costs to formulate current estimates. The **power-sizing model** is useful for scaling up or down a known cost quantity to account for economies of scale, with different power-sizing exponents for industrial plants and equipment of different types. **Triangulation** suggests that one should seek varying perspectives when developing cost estimates. Different information sources, databases, and analytical models can all be used to create unique perspectives. As the number of task repetitions increases, efficiency improves because of learning or improvement. This is summarized in the **learning-curve percentage,** where doubling the cumulative production reduces the time to complete the task, which equals the learning-curve percentage times the current production time.

Cash flow estimation must include project benefits. These include labor cost savings, avoided quality costs, direct revenue from sales, reduced catastrophic risks, improved traffic flow, and cheaper power supplies. **Cash flow diagrams** are used to model the positive and negative cash flows of potential investment opportunities. These diagrams provide a consistent view of the problem (and the alternatives) to support economic analysis.

PROBLEMS

2-1 Bob Johnson decided to purchase a new home. After looking at tracts of new homes, he decided that a custom-built home was preferable. He hired an architect to prepare the drawings. In due time, the architect completed the drawings and submitted them. Bob liked the plans; he was less pleased that he had to pay the architect a fee of $4000 to design the house. Bob asked a building contractor to provide a bid to construct the home on a lot Bob already owned. While the contractor was working to assemble the bid, Bob came across a book of standard house plans. In the book was a home that he and his wife liked better than the one designed for them by the architect. Bob paid $75 and obtained a complete set of plans for this other house. Bob then asked the contractor to provide a bid to construct this "stock plan" home. In this way Bob felt he could compare the costs and make a decision. The building contractor submitted the following bids:

Custom-designed home	$128,000
Stock-plan home	128,500

Bob was willing to pay the extra $500 for it. Bob's wife, however, felt they should go ahead with the custom-designed home, for, as she put it, "We can't afford to throw away a set of plans that cost $4000." Bob agreed, but he disliked the thought of building a home that is less desirable than the stock plan home. Then he asked your advice. Which house would you advise him to build? Explain.

2-2 Venus Computer can produce 23,000 personal computers a year on its daytime shift. The fixed manufacturing costs per year are $2 million and the total labor cost is $9,109,000. To increase its production to 46,000 computers per year, Venus is considering adding a second shift. The unit labor cost for the second shift would be 25% higher than the day shift, but the total fixed manufacturing costs would increase only to $2.4 million from $2 million.

(*a*) Compute the unit manufacturing cost for the daytime shift.

(*b*) Would adding a second shift increase or decrease the unit manufacturing cost at the plant?

2-3 A small machine shop, with 30 hp of connected load, purchases electricity under the following monthly rates (assume any demand charge is included in this schedule):

First 50 kw-hr per hp of connected load at 8.6¢ per kw-hr

Next 50 kw-hr per hp of connected load at 6.6¢ per kw-hr

Next 150 kw-hr per hp of connected load at 4.0¢ per kw-hr

All electricity over 250 kw-hr per hp of connected load at 3.7¢ per kw-hr

The shop uses 2800 kw-hr per month.

(*a*) Calculate the monthly bill for this shop. What are the marginal and average costs per kilowatt-hour?

(*b*) Suppose Jennifer, the proprietor of the shop, has the chance to secure additional business that will require her to operate her existing equipment more hours per day. This will use an extra 1200 kw-hr per month. What is the lowest figure that she might reasonably consider to be the "cost" of this additional energy? What is this per kilowatt-hour?

(*c*) She contemplates installing certain new machines that will reduce the labor time required on certain operations. These will increase the connected load by 10 hp, but since they will operate only on certain special jobs, will add only 100 kw-hr per month. In a study to determine the economy of installing these new machines, what should be considered as the "cost" of this energy? What is this per kilowatt-hour?

2-4 Two automatic systems for dispensing maps are being compared by the state highway department. The accompanying breakeven chart of the comparison of these systems (System I vs System II) shows total yearly costs for the number of maps dispensed per year for both alternatives. Answer the following questions.

(*a*) What is the fixed cost for System I?

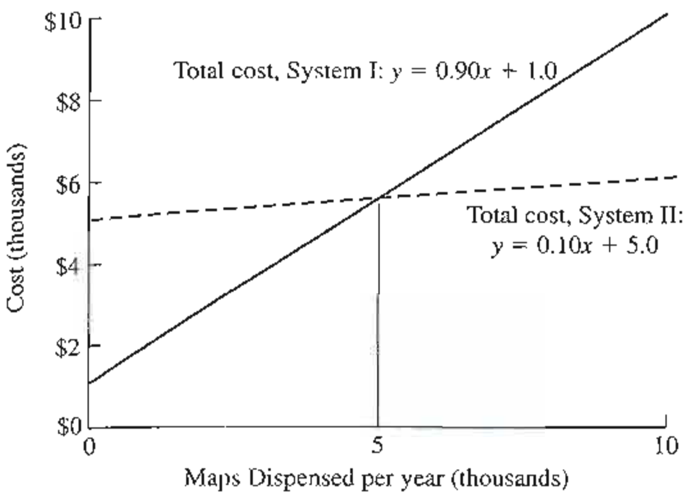
(*b*) What is the fixed cost for System II?

(*c*) What is the variable cost per map dispensed for System I?

(*d*) What is the variable cost per map dispensed for System II?

(*e*) What is the breakeven point in terms of maps dispensed at which the two systems have equal annual costs?

(*f*) For what range of annual number of maps dispensed is System I recommended?



(*g*) For what range of annual number of maps dispensed is System II recommended?

(*h*) At 3000 maps per year, what are the marginal and average map costs for each system?

2-5 Mr. Sam Spade, the president of Ajax, recently read in a report that a competitor named Bendix has the following relationship between cost and production quantity:

$$C = \$3{,}000{,}000 - \$18{,}000Q + \$75Q^2$$

where C = total manufacturing cost per year and Q = number of units produced per year.

A newly hired employee, who previously worked for Bendix, tells Mr. Spade that Bendix is now producing 110 units per year. If the selling price remains unchanged, Sam wonders if Bendix is likely to increase the number of units produced per year, in the near future. He asks you to look at the information and tell him what you are able to deduce from it.

2-6 A privately owned summer camp for youngsters has the following data for a 12-week session:

Charge per camper	$120 per week
Fixed costs	$48,000 per session
Variable cost per camper	$80 per week
Capacity	200 campers

(*a*) Develop the mathematical relationships for total cost and total revenue.

(*b*) What is the total number of campers that will allow the camp to *just break even*?

(*c*) What is the profit or loss for the 12-week session if the camp operates at 80% capacity?

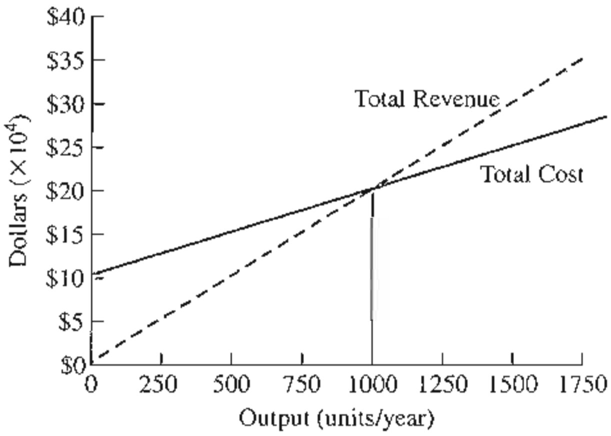
2-7 Two new rides are being compared by a local amusement park in terms of their annual operating costs. The two rides are assumed to be able to generate the same level of revenue (and thus the focus on costs). The Tummy Tugger has fixed costs of $10,000 per year and variable costs of $2.50 per visitor. The Head Buzzer has fixed costs of $4000 per year, and variable costs of $4 per visitor. Provide answers to the following questions so the amusement park can make the needed comparison.

(*a*) Mathematically determine the breakeven number of visitors per year for the two rides to have equal annual costs.

(*b*) Develop a graph that illustrates the following: (*Note:* Put visitors per year on the horizontal axis and costs on the vertical axis.)

- Accurate total cost lines for the two alternatives (show line, slopes, and equations).
- The breakeven point for the two rides in terms of number of visitors.
- The ranges of visitors per year where each alternative is preferred.

2-8 Consider the accompanying breakeven graph for an investment, and answer the following questions as they pertain to the graph.



(*a*) Give the equation to describe total revenue for x units per year.

(*b*) Give the equation to describe total costs for x units per year.

(*c*) What is the "breakeven" level of x in terms of costs and revenues?

(*d*) If you sell 1500 units this year, will you have a profit or loss? How much?

2-9 Quatro Hermanas, Inc. is investigating implementing some new production machinery as part of its operations. Three alternatives have been identified, and they have the following fixed and variable costs:

Alternative	Annual Fixed Costs	Annual Variable Costs per Unit
A	\$100,000	\$20.00
B	200,000	5.00
C	150,000	7.50

Determine the ranges of production (units produced per year) over which each alternative would be recommended for implementation by Quatro Hermanas. Be exact. (*Note:* Consider the range of production to be from 0–30,000 units per year.)

2-10 Three alternative designs have been created by Snakisco engineers for a new machine that spreads cheese between the crackers in a Snakisco snack. Each machine design has unique total costs (fixed and variable) based on the annual production rate of boxes of these crackers. The costs for the three designs are given (where x is the annual production rate of boxes of cheese crackers).

Design	Fixed Cost	Variable Cost (\$/x)
A	\$100,000	$20.5x$
B	350,000	$10.5x$
C	600,000	$8.0x$

You are asked to do the following.

(*a*) Mathematically determine which of the machine designs would be recommended for different levels of annual production of boxes of snack crackers. Management is interested in the production interval of 0–150,000 boxes of crackers per year. Over what production volume would each design (*A* or *B* or *C*) be chosen?

(*b*) Depict your solution from part (*a*) graphically, putting x per year on the horizontal axis and \$ on the vertical axis, so that management can see more easily the following:

i. Accurate total cost lines for each alternative (show line, slopes, and line equations).

ii. Any relevant breakeven, or crossover points in terms of costs between the alternatives.

iii. Ranges of annual production where each alternative is preferred.

iv. Clearly label your axes and include a *title* for the graph.

2-11 A small company manufactures a certain product. Variable costs are \$20 per unit and fixed costs are \$10,875. The price–demand relationship for this product is $P = -0.25D + 250$, where P is the unit sales price of the product and D is the annual demand. Use the data (and helpful hints) that follow to work out answers to parts (*a*)–(*e*).

- Total cost = Fixed cost + Variable cost
- Revenue = Demand × Price
- Profit = Revenue − Total cost

Set up your graph with dollars on the y axis, (between 0 and \$70,000) and, on the x axis, demand D: (units produced or sold), between 0 and 1000 units.

(*a*) Develop the equations for total cost and total revenue.

(*b*) Find the breakeven quantity (in terms of profit and loss) for the product.

(*c*) What profit would the company obtain by maximizing its total revenue?

(*d*) What is the company's maximum possible profit?

(*e*) Neatly graph the solutions from parts (*a*), (*b*), (*c*), and (*d*).

2-12 A painting operation is performed by a production worker at a labor cost of \$1.40 per unit. A robot spray-painting machine, costing \$15,000, would reduce the labor cost to \$0.20 per unit. If the device would be valueless at the end of 3 years, what is the minimum number of units that would have to be painted each year to justify the purchase of the robot machine?

2-13 Company *A* has fixed expenses of \$15,000 per year and each unit of product has a \$0.002 variable cost. Company *B* has fixed expenses of \$5000 per year and can produce the same product at a \$0.05 variable cost. At what number of units of annual production will Company *A* have the same overall cost as Company *B*?

2-14 A firm believes the sales volume (S) of its product depends on its unit selling price (P) and can be determined from the equation $P = \$100 - S$. The cost ($C$) of producing the product is $\$1000 + 10S$.

(*a*) Draw a graph with the sales volume (S) from 0 to 100 on the x axis, and total cost and total income from 0 to 2500 on the y axis. On the graph draw the line $C = \$1000 + 10S$. Then plot the curve of total income [which is sales volume (S) × unit selling price ($\$100 - S$)]. Mark the breakeven points on the graph.

(*b*) Determine the breakeven point (lowest sales volume where total sales income just equals total production cost). (*Hint:* This may be done by trial and error or by using the quadratic equation to locate the point at which profit is zero.)

(*c*) Determine the sales volume (S) at which the firm's profit is a maximum. (*Hint:* Write an equation for profit and solve it by trial and error, or as a minima–maxima calculus problem.)

2-15 Consider the situation of owning rental properties that local university students rent from you on an academic year basis. Develop a set of costs that you could classify as recurring and others that could be classified as nonrecurring.

2-16 Define the difference between a "cash cost" and a "book cost." Is engineering economic analysis concerned with both types of cost? Give an example of each, and provide the context in which it is important.

2-17 In your own words, develop a statement of what the authors mean by "life-cycle costs." Is it important for a firm to be aware of life-cycle costs? Explain why.

2-18 In looking at Figures 2-4 and 2-5, restate in your own words what the authors are trying to get across with these figures. Do you agree that this is an important effect for companies? Explain.

2-19 In the text the authors describe three effects that complicate the process of making estimates to be used in engineering economy analyses. List these three effects and comment on which of these might be most influential.

2-20 Northern Tundra Telephone (NTT) has received a contract to install emergency phones along a new 100-mile section of the Snow-Moose Turnpike. Fifty emergency phone systems will be installed about 2 miles apart. The material cost of a unit is \$125. NTT will need to run underground communication lines that cost NTT \$7500 per mile (including labor) to install. There will also be a one-time cost of \$10,000 to network these phones into NTT's current communication system. You are asked to develop a cost estimate of the project from NTT's perspective. If NTT adds a profit margin of 35% to its costs, how much will it cost the state to fund the project?

2-21 You and your spouse are planning a second honeymoon to the Cayman Islands this summer and would like to have your house painted while you are away. Estimate the total cost of the paint job from the information given below, where:

$$\text{Cost}_{\text{total}} = \text{Cost}_{\text{paint}} + \text{Cost}_{\text{labor}} + \text{Cost}_{\text{fixed}}$$

Paint information: Your house has a surface area of 6000 ft^2. One can of paint can cover 300 ft^2. You are estimating the cost to put on *two coats* of paint for the entire house, using the cost per can given. Note the incremental decrease in unit cost per can as you purchase more and more cans.

Number of Cans Purchased	Cost per Can
First 10 cans purchased	\$15.00
Second 15 cans purchased	\$10.00
Up to next 50 cans purchased	\$7.50

Labor information: You plan to hire five painters who will paint for 10 hours per day each. You estimate that the job will require 4.5 days of their painting time. The painter's labor rate is \$8.75 per hour.

Fixed cost information: There is a fixed cost of \$200 per job that the painting company charges to cover travel expenses, clothing, cloths, thinner, administration, and so on.

2-22 You are interested in having a mountain cabin built for weekend trips, vacations, to host family, and perhaps eventually to retire in. After discussing the project with a local contractor, you receive an estimate that the total construction cost of your 2000 ft^2 lodge will be \$150,000. Costs within each category include labor, material, and overhead items. The percentage of costs for each of several items (categories) is broken down as follows:

Cost Items	Percentage of Total Costs
Construction permits, legal and title fees	8%
Roadway, site clearing, preparation	15
Foundation, concrete, masonry	13
Wallboard, flooring, carpentry	12
Heating, ventilation, air conditioning	13
Electric, plumbing, communications	10
Roofing, flooring	12
Painting, finishing	17
	100

(*a*) What is the cost per square foot of the 2000 ft^2 lodge?

(*b*) If you are also considering a 4000 ft^2 layout option, estimate your construction costs if:

i. All cost items (in the table) change proportionately to the size increase.

ii. The first two cost items do not change at all; all others are proportionate.

2-23 SungSam, Inc. is currently designing a new digital camcorder that is projected to have the following per unit costs to manufacture:

Cost Categories	Unit Costs
Materials costs	$112
Labor costs	85
Overhead costs	213
Total Unit Cost	$410

SungSam adds 30% to its manufacturing cost for corporate profit. Answer the following questions:

(*a*) What unit profit would SungSam realize on each camcorder?

(*b*) What is the overall cost to produce a batch of 10,000 camcorders?

(*c*) What would SungSam's profit be on the batch of 10,000 if historical data shows that 1% of product will be scrapped in manufacturing, and 3% of finished product will go unsold, 2% of *sold* product will be returned for refund?

(*d*) How much can SungSam afford to pay for a contract that would lock in a 50% reduction in the unit material cost previously given? If SungSam does sign the contract, the sales price will remain the same as before.

2-24 Fifty years ago, Grandma Bell purchased a set of gold-plated dinnerware for $55, and last year you inherited it. Unfortunately a house fire at your home destroyed the set. Your insurance company is at a loss to define the replacement cost and has asked your help. You do some research and find that the Aurum Flatware Cost Index (AFCI) for gold-plated dinnerware, which was 112 when Grandma Bell bought her set, is at 2050 today. Use the AFCI to update the cost of Bell's set to today's cost to show to the insurance company.

2-25 Your boss is the director of reporting for the Athens County Construction Agency (ACCA). It has been his job to track the cost of construction in Athens County. Twenty-five years ago he created the ACCA Cost Index to track these costs. Costs during the first year of the index were $12 per square foot of constructed space (the index value was set at 100 for that first year). This past year a survey of contractors revealed that costs were $72 per square foot. What index number will your boss publish in his report for this year? If the index value was 525 last year, what was the cost per square foot last year?

2-26 An refinisher of antiques named Constance has been so successful with her small business that she is planning to expand her shop with all new equipment. She is going to start enlarging her shop by purchasing the following equipment.

Equipment	Original Size	Cost of Original Equipment	Power-Sizing Exponent	New Equipment Size
Varnish bath	50 gal	$3500	0.80	75 gal
Power scraper	3/4 hp	$250	0.22	1.5 hp
Paint booth	3 ft^3	$3000	0.6	12 ft^3

What would be the *net* cost to Constance to obtain this equipment—assume that she can trade the old equipment in for 15% of its original cost. Assume also that the relative price to purchase the equipment has not changed over time (that is, there has been no inflation in equipment prices).

2-27 Refer to Problem 2-26 and now assume the prices for the equipment that Constance wants to replace have not been constant. Use the cost index data for each piece of equipment to update the costs to the price that would be paid today. Develop the overall cost for Constance, again assuming the 15% trade-in allowance for the old equipment. Use any necessary data from Problem 2-26.

Original Equipment	Cost Index When Originally Purchased	Cost Index Today
Varnish bath	154	171
Power scraper	780	900
Paint booth	49	76

2-28 Five years ago, when the relevant cost index was 120, a nuclear centrifuge cost $40,000. The centrifuge had a capacity of separating 1500 gallons of ionized solution per hour. Today, it is desired to build a centrifuge with capacity of 4500 gallons per hour, but the cost index now is 300. Assuming a power-sizing exponent to reflect economies of scale, x, of 0.75, use the power-sizing model to determine the approximate cost (expressed in today's dollars) of the new reactor.

2-29 Padre works for a trade magazine that publishes lists of *Power-Sizing Exponents (PSE)* that reflect economies of scale for developing engineering estimates of various types of equipment. Padre has been unable to find any published data on the VMIC machine and wants to list its *PSE* value in his next issue. Given the following data (your staff was able to find data regarding costs and sizes of the VMIC machine) calculate the *PSE* value that Padre should publish. (*Note:* The VMIC-100 can handle twice the volume of a VMIC-50.)

Cost of VMIC-100 today \$100,000
Cost of VMIC-50 5 years ago \$45,000
VMIC equipment index today = 214
VMIC equipment index 5 years ago = 151

2-30 Develop an estimate for each of the following situations.

(*a*) The cost of a 500-mile automobile trip, if gasoline is \$1 per gallon, vehicle wear and tear is \$0.08 per mile, and our vehicle gets 20 miles per gallon.

(*b*) The total number of hours in the average human life, if the average life is 75 years.

(*c*) The number of days it takes to travel around the equator using a hot air balloon, if the balloon averages 100 miles per day, the diameter of the earth is ~4000 miles. (*Note:* Circumference = π times diameter.)

(*d*) The total area in square miles of the United States of America, if Kansas is an average-sized state. Kansas has an area of 390 miles × 200 miles.

2-31 If 200 labor hours were required to produce the 1st unit in a production run and 60 labor hours were required to produce the 7th unit, what was the *learning-curve rate* during production?

2-32 Rose is a project manager at the civil engineering consulting firm of Sands, Gravel, Concrete, and Waters, Inc. She has been collecting data on a project in which concrete pillars were being constructed, however not all the data are available. She has been able to find out that the 10th pillar required 260 person-hours to construct, and that a 75% learning curve applied. She is interested in calculating the time required to construct the 1st and 20th pillars. Compute the values for her.

2-33 Sally Statistics is implementing a system of statistical process control (SPC) charts in her factory in an effort to reduce the overall cost of scrapped product. The current cost of scrap is \$*X* per month. If an 80% learning curve is expected in the use of the SPC charts to reduce the cost of scrap, what would the *percentage reduction* in monthly scrap cost be after the charts have been implemented for 12 months? (*Hint:* Model each month as a unit of production.)

2-34 Randy Duckout has been asked to develop an estimate of the *per-unit selling price* (the price that each unit will be sold for) of a new line of hand-crafted booklets that offer excuses for missed appointments. His assistant Doc Duckout has collected information that Randy will need in developing his estimate:

Cost of direct labor	\$20 per hour
Cost of materials	\$43.75 per batch of 25 booklets
Cost of overhead items	50% of direct labor cost
Desired profit	20% of total manufacturing cost

Doc also finds out that (1) they should use a 75% learning curve for estimating the cost of direct labor, (2) the time to complete the 1st booklet is estimated at 0.60 hour, and (3) the estimated time to complete the 25th booklet should be used as their standard time for the purpose of determining the *unit selling price*. What would Randy and Doc's estimate be for the *unit selling price*?

2-35 Develop a statement that expresses the extent to which cost estimating topics also apply to estimating benefits. Provide examples to illustrate.

2-36 On December 1, Al Smith purchased a car for \$18,500. He paid \$5000 immediately and agreed to pay three additional payments of \$6000 each (which includes principal and interest) at the end of 1, 2, and 3 years. Maintenance for the car is projected at \$1000 at the end of the first year and \$2000 at the end of each subsequent year. Al expects to sell the car at the end of the fourth year (after paying for the maintenance work) for \$7000. Using these facts, prepare a table of cash flows.

2-37 Bonka Toys is considering a robot that will cost \$20,000 to buy. After 7 years its salvage value will be \$2000. An overhaul costing \$5000 will be needed in year 4. O&M costs will be \$2500 per year. Draw the cash flow diagram.

2-38 Pine Village needs some additional recreation fields. Construction will cost \$225,000 and annual O&M expenses are \$85,000. The city council estimates that the value of added youth leagues is about \$190,000 annually. In year 6 another \$75,000 will be needed to refurbish the fields. The salvage value is estimated to be \$100,000 after 10 years. Draw the cash flow diagram.

2-39 Identify your major cash flows for the current school term as first costs, O&M expenses, salvage values, revenues, overhauls, and so on. Using a week as the time period, draw the cash flow diagram.