Contents

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CHAPTER 1

The objective of Chapter 1 is to analyze short-term alternatives when the time value of money is not a factor. We accomplish this with three types of problems: 1) economic breakeven analysis; 2) cost-driven design optimization; and 3) present economy studies.

Cost Concepts and Design Economics

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THE A380 SUPERJUMBO'S BREAKEVEN POINT

When Europe's Airbus Company approved the A380 program in 2000, it was estimated that only 250 of the giant, 555-seat aircraft needed to be sold to break even. The program was initially based on expected deliveries of 751 aircraft over its life cycle. Long delays and mounting costs, however, have dramatically changed the original breakeven figure. In 2005, this figure was updated to 270 aircraft. According to an article in the *Financial Times* (October 20, 2006, p. 18), Airbus would have to sell 420 aircraft to break even—a 68% increase over the original estimate. To date, only 262 firm orders for the aircraft have been received. The topic of breakeven analysis is an integral part of this chapter.

The correct solution to any problem depends primarily on a true understanding of what the problem really is.

—Arthur M.Wellington (1887)

1.1 Cost Terminology

There are a variety of costs to be considered in an engineering economic analysis.* These costs differ in their frequency of occurrence, relative magnitude, and degree of impact on the study. In this section, we define a number of cost categories and illustrate how they should be treated in an engineering economic analysis.

1.1.1 Fixed, Variable, and Incremental Costs

Fixed costs are those unaffected by changes in activity level over a feasible range of operations for the capacity or capability available. Typical fixed costs include insurance and taxes on facilities, general management and administrative salaries, license fees, and interest costs on borrowed capital.

Of course, any cost is subject to change, but fixed costs tend to remain constant over a specific range of operating conditions. When larger changes in usage of resources occur, or when plant expansion or shutdown is involved, fixed costs can be affected.

Variable costs are those associated with an operation that varies in total with the quantity of output or other measures of activity level. For example, the costs of material and labor used in a product or service are variable costs, because they vary in total with the number of output units, even though the costs per unit stay the same.

An *incremental cost* (or *incremental revenue*) is the additional cost (or revenue) that results from increasing the output of a system by one (or more) units. Incremental cost is often associated with "go–no go" decisions that involve a limited change in output or activity level. For instance, the incremental cost per mile for driving an automobile may be $0.49, but this cost depends on considerations such as total mileage driven during the year (normal operating range), mileage expected for the next major trip, and the age of the automobile. Also, it is common to read about the "incremental cost of producing a barrel of oil" and "incremental cost to the state for educating a student." As these examples indicate, the incremental cost (or revenue) is often quite difficult to determine in practice.

* For the purposes of this book, the words *cost* and *expense* are used interchangeably.

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EXAMPLE 1.1 FIXED AND VARIABLE COSTS

In connection with surfacing a new highway, a contractor has a choice of two sites on which to set up the asphalt-mixing plant equipment. The contractor estimates that it will cost \$2.75 per cubic yard mile (yd^3-mile) to haul the asphalt-paving material from the mixing plant to the job location. Factors relating to the two mixing sites are as follows (production costs at each site are the same):

Cost Factor	Site A	Site B
Average hauling distance	4 miles	3 miles
Monthly rental of site	\$2,000	\$7,000
Cost to set up and remove equipment	\$15,000	\$50,000
Hauling expense	\$2.75/yd^3-mile	\$2.75/yd^3-mile
Flagperson	Not required	\$150/day

The job requires 50,000 cubic yards of mixed-asphalt-paving material. It is estimated that four months (17 weeks of five working days per week) will be required for the job. Compare the two sites in terms of their fixed, variable, and total costs. Assume that the cost of the return trip is negligible. Which is the better site? For the selected site, how many cubic yards of paving material does the contractor have to deliver before starting to make a profit if paid \$12 per cubic yard delivered to the job location?

Solution

The fixed and variable costs for this job are indicated in the table shown next. Site rental, setup, and removal costs (and the cost of the flagperson at Site *B*) would be constant for the total job, but the hauling cost would vary in total amount with the distance and thus with the total output quantity of yd^3-miles (x).

Cost	Fixed	Variable	Site *A*		Site *B*	
Rent	✓		=	\$8,000	=	\$28,000
Setup/ removal	✓		=	15,000	=	50,000
Flagperson	✓		=	0	5(17)(\$150) =	12,750
Hauling		✓	4(50,000)(\$2.75) =	550,000	3(50,000)(\$2.75) =	412,500
			Total:	\$573,000		\$503,250

Site *B*, which has the larger fixed costs, has the smaller total cost for the job. Note that the extra fixed costs of Site *B* are being "traded off" for reduced variable costs at this site.

The contractor will begin to make a profit at the point where total revenue equals total cost as a function of the cubic yards of asphalt pavement mix delivered. Based on Site *B*, we have

$$\begin{aligned} 3(\$2.75) &= \$8.25 \text{ in variable cost per yd}^3 \text{ delivered} \\ \text{Total cost} &= \text{total revenue} \\ \$90{,}750 + \$8.25x &= \$12x \\ x &= 24{,}200 \text{ yd}^3 \text{ delivered.} \end{aligned}$$

Therefore, by using Site *B*, the contractor will begin to make a profit on the job after delivering 24,200 cubic yards of material. ■

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1.1.2 Direct, Indirect, and Standard Costs

These frequently encountered cost terms involve most of the cost elements that also fit into the previous overlapping categories of fixed and variable costs. *Direct costs* are costs that can be reasonably measured and allocated to a specific output or work activity. The labor and material costs directly associated with a product, service, or construction activity are direct costs. For example, the materials needed to make a pair of scissors would be a direct cost.

Indirect costs are costs that are difficult to allocate to a specific output or work activity. Normally, they are costs allocated through a selected formula (such as proportional to direct labor hours, direct labor dollars, or direct material dollars) to the outputs or work activities. For example, the costs of common tools, general supplies, and equipment maintenance in a plant are treated as indirect costs.

Overhead consists of plant operating costs that are not direct labor or direct material costs. In this book, the terms *indirect costs*, *overhead*, and *burden* are used interchangeably. Examples of overhead include electricity, general repairs, property taxes, and supervision. Administrative and selling expenses are usually added to direct costs and overhead costs to arrive at a unit selling price for a product or service. (Appendix 1-A provides a more detailed discussion of cost accounting principles.)

Standard costs are planned costs per unit of output that are established in advance of actual production or service delivery. They are developed from anticipated direct labor hours, materials, and overhead categories (with their established costs per unit). Because total overhead costs are associated with a *certain level of production*, this is an important condition that should be remembered when dealing with standard cost data (for example, see Section 1.4.2). Standard costs play an important role in cost control and other management functions. Some typical uses are the following:

1. Estimating future manufacturing costs
2. Measuring operating performance by comparing actual cost per unit with the standard unit cost
3. Preparing bids on products or services requested by customers
4. Establishing the value of work in process and finished inventories

1.1.3 Cash Cost versus Book Cost

A cost that involves payment of cash is called a *cash cost* (and results in a cash flow) to distinguish it from one that does not involve a cash transaction and is reflected in the accounting system as a *noncash cost*. This noncash cost is often referred to as a *book cost*. Cash costs are estimated from the perspective established for the analysis and are the future expenses incurred for the alternatives being analyzed. Book costs are costs that do not involve cash payments but rather represent the recovery of past expenditures over a fixed period of time. The most common example of book cost is the *depreciation* charged for the use of assets such as plant and equipment. In engineering economic analysis, only those costs that are cash flows or potential cash flows from the defined perspective for the analysis need to be considered. *Depreciation, for example, is not a cash flow* and is important in an analysis only because it affects income taxes, which are cash flows.

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1.1.4 Sunk Cost

A *sunk cost* is one that has occurred in the past and has no relevance to estimates of future costs and revenues related to an alternative course of action. Thus, a sunk cost is common to all alternatives, is not part of the future (prospective) cash flows, and can be disregarded in an engineering economic analysis. For instance, sunk costs are nonrefundable cash outlays, such as earnest money on a house or money spent on a passport.

The concept of sunk cost is illustrated in the next simple example. Suppose that Joe College finds a motorcycle he likes and pays $40 as a down payment, which will be applied to the $1,300 purchase price, but which must be forfeited if he decides not to take the cycle. Over the weekend, Joe finds another motorcycle he considers equally desirable for a purchase price of $1,230. For the purpose of deciding which cycle to purchase, the $40 is a sunk cost and thus would not enter into the decision, except that it lowers the remaining cost of the first cycle. The decision then is between paying an additional $1,260 ($1,300 − $40) for the first motorcycle versus $1,230 for the second motorcycle.

In summary, sunk costs are irretrievable consequences of past decisions and therefore are irrelevant in the analysis and comparison of alternatives that affect the future. Even though it is sometimes emotionally difficult to do, sunk costs should be ignored, except possibly to the extent that their existence assists you to anticipate better what will happen in the future.

EXAMPLE 1.2 SUNK COSTS IN REPLACEMENT ANALYSIS

A classic example of sunk cost involves the replacement of assets. Suppose that your firm is considering the replacement of a piece of equipment. It originally cost $50,000, is presently shown on the company records with a value of $20,000, and can be sold for an estimated $5,000. For purposes of replacement analysis, the $50,000 is a sunk cost. However, one view is that the sunk cost should be considered as the difference between the value shown in the company records and the present realizable selling price. According to this viewpoint, the sunk cost is $20,000 minus $5,000, or $15,000. Neither the $50,000 nor the $15,000, however, should be considered in an engineering economic analysis, except for the manner in which the $15,000 may affect income taxes. ■

1.1.5 Opportunity Cost

An *opportunity cost* is incurred because of the use of limited resources, such that the opportunity to use those resources to monetary advantage in an alternative use is foregone. Thus, it is the cost of the best rejected (i.e., foregone) opportunity and is often hidden or implied.

Consider a student who could earn $20,000 for working during a year, but chooses instead to go to school for a year and spend $5,000 to do so. The opportunity cost of going to school for that year is $25,000: $5,000 cash outlay and $20,000 for income foregone. (This figure neglects the influence of income taxes and assumes that the student has no earning capability while in school.)

EXAMPLE 1.3 OPPORTUNITY COST IN REPLACEMENT ANALYSIS

The concept of an opportunity cost is often encountered in analyzing the replacement of a piece of equipment or other capital asset. Let us reconsider Example 1.2, in which your

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firm considered the replacement of an existing piece of equipment that originally cost \$50,000, is presently shown on the company records with a value of \$20,000, but has a present market value of only \$5,000. For purposes of an engineering economic analysis of whether to replace the equipment, the present investment in that equipment should be considered as \$5,000, because, by keeping the equipment, the firm is giving up the *opportunity* to obtain \$5,000 from its disposal. Thus, the \$5,000 immediate selling price is really the investment cost of not replacing the equipment and is based on the opportunity cost concept. ■

1.1.6 Life-Cycle Cost

In engineering practice, the term *life-cycle* cost is often encountered. This term refers to a summation of all the costs related to a product, structure, system, or service during its life span. The *life cycle* is illustrated in Figure 1.1. The life cycle begins with identification of the economic need or want (the requirement) and ends with retirement and disposal activities. It is a time horizon that must be defined in the context of the specific situation—whether it is a highway bridge, a jet engine for commercial aircraft, or an automated flexible manufacturing cell for a factory. The end of the life cycle may be projected on a functional or an economic basis. For example, the amount of time that a structure or piece of equipment is able to perform economically may be shorter than that permitted by its physical capability. Changes in the design efficiency of a boiler illustrate this situation. The old boiler may be able to produce the steam required, but not economically enough for the intended use.

The life cycle may be divided into two general time periods: the acquisition phase and the operation phase. As shown in Figure 1.1, each of these phases is further subdivided into interrelated but different activity periods.

The acquisition phase begins with an analysis of the economic need or want—the analysis necessary to make explicit the requirement for the product, structure, system, or service. Then, with the requirement explicitly defined, the other activities in the acquisition phase can proceed in a logical sequence. The conceptual design activities translate the defined technical and operational requirements into a preferred preliminary design. Included in these activities are development of the feasible alternatives and engineering economic analyses to assist in the selection of the preferred preliminary design. Also, advanced development and prototype-testing activities to support the preliminary design work occur during this period.

The next group of activities in the acquisition phase involves detailed design and planning for production or construction. This step is followed by the activities necessary to prepare, acquire, and make ready for operation the facilities and other resources needed. *Again, engineering economy studies are an essential part of the design process to analyze and compare alternatives and to assist in determining the final detailed design.*

In the operation phase, the production, delivery, or construction of the end item(s) or service and their operation or customer use occur. This phase ends with retirement from active operation or use and, often, disposal of the physical assets involved. The priorities for engineering economy studies during the operation phase are (1) achieving efficient and effective support to operations, (2) determining whether (and when) replacement of assets should occur, and (3) projecting the timing of retirement and disposal activities.

Figure 1.1 shows relative cost profiles for the life cycle. The greatest potential for achieving life-cycle cost savings is early in the acquisition phase. How much of the life-cycle costs for a product (for example) can be saved is dependent on many factors.

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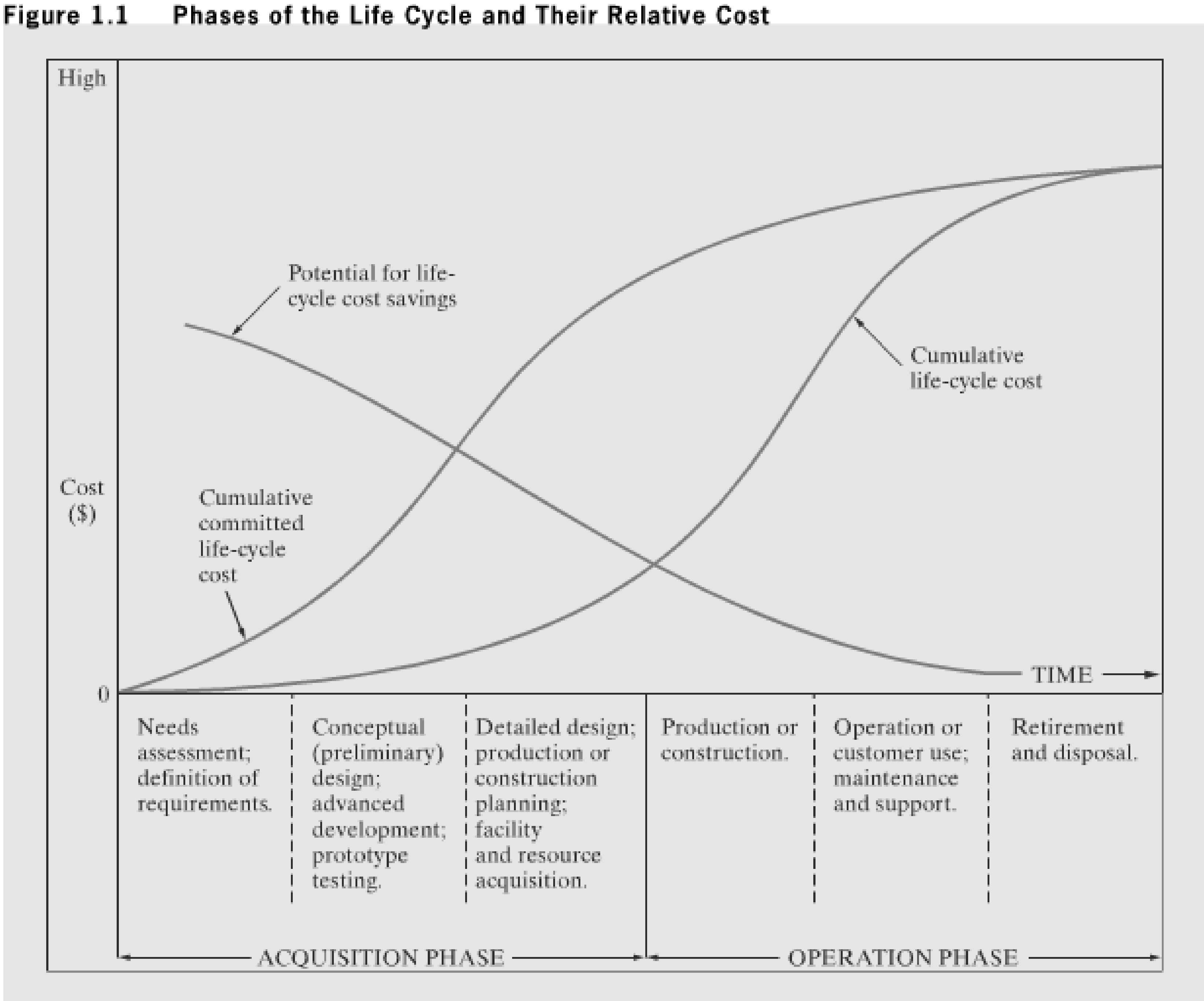
Figure 1.1 Phases of the Life Cycle and Their Relative Cost



However, effective engineering design and economic analysis during this phase are critical in maximizing potential savings.

The cumulative committed life-cycle cost curve increases rapidly during the acquisition phase. In general, approximately 80% of life-cycle costs are "locked in" at the end of this phase by the decisions made during requirements analysis and preliminary and detailed design. In contrast, as reflected by the cumulative life-cycle cost curve, only about 20% of actual costs occur during the acquisition phase, with about 80% being incurred during the operation phase.

Thus, one purpose of the life-cycle concept is to make explicit the interrelated effects of costs over the total life span for a product. An objective of the design process is to minimize the life-cycle cost—while meeting other performance requirements—by making the right trade-offs between prospective costs during the acquisition phase and those during the operation phase.

The cost elements of the life cycle that need to be considered will vary with the situation. Because of their common use, however, several basic life-cycle cost categories will now be defined.

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The *investment* cost is the capital required for most of the activities in the acquisition phase. In simple cases, such as acquiring specific equipment, an investment cost may be incurred as a single expenditure. On a large, complex construction project, however, a series of expenditures over an extended period could be incurred. This cost is also called a *capital investment*.

Operation and maintenance cost (O&M) includes many of the recurring annual expense items associated with the operation phase of the life cycle. The direct and indirect costs of operation associated with the five primary resource areas—people, machines, materials, energy, and information—are a major part of the costs in this category.

Disposal cost includes those nonrecurring costs of shutting down the operation and the retirement and disposal of assets at the end of the life cycle. Normally, costs associated with personnel, materials, transportation, and one-time special activities can be expected. These costs will be offset in some instances by receipts from the sale of assets with remaining market value. A classic example of a disposal cost is that associated with cleaning up a site where a chemical processing plant had been located.

1.2 The General Economic Environment

There are numerous general economic concepts that must be taken into account in engineering studies. In broad terms, economics deals with the interactions between people and wealth, and engineering is concerned with the cost-effective use of scientific knowledge to benefit humankind. This section introduces some of these basic economic concepts and indicates how they may be factors for consideration in engineering studies and managerial decisions.

1.2.1 Consumer and Producer Goods and Services

The goods and services that are produced and utilized maybe divided conveniently into two classes. *Consumer goods and services* are those products or services that are directly used by people to satisfy their wants. Food, clothing, homes, cars, television sets, haircuts, opera, and medical services are examples. The providers of consumer goods and services must be aware of, and are subject to, the changing wants of the people to whom their products are sold.

Producer goods and services are used to produce consumer goods and services or other producer goods. Machine tools, factory buildings, buses, and farm machinery are examples. The amount of producer goods needed is determined indirectly by the amount of consumer goods or services that are demanded by people. However, because the relationship is much less direct than for consumer goods and services, the demand for and production of producer goods may greatly precede or lag behind the demand for the consumer goods that they will produce.

1.2.2 Measures of Economic Worth

Goods and services are produced and desired because they have *utility*—the power to satisfy human wants and needs. Thus, they may be used or consumed directly, or they may be used to produce other goods or services. Utility is most commonly measured in terms of *value*, expressed in some medium of exchange as the *price* that must be paid to obtain the particular item.

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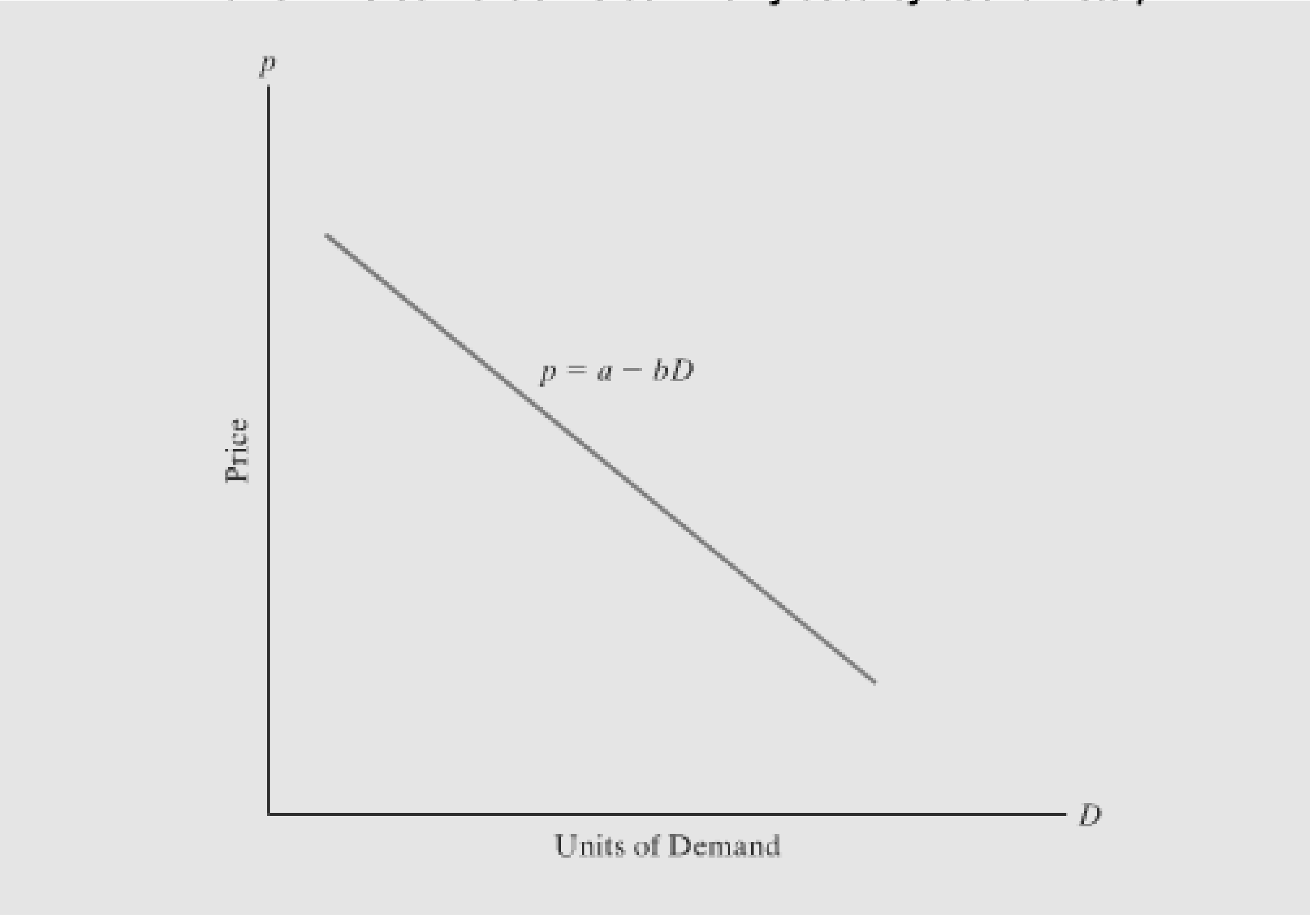
Much of our business activity, including engineering, focuses on increasing the utility (value) of materials and products by changing their form or location. Thus, iron ore, worth only a few dollars per ton, significantly increases in value by being processed, combined with suitable alloying elements, and converted into razor blades. Similarly, snow, worth almost nothing when found high in distant mountains, becomes quite valuable when it is delivered in melted form several hundred miles away to dry southern California.

1.2.3 Necessities, Luxuries, and Price Demand

Goods and services may be divided into two types: *necessities* and *luxuries*. Obviously, these terms are relative, because, for most goods and services, what one person considers a necessity may be considered a luxury by another. For example, a person living in one community may find that an automobile is a necessity to get to and from work. If the same person lived and worked in a different city, adequate public transportation might be available, and an automobile would be a luxury. For all goods and services, there is a relationship between the price that must be paid and the quantity that will be demanded or purchased. This general relationship is depicted in Figure 1.2. As the selling price per unit (p) is increased, there will be less demand (D) for the product, and as the selling price is decreased, the demand will increase. The relationship between price and demand can be expressed as the linear function

$$p = a - bD \qquad \text{for } 0 \leq D \leq \frac{a}{b}, \text{ and } a > 0, b > 0, \tag{1.1}$$

Figure 1.2 General Price–Demand Relationship. (Note that price is considered to be the independent variable but is shown as the vertical axis. This convention is commonly used by economists.)



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where a is the intercept on the price axis and $-b$ is the slope. Thus, b is the amount by which demand increases for each unit decrease in p. Both a and b are constants. It follows, of course, that

$$D = \frac{a - p}{b} \qquad (b \neq 0). \tag{1.2}$$

1.2.4 Competition

Because economic laws are general statements regarding the interaction of people and wealth, they are affected by the economic environment in which people and wealth exist. Most general economic principles are stated for situations in which *perfect competition* exists.

Perfect competition occurs in a situation in which any given product is supplied by a large number of vendors and there is no restriction on additional suppliers entering the market. Under such conditions, there is assurance of complete freedom on the part of both buyer and seller. Perfect competition may never occur in actual practice, because of a multitude of factors that impose some degree of limitation upon the actions of buyers or sellers, or both. However, with conditions of perfect competition assumed, it is easier to formulate general economic laws.

Monopoly is at the opposite pole from perfect competition. A perfect monopoly exists when a unique product or service is only available from a single supplier and that vendor can prevent the entry of all others into the market. Under such conditions, the buyer is at the complete mercy of the supplier in terms of the availability and price of the product. Perfect monopolies rarely occur in practice, because (1) few products are so unique that substitutes cannot be used satisfactorily, and (2) governmental regulations prohibit monopolies if they are unduly restrictive.

1.2.5 The Total Revenue Function

The total revenue, TR, that will result from a business venture during a given period is the product of the selling price per unit, p, and the number of units sold, D. Thus,

$$\text{TR} = \text{price} \times \text{demand} = p \cdot D. \tag{1.3}$$

If the relationship between price and demand as given in Equation (1.1) is used,

$$\text{TR} = (a - bD)D = aD - bD^2 \qquad \text{for } 0 \leq D \leq \frac{a}{b} \text{ and } a > 0, b > 0. \tag{1.4}$$

The relationship between total revenue and demand for the condition expressed in Equation (1.4) may be represented by the curve shown in Figure 1.3. From calculus, the demand, $\hat{D}$, that will produce maximum total revenue can be obtained by solving

$$\frac{d\text{TR}}{dD} = a - 2bD = 0. \tag{1.5}$$

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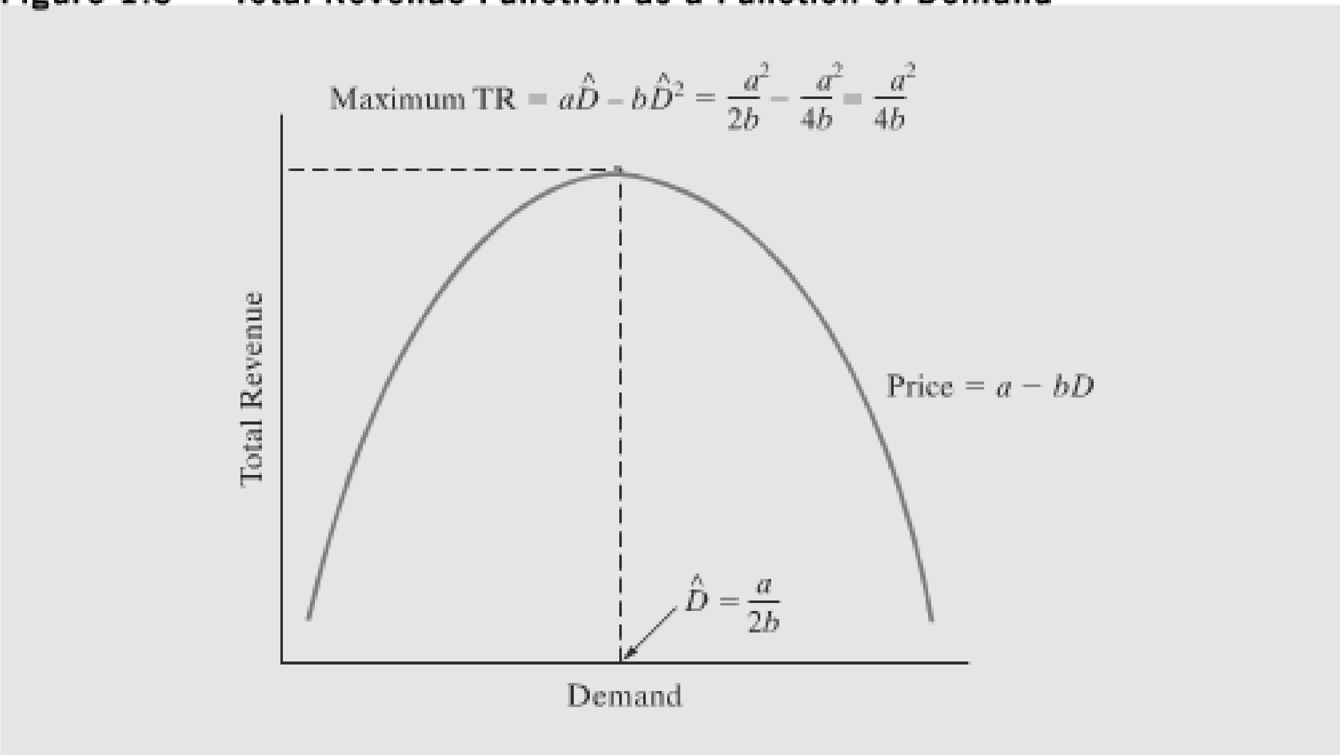
Figure 1.3 Total Revenue Function as a Function of Demand



Thus,*

$$\hat{D} = \frac{a}{2b}. \tag{1.6}$$

It must be emphasized that, because of cost–volume relationships (discussed in the next section), *most businesses would not obtain maximum profits by maximizing revenue*. Accordingly, the cost–volume relationship must be considered and related to revenue, because cost reductions provide a key motivation for many engineering process improvements.

1.2.6 Cost, Volume, and Breakeven Point Relationships

Fixed costs remain constant over a wide range of activities, but variable costs vary in total with the volume of output (Section 1.1.1). Thus, at any demand D, total cost is

$$C_T = C_F + C_V, \tag{1.7}$$

where C_F and C_V denote fixed and variable costs, respectively. For the linear relationship assumed here,

$$C_V = c_v \cdot D, \tag{1.8}$$

* To guarantee that D maximizes total revenue, check the second derivative to be sure it is negative:

$$\frac{d^2\text{TR}}{dD^2} = -2b.$$

Also, recall that in cost-minimization problems, a positively signed second derivative is necessary to guarantee a minimum-value optimal cost solution.

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where c_v is the variable cost per unit. In this section, we consider two scenarios for finding breakeven points. In the first scenario, demand is a function of price. The second scenario assumes that price and demand are independent of each other.

Scenario 1

When total revenue, as depicted in Figure 1.3, and total cost, as given by Equations (1.7) and (1.8), are combined, the typical results as a function of demand are depicted in Figure 1.4. At *breakeven point* D_1', total revenue is equal to total cost, and an increase in demand will result in a profit for the operation. Then at optimal demand, D^*, profit is maximized [Equation (1.10)]. At breakeven point D_2', total revenue and total cost are again equal, but additional volume will result in an operating loss instead of a profit. Obviously, the conditions for which breakeven and maximum profit occur are our primary interest. First, at any volume (demand), D,

$$\begin{aligned} \text{Profit (loss)} &= \text{total revenue} - \text{total costs} \\ &= (aD - bD^2) - (C_F + c_vD) \\ &= -bD^2 + (a - c_v)D - C_F \qquad \text{for } 0 \leq D \leq \frac{a}{b} \text{ and } a > 0,\ b > 0. \end{aligned} \tag{1.9}$$

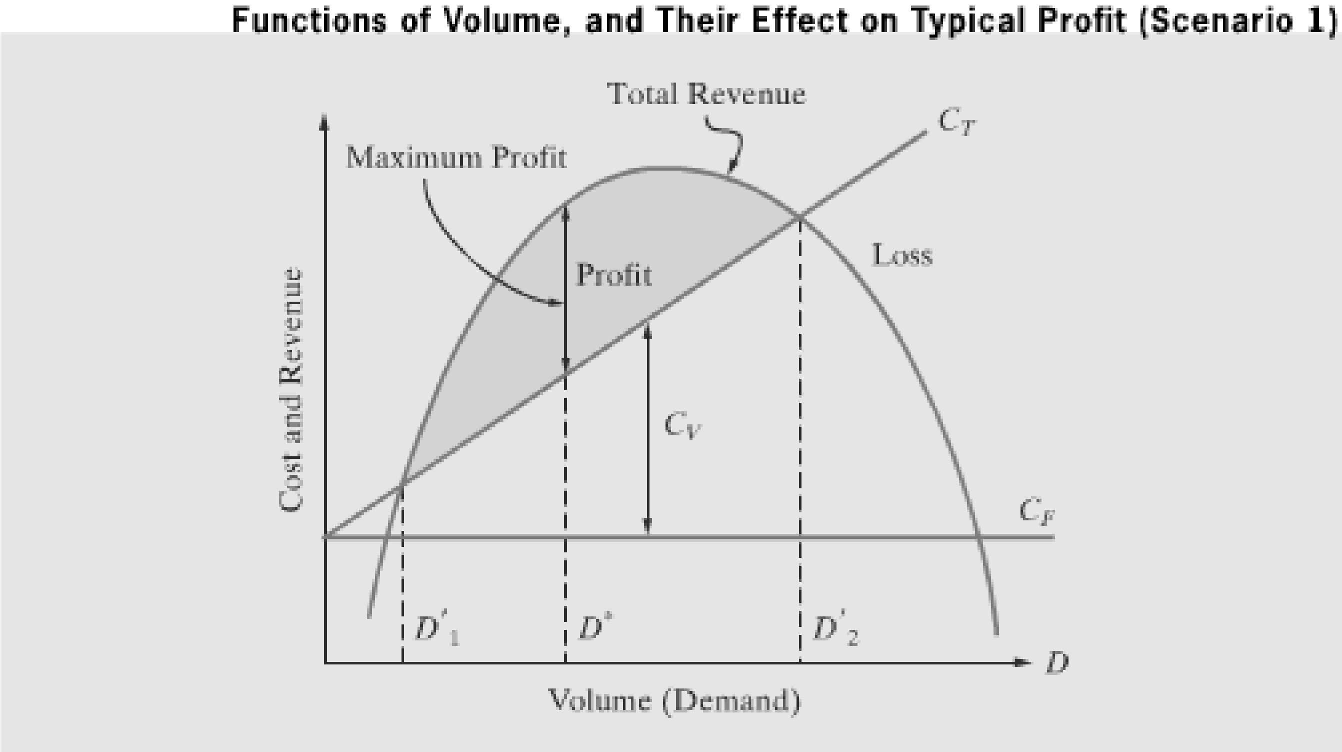
In order for a profit to occur, based on Equation (1.9), and to achieve the typical results depicted in Figure 1.4, two conditions must be met:

1. $(a - c_v) > 0$; that is, the price per unit that will result in no demand has to be greater than the variable cost per unit. (This avoids negative demand.)
2. Total revenue (TR) must exceed total cost (C_T) for the period involved.

If these conditions are met, we can find the optimal demand at which maximum profit will occur by taking the first derivative of Equation (1.9) with respect to D and setting it equal to zero:

$$\frac{d(\text{profit})}{dD} = a - c_v - 2bD = 0.$$

Figure 1.4 Combined Cost and Revenue Functions, and Breakeven Points, as Functions of Volume, and Their Effect on Typical Profit (Scenario 1)



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The optimal value of D that maximizes profit is

$$D^* = \frac{a - c_v}{2b}. \tag{1.10}$$

To ensure that we have *maximized* profit (rather than minimized it), the sign of the second derivative must be negative. Checking this, we find that

$$\frac{d^2\,(\text{profit})}{dD^2} = -2b,$$

which will be negative for $b > 0$ (as specified earlier).

An economic breakeven point for an operation occurs when total revenue equals total cost. Then for total revenue and total cost, as used in the development of Equations (1.9) and 1.10) and at any demand D,

$$\text{Total revenue} = \text{total cost} \qquad \text{(breakeven point)}$$

$$aD - bD^2 = C_F + c_v D$$

$$-bD^2 + (a - c_v)D - C_F = 0. \tag{1.11}$$

Because Equation (1.11) is a quadratic equation with one unknown (D), we can solve for the breakeven points D_1' and D_2' (the roots of the equation):*

$$D' = \frac{-(a - c_v) \pm [(a - c_v)^2 - 4(-b)(-C_F)]^{1/2}}{2(-b)}. \tag{1.12}$$

With the conditions for a profit satisfied [Equation (1.9)], the quantity in the brackets of the numerator (the discriminant) in Equation (1.12) will be greater than zero. This will ensure that D_1' and D_2' have real positive, unequal values.

EXAMPLE 1.4 OPTIMAL DEMAND WHEN DEMAND IS A FUNCTION OF PRICE

A company produces an electronic timing switch that is used in consumer and commercial products. The fixed cost (C_F) is $73,000 per month, and the variable cost (c_v) is $83 per unit. The selling price per unit is $p = \$180 - 0.02(D)$, based on Equation (1.1). For this situation,

(a) determine the optimal volume for this product and confirm that a profit occurs (instead of a loss) at this demand.

(b) find the volumes at which breakeven occurs; that is, what is the range of profitable demand? Solve by hand and by spreadsheet.

Solution by Hand

(a) $D^* = \dfrac{a - c_v}{2b} = \dfrac{\$180 - \$83}{2(0.02)} = 2{,}425$ units per month [from Equation (1.10)].

Is $(a - c_v) > 0$?

$(\$180 - \$83) = \$97,$ which is greater than 0.

* Given the quadratic equation $ax^2 + bx + c = 0$, the roots are given by $x = \dfrac{-b \pm \sqrt{b^2 - 4ac}}{2a}$.

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And is (total revenue − total cost) > 0 for $D^* = 2{,}425$ units per month?

$$[\$180(2{,}425) - 0.02(2{,}425)^2] - [\$73{,}000 + \$83(2{,}425)] = \$44{,}612$$

A demand of $D^* = 2{,}425$ units per month results in a maximum profit of \$44,612 per month. Notice that the second derivative is negative (−0.04).

(b) Total revenue = total cost (breakeven point)

$$-bD^2 + (a - c_v)D - C_F = 0 \qquad \text{[from Equation (1.11)]}$$

$$-0.02D^2 + (\$180 - \$83)D - \$73{,}000 = 0$$

$$-0.02\mathrm{D}^2 + 97D - 73{,}000 = 0$$

And, from Equation (1.12),

$$D' = \frac{-97 \pm [(97)^2 - 4(-0.02)(-73{,}000)]^{0.5}}{2(-0.02)}$$

$$D'_1 = \frac{-97 + 59.74}{-0.04} = 932 \text{ units per month}$$

$$D'_2 = \frac{-97 - 59.74}{-0.04} = 3{,}918 \text{ units per month.}$$

Thus, the range of profitable demand is 932–3,918 units per month.

Spreadsheet Solution

Figure 1.5(a) displays the spreadsheet solution for this problem. This spreadsheet calculates profit for a range of demand values (shown in column A). For a specific value of demand, price per unit is calculated in column B by using Equation (1.1) and Total Revenue is simply demand × price. Total Expense is computed by using Equations (1.7) and (1.8). Finally, Profit (column E) is then Total Revenue − Total Expense.

A quick inspection of the Profit column gives us an idea of the optimal demand value as well as the breakeven points. Note that profit steadily increases as demand increases to 2,500 units per month and then begins to drop off. This tells us that the optimal demand value lies in the range of 2,250 to 2,750 units per month. A move specific value can be obtained by changing the Demand Start point value in cell E1 and the Demand Increment value in cell E2. For example, if the value of cell E1 is set to 2,250 and the increment in cell E2 is set to 10, the optimal demand value is shown to be between 2,420 and 2,430 units per month.

The breakeven points lie within the ranges 750–1,000 units per month and 3,750–4,000 units per month, as indicated by the change in sign of profit. Again, by changing the values in cells E1 and E2, we can obtain more exact values of the breakeven points.

Figure 1.5(b) is a graphical display of the Total Revenue, Total Expense, and Profit functions for the range of demand values given in column A of Figure 1.5(a). This graph enables us to see how profit changes as demand increases. The optimal demand value (maximum point of the profit curve) appears to be around 2,500 units per month.

Figure 1.5(b) is also a graphical representation of the breakeven points. By graphing the total revenue and total cost curves separately, we can easily identify the breakeven points (the intersection of these two functions). From the graph, the range of profitable demand is approximately 1,000 to 4,000 units per month. Notice also that, at these demand values, the profit curve crosses the x-axis (\$0).

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Figure 1.5 Spreadsheet Solution, Example 1.4

= \$B\$3 – \$B\$4 * A7

= \$B\$1 + \$B\$2 * A7

= B7 * A7

= C7 – D7

= E1

	A	B	C	D	E
1	Fixed cost/ mo. =	$ 73,000		Demand Start point (D) =	0
2	Variable cost/unit =	$ 83		Demand Increment =	250
3	a =	$ 180			
4	b =	$ 0.02			
5					
6	**Monthly Demand**	**Price per Unit**	**Total Revenue**	**Total Expense**	**Profit**
7	0	$ 180	$ -	$ 73,000	$ (73,000)
8	250	$ 175	$ 43,750	$ 93,750	$ (50,000)
9	500	$ 170	$ 85,000	$ 114,500	$ (29,500)
10	750	$ 165	$ 123,750	$ 135,250	$ (11,500)
11	1000	$ 160	$ 160,000	$ 156,000	$ 4,000
12	1250	$ 155	$ 193,750	$ 176,750	$ 17,000
13	1500	$ 150	$ 225,000	$ 197,500	$ 27,500
14	1750	$ 145	$ 253,750	$ 218,250	$ 35,500
15	2000	$ 140	$ 280,000	$ 239,000	$ 41,000
16	2250	$ 135	$ 303,750	$ 259,750	$ 44,000
17	2500	$ 130	$ 325,000	$ 280,500	$ 44,500
18	2750	$ 125	$ 343,750	$ 301,250	$ 42,500
19	3000	$ 120	$ 360,000	$ 322,000	$ 38,000
20	3250	$ 115	$ 373,750	$ 342,750	$ 31,000
21	3500	$ 110	$ 385,000	$ 363,500	$ 21,500
22	3750	$ 105	$ 393,750	$ 384,250	$ 9,500
23	4000	$ 100	$ 400,000	$ 405,000	$ (5,000)
24	4250	$ 95	$ 403,750	$ 425,750	$ (22,000)
25	4500	$ 90	$ 405,000	$ 446,500	$ (41,500)
26	4750	$ 85	$ 403,750	$ 467,250	$ (63,500)
27	5000	$ 80	$ 400,000	$ 488,000	$ (88,000)
28	5250	$ 75	$ 393,750	$ 508,750	$ (115,000)
29	5500	$ 70	$ 385,000	$ 529,500	$ (144,500)

= A7 + \$E\$2

(a) Table of profit values for a range of demand values

Comment

As seen in the hand solution to this problem, Equations (1.10) and (1.12) can be used directly to solve for the optimal demand value and breakeven points. The power of the spreadsheet in this example is the ease with which graphical displays can be generated to support your analysis. Remember, a picture really can be worth a thousand words. Spreadsheets also facilitate sensitivity analysis. For example, what is the impact on the optimal demand value and breakeven points if variable costs are reduced by 10% per

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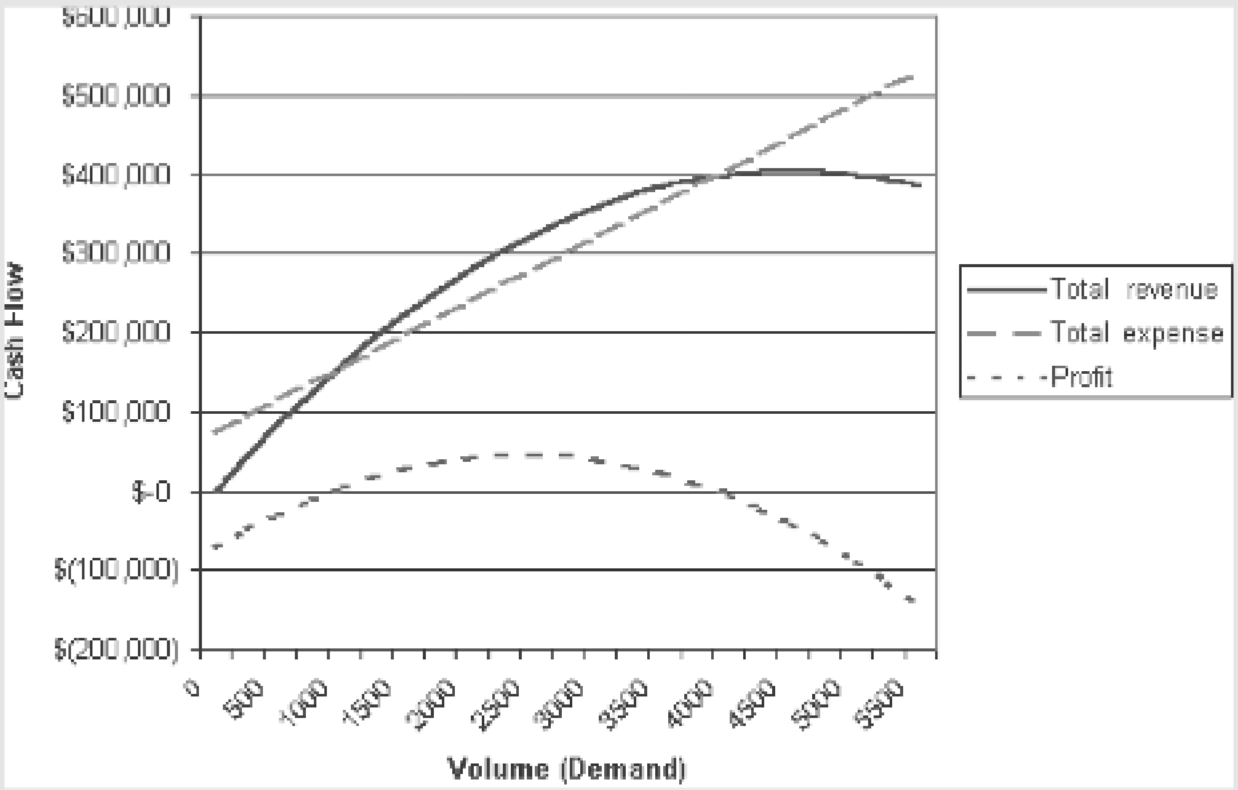
Figure 1.5 Continued



(b) Graphical display of optimal demand and breakeven values

unit? (The new optimal demand value is increased to 2,632 units per month, and the range of profitable demand is widened to 822 to 4,443 units per month.) ■

Scenario 2

When the price per unit (p) for a product or service can be represented more simply as being independent of demand [versus being a linear function of demand, as assumed in Equation (1.1)] and is greater than the variable cost per unit (c_v), a single breakeven point results. Then, under the assumption that demand is immediately met, total revenue (TR) $= p \cdot D$. If the linear relationship for costs in Equations (1.7) and (1.8) is also used in the model, the typical situation is depicted in Figure 1.6. This scenario is typified by the Airbus example presented at the beginning of the chapter.

EXAMPLE 1.5 BREAKEVEN POINT WHEN PRICE IS INDEPENDENT OF DEMAND

An engineering consulting firm measures its output in a standard service hour unit, which is a function of the personnel grade levels in the professional staff. The variable cost (c_v) is \$62 per standard service hour. The charge-out rate [i.e., selling price (p)] is \$85.56 per hour. The maximum output of the firm is 160,000 hours per year, and its fixed cost (C_F) is \$2,024,000 per year. For this firm,

(a) what is the breakeven point in standard service hours and in percentage of total capacity?

(b) what is the percentage reduction in the breakeven point (sensitivity) if fixed costs are reduced 10%; if variable cost per hour is reduced 10%; and if the selling price per unit is increased by 10%?

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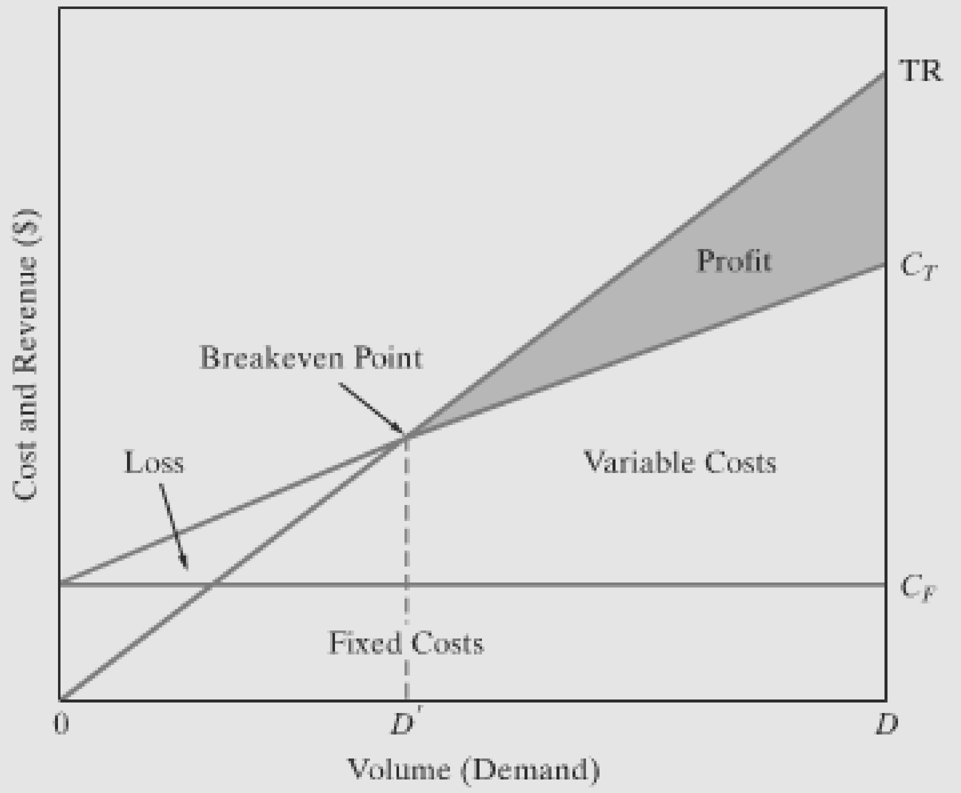
Figure 1.6 Typical Breakeven Chart with Price (p) a Constant (Scenario 2)



Solution

(a) Total revenue = total cost (breakeven point)

$$pD' = C_F + c_v D'$$

$$D' = \frac{C_F}{(p - c_v)}, \tag{1.13}$$

and

$$D' = \frac{\$2{,}024{,}000}{(\$85.56 - \$62)} = 85{,}908 \text{ hours per year}$$

$$D' = \frac{85{,}908}{160{,}000} = 0.537,$$

or 53.7% of capacity.

(b) A 10% reduction in C_F gives

$$D' = \frac{0.9(\$2{,}024{,}000)}{(\$85.56 - \$62)} = 77{,}318 \text{ hours per year}$$

and

$$\frac{85{,}908 - 77{,}318}{85.908} = 0.10,$$

or a 10% reduction in D'.

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A 10% reduction in c_v gives

$$D' = \frac{\$2{,}024{,}000}{[\$85.56 - 0.9(\$62)]} = 68{,}011 \text{ hours per year}$$

and

$$D' = \frac{85{,}908 - 68{,}011}{85{,}908} = 0.208,$$

or a 20.8% reduction in D'.

A 10% increase in p gives

$$D' = \frac{\$2{,}024{,}000}{[1.1(\$85.56) - \$62]} = 63{,}021 \text{ hours per year}$$

and

$$\frac{85{,}908 - 63{,}021}{85{,}908} = 0.266,$$

or a 26.6% reduction in D'.

Thus, the breakeven point is more sensitive to a reduction in variable cost per hour than to the same percentage reduction in the fixed cost. Furthermore, notice that the breakeven point in this example is highly sensitive to the selling price per unit, p. ■

Market competition often creates pressure to lower the breakeven point of an operation; the lower the breakeven point, the less likely that a loss will occur during market fluctuations. Also, if the selling price remains constant (or increases), a larger profit will be achieved at any level of operation above the reduced breakeven point.

1.3 Cost-Driven Design Optimization

As discussed in Section 1.1.6, engineers must maintain a *life-cycle* (i.e., "cradle to grave") viewpoint as they design products, processes, and services. Such a complete perspective ensures that engineers consider initial investment costs, operation and maintenance expenses and other annual expenses in later years, and environmental and social consequences over the life of their designs. In fact, a movement called *Design for the Environment* (DFE), or "green engineering," has prevention of waste, improved materials selection, and reuse and recycling of resources among its goals. Designing for energy conservation, for example, is a subset of green engineering. Another example is the design of an automobile bumper that can be easily recycled. As you can see, *engineering design is an economically driven art.*

Examples of cost minimization through effective design are plentiful in the practice of engineering. Consider the design of a heat exchanger in which tube material and configuration affect cost and dissipation of heat. The problems in this section designated as "cost-driven design optimization" are simple design models intended to illustrate the importance of cost in the design process. These problems show the procedure for determining an optimal design, using cost concepts. We will consider discrete and continuous

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optimization problems that involve a single design variable, X. This variable is also called a *primary cost driver*, and knowledge of its behavior may allow a designer to account for a large portion of total cost behavior.

For cost-driven design optimization problems, the two main tasks are as follows:

1. Determine the optimal value for a certain alternative's design variable. For example, what velocity of an aircraft minimizes the total annual costs of owning and operating the aircraft?
2. Select the best alternative, each with its own unique value for the design variable. For example, what insulation thickness is best for a home in Virginia: R11, R19, R30, or R38?

In general, the cost models developed in these problems consist of three types of costs:

1. fixed cost(s)
2. cost(s) that vary *directly* with the design variable
3. cost(s) that vary *indirectly* with the design variable

A simplified format of a cost model with one design variable is

$$\text{Cost} = aX + \frac{b}{X} + k, \tag{1.14}$$

where a is a parameter that represents the directly varying cost(s),
b is a parameter that represents the indirectly varying cost(s),
k is a parameter that represents the fixed cost(s), and
X represents the design variable in question (e.g., weight or velocity).

In a particular problem, the parameters a, b, and k may actually represent the sum of a group of costs in that category, and the design variable may be raised to some power for either directly or indirectly varying costs.*

The following steps outline a general approach for optimizing a design with respect to cost:

1. Identify the design variable that is the primary cost driver (e.g., pipe diameter or insulation thickness).
2. Write an expression for the cost model in terms of the design variable.
3. Set the first derivative of the cost model with respect to the continuous design variable equal to zero. For discrete design variables, compute the value of the cost model for each discrete value over a selected range of potential values.
4. Solve the equation found in Step 3 for the optimum value of the continuous design variable.† For discrete design variables, the optimum value has the minimum cost value found in Step 3. This method is analogous to taking the first derivative for a continuous design variable and setting it equal to zero to determine an optimal value.

* A more general model is the following: Cost $= k + ax + b_1x^{e_1} + b^2x^{e_2} + \cdots$, where $e_1 = -1$ reflects costs that vary inversely with X, $e_2 = 2$ indicates costs that vary as the square of X, and so forth.

† If multiple optima (stationary points) are found in Step 4, finding the global optimum value of the design variable will require a little more effort. One approach is to systematically use each root in the second derivative equation and assign each point as a maximum or a minimum based on the sign of the second derivative. A second approach would be to use each root in the objective function and see which point best satisfies the cost function.

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5. For continuous design variables, use the second derivative of the cost model with respect to the design variable to determine whether the optimum value found in Step 4 corresponds to a global maximum or minimum.

EXAMPLE 1.6 HOW FAST SHOULD THE AIRPLANE FLY?

The cost of operating a jet-powered commercial (passenger-carrying) airplane varies as the three-halves (3/2) power of its velocity; specifically, $C_O = knv^{3/2}$, where n is the trip length in miles, k is a constant of proportionality, and v is velocity in miles per hour. It is known that at 400 miles per hour, the *average* cost of operation is \$300 per mile. The company that owns the aircraft wants to minimize the cost of operation, but that cost must be balanced against the cost of the passengers' time (C_C), which has been set at \$300,000 per hour.

(a) At what velocity should the trip be planned to minimize the total cost, which is the sum of the cost of operating the airplane and the cost of passengers' time?

(b) How do you know that your answer for the problem in Part (a) minimizes the total cost?

Solution

(a) The equation for total cost (C_T) is

$$C_T = C_O + C_C = knv^{3/2} + (\$300{,}000 \text{ per hour})\left(\frac{n}{v}\right)$$

where n/v has time (hours) as its unit.

Now we solve for the value of k:

$$\frac{C_O}{n} = kv^{3/2}$$

$$\frac{\$300}{\text{mile}} = k\left(400\frac{\text{miles}}{\text{hour}}\right)^{3/2}$$

$$k = \frac{\$300/\text{mile}}{\left(400\dfrac{\text{miles}}{\text{hour}}\right)^{3/2}}$$

$$k = \frac{\$300/\text{mile}}{8000\left(\dfrac{\text{miles}^{3/2}}{\text{hour}^{3/2}}\right)}$$

$$k = \$0.0375\frac{\text{hours}^{3/2}}{\text{miles}^{5/2}}.$$

Thus,

$$C_T = \left(\$0.0375\frac{\text{hours}^{3/2}}{\text{miles}^{5/2}}\right)(n \text{ miles})\left(v\frac{\text{miles}}{\text{hour}}\right)^{3/2} + \left(\frac{\$300{,}000}{\text{hour}}\right)\left(\frac{n \text{ miles}}{v\dfrac{\text{miles}}{\text{hour}}}\right)$$

$$C_T = \$0.0375nv^{3/2} + \$300{,}000\left(\frac{n}{v}\right).$$

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Next, the first derivative is taken:

$$\frac{dC_T}{dv} = \frac{3}{2}(\$0.0375)nv^{1/2} - \frac{\$300{,}000n}{v^2} = 0.$$

So,

$$0.05625v^{1/2} - \frac{300{,}000}{v^2} = 0$$

$$0.05625v^{5/2} - 300{,}000 = 0$$

$$v^{5/2} = \frac{300{,}000}{0.05625} = 5{,}333{,}333$$

$$v^* = (5{,}333{,}333)^{0.4} = 490.68 \text{ mph.}$$

(b) Finally, we check the second derivative to confirm a minimum cost solution:

$$\frac{d^2C_T}{dv^2} = \frac{0.028125}{v^{1/2}} + \frac{600{,}000}{v^3} \quad \text{for } v > 0, \text{ and therefore, } \frac{d^2C_T}{dv^2} > 0.$$

The company concludes that $v = 490.68$ mph minimizes the total cost of this particular airplane's flight. ■

EXAMPLE 1.7 ENERGY SAVINGS THROUGH INCREASED INSULATION

This example deals with a discrete optimization problem of determining the most economical amount of attic insulation for a large single-story home in Virginia. In general, the heat lost through the roof of a single-story home is

$$\begin{matrix}\text{Heat loss} \\ \text{in Btu} \\ \text{per hour}\end{matrix} = \left(\begin{matrix}\Delta\text{ Temperature} \\ \text{in °F}\end{matrix}\right)\left(\begin{matrix}\text{Area} \\ \text{in} \\ \text{ft}^2\end{matrix}\right)\left(\frac{\begin{matrix}\text{Conductance in} \\ \text{Btu/hour}\end{matrix}}{\text{ft}^2 - \text{°F}}\right),$$

or

$$Q = (T_{\text{in}} - T_{\text{out}}) \cdot A \cdot U.$$

In southwest Virginia, the number of heating days per year is approximately 230, and the annual heating degree-days equals 230 (65°F–46°F) = 4,370 degree-days per year. Here, 65°F is assumed to be the average inside temperature and 46°F is the average outside temperature each day.

Consider a 2,400-ft^2 single-story house in Blacksburg. The typical annual space-heating load for this size of a house is 100×10^6 Btu. That is, with no insulation in the attic, we lose about 100×10^6 Btu per year.* Common sense dictates that the "no insulation" alternative is not attractive and is to be avoided.

With insulation in the attic, the amount of heat lost each year will be reduced. The value of energy savings that results from adding insulation and reducing heat loss is dependent

* 100×10^6 Btu/yr $\cong \left(\frac{4{,}370\text{ °F-days per year}}{1.00\text{ efficiency}}\right)(2{,}400\text{ ft}^2)(24\text{ hours/day})\left(\frac{0.397\text{ Btu/hr}}{\text{ft}^2 - \text{°F}}\right)$, where 0.397 is the U-factor with no insulation.

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on what type of residential heating furnace is installed. For this example, we assume that an electrical resistance furnace is installed by the builder, and its efficiency is near 100%.

Now we're in a position to answer the following question: What amount of insulation is most economical? An additional piece of data we need involves the cost of electricity, which is \$0.074 per kWh. This can be converted to dollars per 10^6 Btu as follows (1 kWh = 3,413 Btu):

$$\frac{\text{kWh}}{3{,}413 \text{ Btu}} = 293 \text{ kWh per million Btu}$$

$$\frac{293 \text{ kWh}}{10^6 \text{ Btu}}\left(\frac{\$0.074}{\text{kWh}}\right) \cong \$21.75/10^6 \text{ Btu.}$$

The cost of several insulation alternatives and associated space-heating loads for this house are given in the following table (an R-value indicates the resistance to heat transfer—the higher the number the less the heat transfer):

	Amount of Insulation			
	R11	**R19**	**R30**	**R38**
Investment cost (\$)	600	900	1,300	1,600
Annual heating load (Btu/year)	74×10^6	69.8×10^6	67.2×10^6	66.2×10^6

In view of these data, which amount of attic insulation is most economical? The life of the insulation is estimated to be 25 years.

Solution

Set up a table to examine total life-cycle costs:

	R11	**R19**	**R30**	**R38**
A. Investment cost	\$600	\$900	\$1,300	\$1,600
B. Cost of heat loss per year	\$1,609.50	\$1,518.15	\$1,461.60	\$1,439.85
C. Cost of heat loss over 25 years	\$40,237.50	\$37,953.75	\$36,540	\$35,996.25
D. Total life cycle costs (A + C)	\$40,837.50	\$38,853.75	\$37,840	\$37,596.25

Answer: To minimize total life-cycle costs, select R38 insulation.

Caution

This conclusion may change when we consider the time value of money (i.e., an interest rate greater than zero). In such a case, it will not necessarily be true that adding more and more insulation is the optimal course of action. ■

1.4 Present Economy Studies

When alternatives for accomplishing a specific task are being compared over *one year or less* and the influence of time on money can be ignored, engineering economic analyses are referred to as *present economy studies*. Several situations involving present economy studies are illustrated in this section. The rules, or criteria, shown next will be used to select the preferred alternative when defect-free output (yield) is variable *or* constant among the alternatives being considered.

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RULE 1

When revenues and other economic benefits are present and vary among alternatives, choose the alternative that *maximizes* overall profitability based on the number of defect-free units of a product or service produced.

RULE 2

When revenues and other economic benefits are *not* present *or* are constant among all alternatives, consider only the costs and select the alternative that *minimizes* total cost per defect-free unit of product or service output.

1.4.1 Total Cost in Material Selection

In many cases, economic selection among materials cannot be based solely on the costs of materials. Frequently, a change in materials will affect the design and processing costs, and shipping costs may also be altered.

EXAMPLE 1.8 CHOOSING THE MOST ECONOMIC MATERIAL FOR A PART

A good example of this situation is illustrated by a part for which annual demand is 100,000 units. The part is produced on a high-speed turret lathe, using 1112 screw-machine steel costing \$0.30 per pound.A study was conducted to determine whether it might be cheaper to use brass screw stock, costing \$1.40 per pound. Because the weight of steel required per piece was 0.0353 pounds and that of brass was 0.0384 pounds, the material cost per piece was \$0.0106 for steel and \$0.0538 for brass. However, when the manufacturing engineering department was consulted, it was found that, although 57.1 defect-free parts per hour were being produced by using steel, the output would be 102.9 defect free parts per hour if brass were used. Which material should be used for this part?

Solution

The machine attendant is paid \$15.00 per hour, and the variable (i.e., traceable) overhead costs for the turret lathe are estimated to be \$10.00 per hour. Thus, the total cost comparison for the two materials is as follows:

	1112 Steel	Brass
Material	\$0.30 × 0.0353 = \$0.0106	\$1.40 × 0.0384 = \$0.0538
Labor	\$15.00/57.1 = 0.2627	\$15.00/102.9 = 0.1458
Variable overhead	\$10.00/57.1 = 0.1751	\$10.00/102.9 = 0.0972
Total cost per piece	\$0.4484	\$0.2968
Saving per piece by use of brass = \$0.4484 − \$0.2968 = \$0.1516		

Because 100,000 parts are made each year, revenues are constant across the alternatives. Rule 2 would select brass, and its use will produce a savings of \$151.60 per thousand (a total of \$15,160 for the year). It is also clear that costs other than the cost of material (such as labor and overhead) were important in the study. ■

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Care should be taken in making economic selections between materials to ensure that any differences in shipping costs, yields, or resulting scrap are taken into account. Commonly, alternative materials do not come in the same stock sizes, such as sheet sizes and bar lengths. This may considerably affect the yield obtained from a given weight of material. Similarly, the resulting scrap may differ for various materials.

In addition to deciding what material a product should be made of, there are often alternative methods or machines that can be used to produce the product, which, in turn, can impact processing costs. Processing times may vary with the machine selected, as may the product yield. As illustrated in Example 1.9, these considerations can have important economic implications.

EXAMPLE 1.9 CHOOSING THE MOST ECONOMICAL MACHINE FOR PRODUCTION

Two currently owned machines are being considered for the production of a part. The capital investment associated with the machines is about the same and can be ignored for purposes of this example. The important differences between the machines are their production capacities (production rate × available production hours) and their reject rates (percentage of parts produced that cannot be sold). Consider the following table:

	Machine *A*	**Machine *B***
Production rate	100 parts/hour	130 parts/hour
Hours available for production	7 hours/day	6 hours/day
Percent parts rejected	3%	10%

The material cost is \$6.00 per part, and all defect-free parts produced can be sold for \$12 each. (Rejected parts have negligible scrap value.) For either machine, the operator cost is \$15.00 per hour and the variable overhead rate for traceable costs is \$5.00 per hour.

(a) Assume that the daily demand for this part is large enough that all defect-free parts can be sold. Which machine should be selected?

(b) What would the percent of parts rejected have to be for Machine *B* to be as profitable as Machine *A*?

Solution

(a) Rule 1 applies in this situation because total daily revenues (selling price per part times the number of parts sold per day) and total daily costs will vary depending on the machine chosen. Therefore, we should select the machine that will maximize the profit per day:

$$\begin{aligned}\text{Profit per day} &= \text{Revenue per day} - \text{Cost per day}\\ &= (\text{Production rate})(\text{Production hours})(\$12/\text{part})\\ &\quad \times [1 - (\%\text{rejected}/100)]\\ &\quad - (\text{Production rate})(\text{Production hours})(\$6/\text{part})\\ &\quad - (\text{Production hours})(\$15/\text{hour} + \$5/\text{hour}).\end{aligned}$$

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$$\begin{aligned}
\text{Machine } A\text{: Profit per day} &= \left(\frac{100 \text{ parts}}{\text{hour}}\right)\left(\frac{7 \text{ hours}}{\text{day}}\right)\left(\frac{\$12}{\text{part}}\right)(1 - 0.03) \\
&\quad - \left(\frac{100 \text{ parts}}{\text{hour}}\right)\left(\frac{7 \text{ hours}}{\text{day}}\right)\left(\frac{\$6}{\text{part}}\right) \\
&\quad - \left(\frac{7 \text{ hours}}{\text{day}}\right)\left(\frac{\$15}{\text{hour}} + \frac{\$5}{\text{hour}}\right) \\
&= \$3{,}808 \text{ per day.} \\
\text{Machine } B\text{: Profit per day} &= \left(\frac{130 \text{ parts}}{\text{hour}}\right)\left(\frac{6 \text{ hours}}{\text{day}}\right)\left(\frac{\$12}{\text{part}}\right)(1 - 0.10) \\
&\quad - \left(\frac{130 \text{ parts}}{\text{hour}}\right)\left(\frac{6 \text{ hours}}{\text{day}}\right)\left(\frac{\$6}{\text{part}}\right) \\
&\quad - \left(\frac{6 \text{ hours}}{\text{day}}\right)\left(\frac{\$15}{\text{hour}} + \frac{\$5}{\text{hour}}\right) \\
&= \$3{,}624 \text{ per day.}
\end{aligned}$$

Therefore, *select Machine A* to maximize profit per day.

(b) To find the breakeven percent of parts rejected, X, for Machine B, set the profit per day of Machine A equal to the profit per day of Machine B, and solve for X:

$$\begin{aligned}
\$3{,}808/\text{day} &= \left(\frac{130 \text{ parts}}{\text{hour}}\right)\left(\frac{6 \text{ hours}}{\text{day}}\right)\left(\frac{\$12}{\text{part}}\right)(1 - X) - \left(\frac{130 \text{ parts}}{\text{hour}}\right) \\
&\quad \times \left(\frac{6 \text{ hours}}{\text{day}}\right)\left(\frac{\$6}{\text{part}}\right) - \left(\frac{6 \text{ hours}}{\text{day}}\right)\left(\frac{\$15}{\text{hour}} + \frac{\$5}{\text{hour}}\right).
\end{aligned}$$

Thus, $X = 0.08$, so the percent of parts rejected for Machine B can be no higher than 8% for it to be as profitable as Machine A. ■

1.4.2 Making versus Purchasing (Outsourcing) Studies*

In the short run, say, one year or less, a company may consider producing an item in-house even though the item can be purchased (outsourced) from a supplier at a price lower than the company's standard production costs. (See Section 1.1.2.) This could occur if (1) direct, indirect, and overhead costs are incurred regardless of whether the item is purchased from an outside supplier and (2) the *incremental* cost of producing an item in the short run is less than the supplier's price. Therefore, the relevant short-run costs of make versus purchase decisions are the *incremental costs* incurred and the *opportunity costs* of the resources involved.

* Much interest has been shown in outsourcing decisions. For example, see P. Chalos, "Costing, Control, and Strategic Analysis in Outsourcing Decisions," *Journal of Cost Management,* 8, no. 4 (Winter 1995): pp. 31–37.

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Opportunity costs may become significant when in-house manufacture of an item causes other production opportunities to be forgone (often because of insufficient capacity). But in the long run, capital investments in additional manufacturing plant and capacity are often feasible alternatives to outsourcing. (Much of this book is concerned with evaluating the economic worthiness of proposed capital investments.) Because engineering economy often deals with *changes* to existing operations, standard costs may not be too useful in make-versus-purchase studies. In fact, if they are used, standard costs can lead to uneconomical decisions. Example 1.10 illustrates the correct procedure to follow in performing make-versus-purchase studies based on incremental costs.

EXAMPLE 1.10 TO PRODUCE OR NOT TO PRODUCE?—THAT IS THE QUESTION

A manufacturing plant consists of three departments: *A*, *B*, and *C*. Department *A* occupies 100 square meters in one corner of the plant. Product *X* is one of several products being produced in Department *A*. The daily production of Product *X* is 576 pieces. The cost accounting records show the following average daily production costs for Product *X*:

Direct labor	(1 operator working 4 hours per day at \$22.50/hr, including fringe benefits, plus a part-time foreman at \$30 per day)	\$120.00
Direct material		86.40
Overhead	(at \$0.82 per square meter of floor area)	82.00
	Total cost per day =	\$288.40

The department foreman has recently learned about an outside company that sells Product *X* at \$0.35 per piece. Accordingly, the foreman figured a cost per day of \$0.35(576) = \$201.60, resulting in a daily savings of \$288.40 − \$201.60 = \$86.80. Therefore, a proposal was submitted to the plant manager for shutting down the production line of Product *X* and buying it from the outside company.

However, after examining each component separately, the plant manager decided not to accept the foreman's proposal based on the unit cost of Product *X*:

1. ***Direct labor:*** Because the foreman was supervising the manufacture of other products in Department *A* in addition to Product *X*, the only possible savings in labor would occur if the operator working 4 hours per day on Product *X* were not reassigned after this line is shut down. That is, a maximum savings of \$90.00 per day would result.
2. ***Materials:*** The maximum savings on direct material will be \$86.40. However, this figure could be lower if some of the material for Product *X* is obtained from scrap of another product.
3. ***Overhead:*** Because other products are made in Department *A*, no reduction in total floor space requirements will probably occur. Therefore, no reduction in overhead costs will result from discontinuing Product *X*. It has been estimated that there will be daily savings in the variable overhead costs traceable to Product *X* of about \$3.00 due to a reduction in power costs and in insurance premiums.

Solution

If the manufacture of Product *X* is discontinued, the firm will save at most \$90.00 in direct labor, \$86.40 in direct materials, and \$3.00 in variable overhead costs, which totals \$179.40 per day. This estimate of actual cost savings per day is less than the potential

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savings indicated by the cost accounting records ($288.40 per day), and it would not exceed the $201.60 to be paid to the outside company if Product X is purchased. For this reason, the plant manager used Rule 2 and rejected the proposal of the foreman and continued the manufacture of Product X.

In conclusion, Example 1.10 shows how an erroneous decision might be made by using the unit cost of Product X from the cost accounting records without detailed analysis. The fixed cost portion of Product X's unit cost, which is present even if the manufacture of Product X is discontinued, was not properly accounted for in the original analysis by the foreman. ■

1.4.3 Trade-Offs in Energy Efficiency Studies

Energy efficiency affects the annual expense of operating an electrical device such as a pump or motor. Typically, a more energy-efficient device requires a higher capital investment than does a less energy-efficient device, but the extra capital investment usually produces annual savings in electrical power expenses relative to a second pump or motor that is less energy efficient. This important tradeoff between capital investment and annual electric power consumption will be considered in several chapters of this book. Hence, the purpose of Section 1.4.3 is to explain how the annual expense of operating an electrical device is calculated and traded off against capital investment cost.

If an electric pump, for example, can deliver a given horsepower (hp) or kilowatt (kW) rating to an industrial application, the *input* energy requirement is determined by dividing the given output by the energy efficiency of the device. The input requirement in hp or kW is then multiplied by the annual hours that the device operates and the unit cost of electric power. You can see that the higher the efficiency of the pump, the lower the annual cost of operating the device is relative to another less-efficient pump.

EXAMPLE 1.11 INVESTING IN ELECTRICAL EFFICIENCY

Two pumps capable of delivering 100 hp to an agricultural application are being evaluated in a present economy study. The selected pump will only be utilized for one year, and it will have no market value at the end of the year. Pertinent data are summarized as follows:

	ABC Pump	XYZ Pump
Purchase price	$2,900	$6,200
Maintenance cost	$170	$510
Efficiency	80%	90%

If electric power costs $0.10 per kWh and the pump will be operated 4,000 hours per year, which pump should be chosen? Recall that 1 hp = 0.746 kW.

Solution

The expense of electric power for the ABC pump is

$$(100\text{ hp}/0.80)(0.746\text{ kW/hp})(\$0.10/\text{kWh})(4{,}000\text{ hours/yr}) = \$37{,}300.$$

For the XYZ Pump, the expense of electric power is

$$(100\text{ hp}/0.90)(0.746\text{ kW/hp})(\$0.10/\text{kWh})(4{,}000\text{ hours/yr}) = \$33{,}156.$$

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Thus, the total cost of owning and operating the ABC pump is $40,370, while the total cost of owning and operating the XYZ pump for one year is $39,866. Consequently, the more energy-efficient XYZ pump should be selected to minimize total cost. Notice the difference in energy expense ($4,144) that results from a 90% efficient pump relative to an 80% efficient pump. This cost reduction more than balances the extra $3,300 in capital investment and $340 in maintenance required for the XYZ pump. ■

CASE STUDY 1.5

The Economics of Daytime Running Lights

The use of Daytime Running Lights (DRLs) has increased in popularity with car designers throughout the world. In some countries, motorists are required to drive with their headlights *on* at all times. U.S. car manufacturers now offer models equipped with daytime running lights. Most people would agree that driving with the headlights on at night is cost effective with respect to extra *fuel* consumption and safety considerations (not to mention required by law!). Cost effective means that benefits outweigh (exceed) the costs. However, some consumers have questioned whether it is cost effective to drive with your headlights on during the day.

In an attempt to provide an answer to this question, let us consider the following suggested data:

75% of driving takes place during the daytime.

2% of fuel consumption is due to accessories (radio, headlights, etc.).

Cost of fuel = $4.00 per gallon.

Average distance traveled per year = 15,000 miles.

Average cost of an accident = $2,800.

Purchase price of headlights = $25.00 per set (2 headlights).

Average time car is in operation per year = 350 hours.

Average life of a headlight = 200 operating hours.

Average fuel consumption = 1 gallon per 30 miles.

Let's analyze the cost effectiveness of driving with headlights on during the day by considering the following set of questions:

- What are the extra costs associated with driving with headlights on during the day?
- What are the benefits associated with driving with headlights on during the day?
- What additional assumptions (if any) are needed to complete the analysis?
- Is it cost effective to drive with headlights on during the day?

Solution

After some reflection on the above questions, you could reasonably contend that the extra costs of driving with headlights on during the day include increased fuel consumption and more frequent headlight replacement. Headlights increase visibility to other drivers on the road. Another possible benefit is the reduced chance of an accident.

Additional assumptions needed to consider during our analysis of the situation include:

1. the percentage of fuel consumption due to headlights alone and
2. how many accidents can be avoided per unit time.

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Selecting the dollar as our common unit of measure, we can compute the extra cost associated with daytime use of headlights and compare it to the expected benefit (also measured in dollars). As previously determined, the extra costs include increased fuel consumption and more frequent headlight replacement.

Let's develop an estimate of the annual fuel cost:

Annual fuel cost = (15,000 mi/yr)(1 gal/30 mi)($4.00/gal) = $2,000/yr.

Assume (worst case) that 2% of fuel consumption is due to normal (night-time) use of headlights.

Fuel cost due to normal use of headlights = ($2,000/yr)(0.02) = $40/yr.

Fuel cost due to continuous use of headlights = (4)($40/yr) = $160/yr.

$$\text{Headlight cost for normal use} = (0.25)\left(\frac{350 \text{ hours/yr}}{200 \text{ hours/set}}\right)\left(\frac{\$25}{\text{set}}\right) = \$10.94/\text{yr}.$$

$$\text{Headlight cost for continuous use} = \left(\frac{350 \text{ hours/yr}}{200 \text{ hours/set}}\right)\left(\frac{\$25}{\text{set}}\right) = \$43.75/\text{yr}.$$

$$\begin{aligned}\text{Total cost associated with daytime use} &= (\$160 - \$40) + (\$43.75 - \$10.94) \\ &= \$152.81/\text{yr}.\end{aligned}$$

If driving with your headlights on during the day results in at least one accident being avoided during the next ($2,800)/($152.81) = 18.3 years, then the continuous use of your headlights is cost effective. Although in the short term, you may be able to contend that the use of DRLs lead to increased fuel and replacement bulb costs, the benefits of increased personal safety and mitigation of possible accident costs in the long run more than offset the apparent short-term cost savings.

1.6 Try Your Skills

The number in parentheses that follows each problem refers to the section from which the problem is taken.

1.A. A company in the process industry produces a chemical compound that is sold to manufacturers for use in the production of certain plastic products. The plant that produces the compound employs approximately 300 people. Develop a list of six different cost elements that would be *fixed* and a similar list of six cost elements that would be *variable*. **(1.1)**

1.B. A farmer estimates that if he harvests his soybean crop now, he will obtain 1,000 bushels, which he can sell at $3.00 per bushel. However, he estimates that this crop will increase by an additional 1,200 bushels of soybeans for each week he delays harvesting, but the price will drop at a rate of 50 cents per bushel per week; in addition, it is likely that he will experience spoilage of approximately 200 bushels per week for each week he delays harvesting. When should he harvest his crop to obtain the largest net cash return, and how much will be received for his crop at that time? **(1.3)**

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SUMMARY

In this chapter, we have discussed cost terminology and concepts important in engineering economy. It is important that the meaning and use of various cost terms and concepts be understood in order to communicate effectively with other engineering and management personnel.

Several general economic concepts were discussed and illustrated. First, the ideas of consumer and producer goods and services, measures of economic growth, and competition were covered. Then, some relationships among costs, price, and volume (demand) were discussed. Included were the concepts of optimal volume and breakeven points. Important economic principles of design optimization were also illustrated in this chapter.

The use of present-economy studies in engineering decision making can provide satisfactory results and save considerable analysis effort. When an adequate engineering economic analysis can be accomplished by considering the various monetary consequences that occur in a short time period (usually one year or less), a present-economy study should be used.

PROBLEMS

The number in parentheses that follows each problem refers to the section from which the problem is taken.

1.1 An experimental composite engine block for an automobile will trim 20 pounds of weight compared with a traditional cast iron engine block. It is estimated that at least $2,500 in life-cycle costs will be saved for every pound of weight reduction over the engine's 8-year expected life. Given that the engine's life is 8 years, what assumptions have been made to arrive at the $2,500 per pound savings? **(1.1)**

1.2 Classify each of the following cost items as mostly fixed or variable: **(1.1)**

Raw materials	Administrative salaries
Direct labor	Payroll taxes
Depreciation	Insurance (building and equipment)
Supplies	Clerical salaries
Utilities	Sales commissions
Property taxes	Rent
Interest on borrowed money	

1.3 A group of enterprising engineering students has developed a process for extracting combustible methane gas from cow manure (don't worry, the exhaust is odorless). With a specially adapted internal combustion engine, the students claim that an automobile can be propelled 15 miles per day from the "cow gas" produced by a single cow. Their experimental car can travel 60 miles per day for an estimated cost of $5 (this is the allocated cost of the methane process equipment—the cow manure is essentially free). **(1.1)**

(a) How many cows would it take to fuel 1,000,000 miles of annual driving by a fleet of cars? What is the annual cost?

(b) How does your answer to Part (a) compare to a gasoline-fueled car averaging 30 miles per gallon when the cost of gasoline is $3.00 per gallon?

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1.4 A municipal solid-waste site for a city must be located at Site A or Site B. After sorting, some of the solid refuse will be transported to an electric power plant where it will be used as fuel. Data for the hauling of refuse from each site to the power plant are shown in Table P1.4.

Table P1.4 Table for Problem 1.4

	Site *A*	Site *B*
Average hauling distance	4 miles	3 miles
Annual rental fee for solid-waste site	\$5,000	\$100,000
Hauling cost	\$1.50/yd^3-mile	\$1.50/yd^3-mile

If the power plant will pay \$8.00 per cubic yard of sorted solid waste delivered to the plant, where should the solid-waste site be located? Use the city's viewpoint and assume that 200,000 cubic yards of refuse will be hauled to the plant for one year only. One site must be selected. **(1.1)**

1.5 Stan Moneymaker presently owns a 10-year-old automobile with low mileage (78,000 miles). The NADA "blue book" value of the car is \$2,500. Unfortunately, the car's transmission just failed, and Stan decided to spend \$1,500 to have it repaired. Now, six months later, Stan has decided to sell the car, and he reasons that his asking price should be \$2,500 + \$1,500 = \$4,000. Comment on the wisdom of Stan's logic. If he receives an offer for \$3,000, should he accept it? Explain your reasoning. **(1.1)**

1.6 You have been invited by friends to fly to Germany for Octoberfest next year. For international travel, you apply for a passport that costs \$97 and is valid for 10 years. After you receive your passport, your travel companions decide to cancel the trip because of "insufficient funds." You decide to also cancel your travel plans because traveling alone is no fun. Is your passport expense a sunk cost or an opportunity cost? Explain your answer. **(1.1)**

1.7 Suppose your company has just discovered \$100,000 worth (this is the original manufacturing cost) of obsolete inventory in an old warehouse. Your boss asks you to evaluate two options: (1) remachine the obsolete parts at a cost of \$30,000 and then hopefully resell them for \$60,000 or (2) scrap them for \$15,000 cash (which is certain) through a secondhand market. What recommendation would you make to your boss? Explain your reasoning. **(1.1)**

1.8 A friend of yours has been thinking about quitting her regular day job and going into business for herself. She currently makes \$60,000 per year as an employee of the Ajax Company, and she anticipates no raise for at least another year. She believes she can make \$200,000 as an independent consultant in six-sigma "black belt" training for large corporations. Her start-up expenses are expected to be \$120,000 over the next year. If she decides to keep her current job, what is the expected opportunity cost of this decision? Attempt to balance the pros and cons of the option that your friend is turning away from. **(1.1)**

1.9 Suppose your wealthy aunt has given you a gift of \$25,000. You have come up with three options for spending (or investing) the money. First, you'd like (but do not need) a new car to brighten up your home and social life. Second, you can invest the money in a high-tech firm's common stock. It is expected to increase in value by 20% per year, but

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this option is fairly risky. Third, you can put the money into a three-year certificate of deposit with a local bank and earn 6% per year. There is little risk in the third option. **(1.1)**

(a) If you decide to purchase the new car, what is the opportunity cost of this choice? Explain your reasoning.

(b) If you invest in the high-tech common stock, what is the opportunity cost of this choice? Explain your reasoning.

1.10 In your own words, describe the life-cycle cost concept. Why is the potential for achieving life-cycle cost savings greatest in the acquisition phase of the life cycle? **(1.1)**

1.11 A large, profitable commercial airline company flies 737-type aircraft, each with a maximum seating capacity of 132 passengers. Company literature states that the economic breakeven point with these aircraft is 62 passengers. **(1.2)**

(a) Draw a conceptual graph to show total revenue and total costs that this company is experiencing.

(b) Identify three types of fixed costs that the airline should carefully examine to lower its breakeven point. Explain your reasoning.

(c) Identify three types of variable costs that can possibly be reduced to lower the breakeven point. Why did you select these cost items?

1.12 A lash adjuster keeps pressure constant on engine valves, thereby increasing fuel efficiency in automobile engines. The relationship between price (p) and monthly demand (D) for lash adjusters made by the Wicks Company is given by this equation: $D = (2{,}000 - p)/0.10$. What is the demand ($\hat{D}$) when total revenue is maximized? What important data are needed if maximum profit is desired? **(1.2)**

1.13 A large company in the communication and publishing industry has quantified the relationship between the price of one of its products and the demand for this product as Price $= 150 - 0.01 \times$ Demand for an annual printing of this particular product. The fixed costs per year (i.e., per printing) $=$ \$50,000 and the variable cost per unit $=$ \$40. What is the maximum profit that can be achieved if the maximum expected demand is 6,000 units per year? What is the unit price at this point of optimal demand? **(1.2)**

1.14 A large wood products company is negotiating a contract to sell plywood overseas. The fixed cost that can be allocated to the production of plywood is \$800,000 per month. The variable cost per thousand board feet is \$155.50. The price charged will be determined by $p = \$600 - (0.5)D$ per 1,000 board feet. **(1.2)**

(a) For this situation, determine the optimal monthly sales volume for this product and calculate the profit (or loss) at the optimal volume.

(b) What is the domain of profitable demand during a month?

1.15 A company produces and sells a consumer product and is able to control the demand for the product by varying the selling price. The approximate relationship between price and demand is

$$p = \$38 + \frac{2{,}700}{D} - \frac{5{,}000}{D^2}, \text{ for } D > 1,$$

where p is the price per unit in dollars and D is the demand per month. The company is seeking to maximize its profit. The fixed cost is \$1,000 per month and the variable cost (c_v) is \$40 per unit. **(1.2)**

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(a) What is the number of units that should be produced and sold each month to maximize profit?

(b) Show that your answer to Part (a) maximizes profit.

1.16 An electric power plant uses solid waste for fuel in the production of electricity. The cost Y in dollars per hour to produce electricity is $Y = 12 + 0.3X + 0.27X^2$, where X is in megawatts. Revenue in dollars per hour from the sale of electricity is $15X - 0.2X^2$. Find the value of X that gives maximum profit. **(1.2)**

1.17 The annual fixed costs for a plant are \$100,000, and the variable costs are \$140,000 at 70% utilization of available capacity, with net sales of \$280,000. What is the breakeven point in units of production if the selling price per unit is \$40? **(1.2)**

1.18 The world price of zinc has increased to the point where "moth balled" zinc mines in east Tennessee have been reopened because of their potential profitability. (a) What is the estimated annual profit for a mine producing 20,000 tons per year (which is at 100% capacity) when zinc sells for \$1.00 per pound? There are variable costs of \$20 million at 100% capacity and fixed costs of \$17 million per year. (b) If production is only 17,000 tons per year, will the mine be profitable? **(1.2)**

1.19 A cell phone company has a fixed cost of \$1,500,000 per month and a variable cost of \$20 per month per subscriber. The company charges \$39.95 per month to its cell phone customers. **(1.2)**

(a) What is the breakeven point for this company?

(b) The company currently has 73,000 subscribers and proposes to raise its monthly fees to \$49.95 to cover add-on features such as text messaging, song downloads, game playing, and video watching. What is the new breakeven point if the variable cost increases to \$25 per customer per month?

(c) If 10,000 subscribers will drop their service because of the monthly fee increase in Part (b), will the company still be profitable?

1.20 A plant operation has fixed costs of \$2,000,000 per year, and its output capacity is 100,000 electrical appliances per year. The variable cost is \$40 per unit, and the product sells for \$90 per unit.

(a) Construct the economic breakeven chart.

(b) Compare annual profit when the plant is operating at 90% of capacity with the plant operation at 100% capacity. Assume that the first 90% of capacity output is sold at \$90 per unit and that the remaining 10% of production is sold at \$70 per unit. **(1.2)**

1.21 A regional airline company estimated four years ago that each pound of aircraft weight adds \$30 per year to its fuel expense. Now the cost of jet fuel has doubled from what it was four years ago. A recent engineering graduate employed by the company has made a recommendation to reduce fuel consumption of an aircraft by installing leather seats as part of a "cabin refurbishment program." The total reduction in weight would be approximately 600 pounds per aircraft. If seats are replaced annually (a worst-case situation), how much can this airline afford to spend on the cabin refurbishments? What nonmonetary advantages might be associated with the refurbishments? Would you support the engineer's recommendation? **(1.1)**

1.22 Jerry Smith's residential air conditioning (AC) system has not been able to keep his house cool enough in 90°F weather. He called his local AC maintenance person, who

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discovered a leak in the evaporator. The cost to recharge the AC unit is \$40 for gas and \$45 for labor, but the leak will continue and perhaps grow worse. The AC person cautioned that this service would have to be repeated each year unless the evaporator is replaced. A new evaporator would run about \$800–\$850.

Jerry reasons that fixing the leak in the evaporator on an annual basis is the way to go. "After all, it will take 10 years of leak repairs to equal the evaporator's replacement cost." Comment on Jerry's logic. What would you do? **(1.1)**

1.23 Ethanol blended with gasoline can be used to power a "flex-fueled" car. One particular blend that is gaining in popularity is E85, which is 85% ethanol and 15% gasoline. E85 is 80% cleaner burning than gasoline alone, and it reduces our dependency on foreign oil. But a flex-fueled car costs \$1,000 more than a conventional gasoline-fueled car. Additionally, E85 fuel gets 10% less miles per gallon than a conventional automobile.

Consider a 100% gasoline-fueled car that averages 30 miles per gallon. The E85-fueled car will average about 27 miles per gallon. If either car will be driven 81,000 miles before being traded in, how much will the E85 fuel have to cost (per gallon) to make the flexfueled car as economically attractive as a conventional gasoline-fueled car? Gasoline costs \$3.89 per gallon. Work this problem without considering the time value of money. **(1.1)**

1.24 The fixed cost for a steam line per meter of pipe is $\$450X + \$50$ per year. The cost for loss of heat from the pipe per meter is $\$4.8/X^{1/2}$ per year. Here, X represents the thickness of insulation in meters, and X is a continuous design variable. **(1.3)**

(a) What is the optimum thickness of the insulation?

(b) How do you know that your answer in Part (a) minimizes total cost per year?

(c) What is the basic trade-off being made in this problem?

1.25 The fixed costs incurred by a small genetics research lab are \$200,000 per year. Variable costs are 60% of the annual revenue. If annual revenue is \$300,000, the annual profit (loss) is most nearly **(1.2)**:

(a) \$66,000 profit

(b) (\$66,000) loss

(c) \$80,000 profit

(d) (\$80,000) loss

1.26 The cost of operating a large ship (C_O) varies as the square of its velocity (v); specifically, $C_O = knv^2$, where n is the trip length in miles and k is a constant of proportionality. It is known that at 12 miles/hour, the *average* cost of operation is \$100 per mile. The owner of the ship wants to minimize the cost of operation, but it must be balanced against the cost of the perishable cargo (C_c), which the customer has set at \$1,500 per hour. At what velocity should the trip be planned to minimize the total cost (C_T), which is the sum of the cost of operating the ship and the cost of perishable cargo? **(1.3)**

1.27 Refer to Example 1.7 on pages 21–22. Which alternative (insulation thickness) would be most economical if the cost of insulation triples? Show all your work. **(1.3)**

1.28 According to the U.S. Department of the Interior, the amount of energy lost because of poorly insulated homes is equivalent to 2 million barrels of oil per day. In 2009, this is more oil than the United States imports from Saudi Arabia each day. If we were to insulate our homes as determined by Example 1.7, we could eliminate our oil dependence on

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Saudi Arabia. If the cost of electricity increases to \$0.15 per kWh and the cost of insulation quadruples, how much insulation should be chosen in Example 1.7? **(1.3)**

1.29 One component of a system's life-cycle cost is the cost of system failure. Failure costs can be reduced by designing a more reliable system. A simplified expression for system life-cycle cost, C, can be written as a function of the system's failure rate:

$$C = \frac{C_I}{\lambda} + C_R \cdot \lambda \cdot t.$$

Here, C_I = investment cost (\$ per hour per failure),
C_R = system repair cost,
λ = system failure rate (failures/operating hour),
t = operating hours.

(a) Assume that C_I, C_R, and t are constants. Derive an expression for λ, say λ^*, that optimizes C. **(1.3)**

(b) Does the equation in Part (a) correspond to a maximum or minimum value of C? Show all work to support your answer.

(c) What trade-off is being made in this problem?

1.30 Stan Moneymaker has been shopping for a new car. He is interested in a certain 4-cylinder sedan that averages 28 miles per gallon. But the salesperson tried to persuade Stan that the 6-cylinder model of the same automobile only costs \$2,500 more and is really a "more sporty and responsive" vehicle. Stan is impressed with the zip of the 6-cylinder car and reasons that \$2,500 is not too much to pay for the extra power.

How much extra is Stan really paying if the 6-cylinder car averages 22 miles per gallon? Assume that Stan will drive either automobile 100,000 miles, gasoline will average \$4.00 per gallon, and maintenance is roughly the same for both cars. State other assumptions you think are appropriate. **(1.4)**

1.31 A producer of synthetic motor oil for automobiles and light trucks has made the following statement: "One quart of Dynolube added to your next oil change will increase fuel mileage by one percent. This one-time additive will improve your fuel mileage over 50,000 miles of driving." **(1.4)**

(a) Assume the company's claim is correct. How much money will be saved by adding one quart of Dynolube if gasoline costs \$4.00 per gallon and your car averages 20 miles per gallon without the Dynolube?

(b) If a quart of Dynolube sells for \$19.95, would you use this product in your automobile?

1.32 An automobile dealership offers to fill the four tires of your new car with 100% nitrogen for a cost of \$20. The dealership claims that nitrogen-filled tires run cooler than those filled with compressed air, and they advertise that nitrogen extends tire mileage (life) by 25%. If new tires cost \$50 each and are guaranteed to get 50,000 miles (filled with air) before they require replacement, is the dealership's offer a good deal? **(1.4)**

1.33 In the design of an automobile radiator, an engineer has a choice of using either a brass–copper alloy casting or a plastic molding. Either material provides the same service. However, the brass–copper alloy casting weighs 25 pounds, compared with 20 pounds for the plastic molding. Every pound of extra weight in the automobile has been assigned a penalty of \$6 to account for increased fuel consumption during the life

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cycle of the car. The brass–copper alloy casting costs $3.35 per pound, whereas the plastic molding costs $7.40 per pound. Machining costs per casting are $6.00 for the brass–copper alloy. Which material should the engineer select, and what is the difference in unit costs? **(1.4)**

1.34 Rework Example 1.9 for the case where the capacity of each machine is further reduced by 25% because of machine failures, materials shortages, and operator errors. In this situation, 30,000 units of good (nondefective) product must be manufactured during the next three months. Assume one shift per day and five work days per week. **(1.4)**

(a) Can the order be delivered on time?

(b) If only one machine (*A* or *B*) can be used in Part (a), which one should it be?

1.35 Two alternative designs are under consideration for a tapered fastening pin. The fastening pins are sold for $0.70 each. Either design will serve equally well and will involve the same material and manufacturing cost except for the lathe and drill operations. Design A will require 12 hours of lathe time and 5 hours of drill time per 1,000 units. Design B will require 7 hours of lathe time and 8 hours of drill time per 1,000 units. The variable operating cost of the lathe, including labor, is $18.60 per hour. The variable operating cost of the drill, including labor, is $16.90 per hour. Finally, there is a sunk cost of $5,000 for Design A and $9,000 for Design B due to obsolete tooling. **(1.4)**

(a) Which design should be adopted if 125,000 units are sold each year?

(b) What is the annual saving over the other design?

1.36 A bicycle component manufacturer produces hubs for bike wheels. Two processes are possible for manufacturing, and the parameters of each process are as follows:

	Process 1	**Process 2**
Production rate	35 parts/hour	15 parts/hour
Daily production time	4 hours/day	7 hours/day
Percent of parts rejected based on visual inspection	20%	9%

Assume that the daily demand for hubs allows all defect-free hubs to be sold. Additionally, tested or rejected hubs cannot be sold.

Find the process that maximizes profit per day if each part is made from $4 worth of material and can be sold for $30. Both processes are fully automated, and variable overhead cost is charged at the rate of $40 per hour. **(1.4)**

1.37 The speed of your automobile has a huge effect on fuel consumption. Traveling at 65 miles per hour (mph) instead of 55 mph can consume almost 20% more fuel. As a general rule, for every mile per hour over 55, you lose 2% in fuel economy. For example, if your automobile gets 30 miles per gallon at 55 mph, the fuel consumption is 21 miles per gallon at 70 mph.

If you take a 400-mile trip and your average speed is 80 mph rather than the posted speed limit of 70 mph, what is the extra cost of fuel if gasoline costs $4.00 per gallon? Your car gets 30 miles per gallon (mpg) at 60 mph. **(1.4)**

1.38 Suppose that four 85-octane gasoline pumps and three 89-octane gasoline pumps provide as much profit at a local convenience store in five days as three 85-octane pumps and five 89-octane pumps provide in four days. Which gasoline pump produces greater profit for the store? **(1.4)**

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1.39 Refer to Example 1-11. Would the pump recommendation change if the cost of electricity was \$0.15 per kWh? What if the pumps were only required for 3,000 operating hours? **(1.4)**

1.40 A company is analyzing a make-versus-purchase situation for a component used in several products, and the engineering department has developed these data:

Option *A*: Purchase 10,000 items per year at a fixed price of \$8.50 per item. The cost of placing the order is negligible according to the present cost accounting procedure.

Option *B*: Manufacture 10,000 items per year, using available capacity in the factory. Cost estimates are direct materials = \$5.00 per item and direct labor = \$1.50 per item. Manufacturing overhead is allocated at 200% of direct labor (= \$3.00 per item).

Based on these data, should the item be purchased or manufactured? **(1.4)**

1.41 A national car rental agency asks, "Do you want to bring back the economy-class car full of gas or with an empty tank? If we fill up the tank for you, we'll charge you \$3.50 per gallon, which is 50 cents less than the local price for gasoline." Which choice should you make? State your assumptions. **(1.4)**

1.42 One method for developing a mine containing an estimated 100,000 tons of ore will result in the recovery of 62% of the available ore deposit and will cost \$23 per ton of material removed. A second method of development will recover only 50% of the ore deposit, but it will cost only \$15 per ton of material removed. Subsequent processing of the removed ore recovers 300 pounds of metal from each ton of processed ore and costs \$40 per ton of ore processed. The recovered metal can be sold for \$0.80 per pound. Which method for developing the mine should be used if your objective is to maximize total profit from the mine? **(1.4)**

1.43 Ocean water contains 0.9 ounces of gold per ton. Method A costs \$550 per ton of water processed and will recover 90% of the metal. Method B costs \$400 per ton of water processed and will recover 60% of the metal. The two methods require the same capital investment and are capable of producing the same amount of gold each day. If the extracted gold can be sold for \$1,750 per ounce, which method should be recommended? The supply of ocean water is essentially unlimited. Hint: Work this problem on the basis of profit per ounce of gold extracted. **(1.4)**

1.44 Which of the following statements are true and which are false? **(all sections)**

(a) Working capital is a variable cost.

(b) The greatest potential for cost savings occurs in the operation phase of the life cycle.

(c) If the capacity of an operation is significantly changed (e.g., a manufacturing plant), the fixed costs will also change.

(d) A noncash cost is a cash flow.

(e) Goods and services have utility because they have the power to satisfy human wants and needs.

(f) The demand for necessities is more inelastic than the demand for luxuries.

(g) Indirect costs can normally be allocated to a specific output or work activity.

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(h) Present economy studies are often done when the time value of money is not a significant factor in the situation.

(i) Overhead costs normally include all costs that are not direct costs.

(j) Optimal volume (demand) occurs when total costs equal total revenues.

(k) Standard costs per unit of output are established in advance of actual production or service delivery.

(l) A related sunk cost will normally affect the prospective cash flows associated with a situation.

(m) The life cycle needs to be defined within the context of the specific situation.

(n) The greatest commitment of costs occurs in the acquisition phase of the life cycle.

(o) High breakeven points in capital intensive industries are desirable.

(p) The fixed return on borrowed capital (i.e., interest) is more risky than profits paid to equity investors (i.e., stockholders) in a firm.

(q) There is no D^* for this Scenario 1 situation: $p = 40 - 0.2D$ and $C_T = \$100 + \$50D$.

(r) Most decisions are based on differences that are perceived to exist among alternatives.

(s) A nonrefundable cash outlay (e.g., money spent on a passport) is an example of an opportunity cost.

1.45 A hot water leak in one of the faucets of your apartment can be very wasteful. A continuous leak of one quart per hour (a "slow" leak) at 155°F causes a loss of 1.75 million Btu per year. Suppose your water is heated with electricity. **(1.3)**

(a) How many pounds of coal delivered to your electric utility does this leak equate to if one pound of coal contains 12,000 Btu and the boiler combustion process and water distribution system have an overall efficiency of 30%?

(b) If a pound of coal produces 1.83 pounds of CO_2 during the combustion process, how much extra carbon dioxide does the leaky faucet produce in a year?

1.46 *Extended Learning Exercise* The student chapter of the American Society of Mechanical Engineers is planning a six-day trip to the national conference in Albany, NY. For transportation, the group will rent a car from either the State Tech Motor Pool or a local car dealer. The Motor Pool charges \$0.36 per mile, has no daily fee, and pays for the gas. The local car dealer charges \$30 per day and \$0.20 per mile, but the group must pay for the gas. The car's fuel rating is 20 miles per gallon, and the price of gas is estimated to be \$2.00 per gallon. **(1.2)**

(a) At what point, in miles, is the cost of both options equal?

(b) The car dealer has offered a special student discount and will give the students 100 free miles per day. What is the new breakeven point?

(c) Suppose now that the Motor Pool reduces its all inclusive rate to \$0.34 per mile and that the car dealer increases the rate to \$30 per day and \$0.28 per mile. In this case, the car dealer wants to encourage student business, so he offers 900 free miles for

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the entire six day trip. He claims that if more than 750 miles are driven, students will come out ahead with one of his rental cars. If the students anticipate driving 2,000 miles (total), from whom should they rent a car? Is the car dealer's claim entirely correct?

1.47 *Web Exercise* Home heating accounts for approximately one-third of energy consumption in a typical U.S. household. Despite soaring prices of oil, coal, and natural gas, one can make his/her winter heating bill noninflationary by installing an ultraconvenient corn burning stove that costs in the neighborhood of $2,400. That's right—a small radiant-heating stove that burns corn and adds practically nothing to global warming or air pollution can be obtained through www.magnumfireplace.com. Its estimated annual savings per household in fuel is $300 in a regular U.S. farming community.

Conduct research on this means of home heating by accessing the above Web site. Do the annual savings you determine in your locale for a 2,000-square foot ranch style house more than offset the cost of installing and maintaining a corn-burning stove? What other factors besides dollars might influence your decision to use corn for your home heating requirements? Be specific with your suggestions. **(1.4)**

SPREADSHEET EXERCISES

1.48 Refer to Example 1.4. If your focus was on reducing expenses, would it be better to reduce the fixed cost (B1) or variable cost (B2) component? What is the effect of a ± 10% change in both of these factors? **(1.2)**

1.49 Refer to Example 1.7. If the average inside temperature of this house in Virginia is increased from 65°F to 72°F, what is the most economical insulation amount? Assume that 100,000,000 Btu are lost with no insulation when the thermostat is set at 65°F. The cost of electricity is now $0.086 per kWh. In addition, the cost of insulation has increased by 50%. Develop a spreadsheet to solve this problem. **(1.3)**

CASE STUDY EXERCISES

1.50 What are the key factors in this analysis, and how would your decision change if the assumed value of these factors changes? For example, what impact does rising fuel costs have on this analysis? Or, what if studies have shown that drivers can expect to avoid at least one accident every 10 years due to daytime use of headlights? **(1.5)**

1.51 Visit your local car dealer (either in person or online) to determine the cost of the daytime running lights option. How many accidents (per unit time) would have to be avoided for this option to be cost effective? **(1.5)**

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FE PRACTICE PROBLEMS

A company has determined that the price and the monthly demand of one of its products are related by the equation

$D = \sqrt{(400) - p)},$

where p is the price per unit in dollars and D is the monthly demand. The associated fixed costs are \$1,125/month, and the variable costs are \$100/unit. Use this information to answer Problems 1.52 and 1.53. Select the closest answer. **(1.2)**

1.52 What is the optimal number of units that should be produced and sold each month?

(a) 10 units

(b) 15 units

(c) 20 units

(d) 25 units

1.53 Which of the following values of D represents the breakeven point?

(a) 10 units

(b) 15 units

(c) 20 units

(d) 25 units

A manufacturing company leases a building for \$100,000 per year for its manufacturing facilities. In addition, the machinery in this building is being paid for in installments of \$20,000 per year. Each unit of the product produced costs \$15 in labor and \$10 in materials. The product can be sold for \$40. Use this information to answer Problems 1.54 through 1.56. Select the closest answer. **(1.2)**

1.54 How many units per year must be sold for the company to breakeven?

(a) 4,800

(b) 3,000

(c) 8,000

(d) 6,667

(e) 4,000

1.55 If 10,000 units per year are sold, what is the annual profit?

(a) \$280,000

(b) \$50,000

(c) \$150,000

(d) −\$50,000

(e) \$30,000

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1.56 If the selling price is lowered to \$35 per unit, how many units must be sold each year for the company to earn a profit of \$60,000 per year?

(a) 12,000

(b) 10,000

(c) 16,000

(d) 18,000

(e) 5,143

1.57 The fixed costs incurred by a small genetics research lab are \$200,000 per year. Variable costs are 60% of the annual revenue. If annual revenue is \$300,000, the annual profit/loss is most nearly which answer below? **(1.2)**

(a) \$66,000 profit

(b) \$66,000 loss

(c) \$80,000 profit

(d) \$80,000 loss

1.58 A manufacturer makes 7,900,000 memory chips per year. Each chip takes 0.4 minutes of direct labor at the rate of \$8 per hour. The overhead costs are estimated at \$11 per direct labor hour. A new process will reduce the unit production time by 0.01 minutes. If the overhead cost will be reduced by \$5.50 for each hour by which total direct hours are reduced, what is the maximum amount you will pay for the new process? Assume that the new process must pay for itself by the end of the first year. **(1.4)**

(a) \$25,017

(b) \$1,066,500

(c) \$10,533

(d) \$17,775

(e) \$711,000

Appendix 1A Accounting Fundamentals

Accounting is often referred to as the language of business. Engineers should make serious efforts to learn about a firm's accounting practice so that they can better communicate with top management. This section contains an extremely brief and simplified exposition of the elements of financial accounting in recording and summarizing transactions affecting the finances of the enterprise. These fundamentals apply to any entity (such as an individual or a corporation) called here a *firm*.

1A.1 The Accounting Equation

All accounting is based on the *fundamental accounting equation*, which is

$$\text{Assets} = \text{liabilities} + \text{owners' equity}, \tag{1A.1}$$

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where *assets* are those things of monetary value that the firm possesses, *liabilities* are those things of monetary value that the firm owes, and *owners' equity* is the worth of what the firm owes to its stockholders (also referred to as *equities*, *net worth*, etc.). For example, typical accounts in each term of Equation (1A.1) are as follows:

Asset Accounts =	**Liability Accounts +**	**Owner's Equity Accounts**
Cash	Short-term debt	Capital stock
Receivables	Payables	Retained earnings (income retained in the firm)
Inventories	Long-term debt	
Equipment		
Buildings		
Land		

The fundamental accounting equation defines the format of the *balance sheet*, which is one of the two most common accounting statements and which shows the financial position of the firm at any given point in time.

Another important, and rather obvious, accounting relationship is

$$\text{Revenues} - \text{expenses} = \text{profit (or loss)}. \tag{1A.2}$$

This relationship defines the format of the *income statement* (also commonly known as a *profit-and-loss statement*), which summarizes the revenue and expense results of operations *over a period of time*. Equation (1A.1) can be expanded to take into account profit as defined in Equation (1A.2):

$$\text{Assets} = \text{liabilities} + (\text{beginning owners' equity} + \text{revenue} - \text{expenses}). \tag{1A.3}$$

Profit is the increase in money value (not to be confused with cash) that results from a firm's operations and is available for distribution to stockholders. It therefore represents the return on owners' invested capital.

A useful analogy is that a balance sheet is like a snapshot of the firm at an instant in time, whereas an income statement is a summarized moving picture of the firm over an interval of time. It is also useful to note that revenue serves to increase owners' interests in a firm, but an expense serves to decrease the owners' equity amount for a firm.

To illustrate the workings of accounts in reflecting the decisions and actions of a firm, suppose that an individual decides to undertake an investment opportunity and the following sequence of events occurs over a period of one year:

1. Organize XYZ firm and invest \$3,000 cash as capital.
2. Purchase equipment for a total cost of \$2,000 by paying cash.
3. Borrow \$1,500 through a note to the bank.
4. Manufacture year's supply of inventory through the following:
   (a) Pay \$1,200 cash for labor.
   (b) Incur \$400 accounts payable for material.
   (c) Recognize the partial loss in value (depreciation) of the equipment amounting to \$500.

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5. Sell on credit all goods produced for year, 1,000 units at \$3 each. Recognize that the accounting cost of these goods is \$2,100, resulting in an increase in equity (through profits) of \$900.
6. Collect \$2,200 of accounts receivable.
7. Pay \$300 of accounts payable and \$1,000 of bank note.

A simplified version of the accounting entries recording the same information in a format that reflects the effects on the fundamental accounting equation (with a "+" denoting an increase and a "−" denoting a decrease) is shown in Figure 1A.1. A summary of the results is shown in Figure 1A.2.

It should be noted that the profit for a period serves to increase the value of the owners' equity in the firm by that amount. Also, it is significant that the net cash flow from operation of \$700 (= \$2,200 − \$1,200 − \$300) is not the same as profit. This amount was recognized in transaction 4(c), in which capital consumption (depreciation) for equipment of \$500 was declared. Depreciation serves to convert part of an asset into an expense, which is then reflected in a firm's profits, as seen in Equation (1A.2). Thus, the profit was \$900, or \$200 more than the net cash flow. For our purposes, revenue is recognized when it is earned, and expenses are recognized when they are incurred.

One important and potentially misleading indicator of after-the-fact financial performance that can be obtained from Figure 1A.2 is "annual rate of return." If the invested capital is taken to be the owners' (equity) investment, the annual rate of return at the end of this particular year is \$900/\$3,900 = 23%.

Financial statements are usually most meaningful if figures are shown for two or more years (or other reporting periods such as quarters or months) or for two or more individuals or firms. Such comparative figures can be used to reflect trends or financial indications that are useful in enabling investors and management to determine the effectiveness of investments *after* they have been made.

1A.2 Cost Accounting

Cost accounting, or management accounting, is a phase of accounting that is of particular importance in engineering economic analysis because it is concerned principally with decision making and control in a firm. Consequently, cost accounting is the source of much of the cost data needed in making engineering economy studies. Modern cost accounting may satisfy any or all of the following objectives:

1. Determination of the actual cost of products or services
2. Provision of a rational basis for pricing goods or services
3. Provision of a means for allocating and controlling expenditures
4. Provision of information on which operating decisions may be based and by means of which operating decisions may be evaluated.

Although the basic objectives of cost accounting are simple, the exact determination of costs usually is not. As a result, some of the procedures used are arbitrary devices that make it possible to obtain reasonably accurate answers for most cases but that may contain a considerable percentage of error in other cases, particularly with respect to the actual cash flow involved.

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Figure 1A.1 Accounting Effects of Transactions: XYZ Firm

	Account	Transaction 1	2	3	4	5	6	7	Balances at End of Year	
Assets	Cash	+$3,000	−$2,000	+$1,500	−$1,200		+$2,200	−$1,300	+$2,200	$4,500
	Accounts receivable					+$3,000	−2,200		+800	
	Inventory				+2,100	−2,100			0	
	Equipment		+2,000		−500				+1,500	
equals										
Liabilities	Accounts payable				+400			−300	+100	$4,500
	Bank note			+1,500				−1,000	+500	
plus										
Owners' equity	Equity	+3,000				+900			+3,900	

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Figure 1A.2 Balance Sheet and Income Statement Resulting from Transactions Shown in Figure 1A.1

XYZ Firm Balance Sheet as of December 31, 2015			
Assets		**Liabilities and Owners' Equity**	
Cash	$2,200	Bank note	$500
Accounts receivable	800	Accounts payable	100
Equipment	1,500	Equity	3,900
Total	$4,500	Total	$4,500

XYZ Firm Income Statement for Year Ending December 31, 2015			
			Cash Flow
Operating revenues (Sales)		$3,000	$2,200
Operating costs (Inventory depleted)			
Labor	$1,200		−1,200
Material	400		−300
Depreciation	500		0
		$2,100	
Net income (Profits)		$900	$700

1A.3 Cost Accounting Example

This relatively simple example involves a job-order system in which costs are assigned to work by job number. Schematically, this process is illustrated in the following diagram:

Costs are assigned to jobs in the following manner:

1. Raw materials attach to jobs via material requisitions.
2. Direct labor attaches to jobs via direct labor tickets.
3. Overhead cannot be attached to jobs directly but must have an allocation procedure that relates it to one of the resource factors, such as direct labor, which is already accumulated by the job.

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Consider how an order for 100 tennis rackets accumulates costs at the Bowling Sporting Goods Company:

Job #161	100 tennis rackets
Labor rate	\$7 per hour
Leather	50 yards at \$2 per yard
Gut	300 yards at \$0.50 per yard
Graphite	180 pounds at \$3 per pound
Labor hours for the job	200 hours
Total annual factory overhead costs	\$600,000
Total annual direct labor hours	200,000 hours

The three major costs are now attached to the job. Direct labor and material expenses are straightforward:

Job #161			
Direct labor	200 × \$7	=	\$1,400
Direct material	leather: 50 × \$2	=	100
	gut: 300 × \$0.5	=	150
	graphite: 180 × \$3	=	540
Prime costs (direct labor + direct materials)			\$2,190

Notice that this cost is not the total cost. We must somehow find a way to attach (allocate) factory costs that cannot be directly identified to the job but are nevertheless involved in producing the 100 rackets. Costs such as the power to run the graphite molding machine, the depreciation on this machine, the depreciation of the factory building, and the supervisor's salary constitute overhead for this company. These overhead costs are part of the cost structure of the 100 rackets but cannot be directly traced to the job. For instance, do we really know how much machine obsolescence is attributable to the 100 rackets? Probably not. Therefore, we must allocate these overhead costs to the 100 rackets by using the overhead rate determined as follows:

$$\text{Overhead rate} = \frac{\$600{,}000}{200{,}000} = \$3 \text{ per direct labor hour.}$$

This means that \$600 (\$3 × 200) of the total annual overhead cost of \$600,000 would be allocated to Job #161. Thus, the total cost of Job #161 would be as follows:

Direct labor	\$1,400
Direct material	790
Factory overhead	600
	\$2,790

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The cost of manufacturing each racket is thus \$27.90. If selling expenses and administrative expenses are allocated as 40% of the cost of goods sold, the total expense of a tennis racket becomes 1.4(\$27.90) = \$39.06.

Appendix 1A Problems

1A.1* Jill Smith opens an apartment-locator business near a college campus. She is the sole owner of the proprietorship, which she names Campus Apartment Locators. During the first month of operations, July 2015, she engages in the following transactions:

(a) Smith invests \$35,000 of personal funds to start the business.

(b) She purchases on account office supplies costing \$350.

(c) Smith pays cash of \$30,000 to acquire a lot next to the campus. She intends to use the land as a future building site for her business office.

(d) Smith locates apartments for clients and receives cash of \$1,900.

(e) She pays \$100 on the account payable she created in transaction (b).

(f) She pays \$2,000 of personal funds for a vacation.

(g) She pays cash expenses for office rent, \$400, and utilities, \$100.

(h) The business sells office supplies to another business for its cost of \$150.

(i) Smith withdraws cash of \$1,200 for personal use.

Required

(a) Analyze the preceding transactions in terms of their effects on the accounting equation of Campus Apartment Locators. Use Figure 1A.1 as a guide.

(b) Prepare the income statement and balance sheet of the business after recording the transactions. Use Figure 1A.2 as a guide.

1A.2† Daniel Peavy owns and operates an architectural firm called Peavy Design. Table P1A.2 summarizes the financial position of his business on April 30, 2015.

During May 2010, the following events occurred:

(a) Peavy received \$12,000 as a gift and deposited the cash in the business bank account.

(b) He paid off the beginning balance of accounts payable.

(c) He performed services for a client and received cash of \$1,100.

(d) He collected cash from a customer on account, \$750.

(e) Peavy purchased supplies on account, \$720.

* Adapted from C. T. Horngren, W. T. Harrison Jr., and L. S. Bamber, *Accounting,* 6th ed. (Upper Saddle River, NJ: Prentice Hall, 2005), p. 23 and p. 32. Reprinted by permission of the publisher.
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Table P1A.2 Data for Problem 1A.2

Assets				=	Liabilities	+	Owners' Equity
Cash +	Accounts Receivable +	Supplies +	Land	=	Accounts Payable	+	Daniel Peavy, Capital
Bal. 1,720	3,240		24,100		5,400		23,660

Previous Page

(f) He consulted on the interior design of a major office building and billed the client for services rendered, $5,000.

(g) He invested personal cash of $1,700 in the business.

(h) He recorded the following business expenses for the month:

1. Paid office rent, $1,200.
2. Paid advertising, $660.

(i) Peavy sold supplies to another interior designer for $80 cash, which was the cost of the supplies.

(j) He withdrew cash of $4,000 for personal use.

Required

(a) Analyze the effects of the preceding transactions on the accounting equation of Peavy Design. Adapt the format of Figure 1A.1.

(b) Prepare the income statement of Peavy Design for the month ended May 31, 2015. List expenses in decreasing order by amount.

(c) Prepare the balance sheet of Peavy Design at May 31, 2015.

1A.3.* Lubbock Engineering Consultants is a firm of professional civil engineers. It mostly does surveying jobs for the heavy construction industry throughout Texas. The firm obtains its jobs by giving fixed-price quotations, so profitability depends on the ability to predict the time required for the various subtasks on the job. (This situation is similar to that in the auditing profession, where times are budgeted for such audit steps as reconciling cash and confirming accounts receivable.)

A client may be served by various professional staff, who hold positions in the hierarchy from partners to managers to senior engineers to assistants. In addition, there are secretaries and other employees.

Lubbock Engineering has the following budget for 2016:

Compensation of professional staff	$3,600,000
Other costs	1,449,000
Total budgeted costs	$5,049,000

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Each professional staff member must submit a weekly time report, which is used for charging hours to a client job-order record. The time report has seven columns, one for each day of the week. Its rows are as follows:

- Chargeable hours

  Client 156

  Client 183

  Etc.

- Nonchargeable hours

  Attending seminar on new equipment

  Unassigned time

  Etc.

In turn, these time reports are used for charging hours and costs to the client job-order records. The managing partner regards these job records as absolutely essential for measuring the profitability of various jobs and for providing an "experience base for improving predictions on future jobs."

(a) The firm applies overhead to jobs at a budgeted percentage of the professional compensation charged directly to the job ("direct labor"). For all categories of professional personnel, chargeable hours average 85% of available hours. Nonchargeable hours are regarded as additional overhead. What is the overhead rate as a percentage of "direct labor," the chargeable professional compensation cost?

(b) A senior engineer works 48 weeks per year, 40 hours per week. His compensation is \$60,000. He has worked on two jobs during the past week, devoting 10 hours to Job #156 and 30 hours to Job #183. How much cost should be charged to Job #156 because of his work there?

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CHAPTER 2

The objective of Chapter 2 is to present an assortment of methods for estimating important factors in an engineering economy study.

Cost-Estimation Techniques

Taken from *Engineering Economy*, Sixteenth Edition, by William G. Sullivan, Elin M. Wicks, and C. Patrick Koelling.

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THE HIGH COST OF ENVIRONMENTAL CLEANUP

CERCLA

In December of 1980, Congress enacted the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), also known as the "Superfund." This law created broad federal authority to respond to releases or threatened releases of hazardous substances. CERCLA provides liability for corporations responsible for closed and abandoned hazardous waste sites. Regrettably, affected parties soon found that the cost of neglecting hazardous waste sites was extremely high. But how high?

Prior to 1980, many corporations had not set aside money for cleaning up behind themselves as their business models evolved and changed. For example, hazardous chemicals were left behind in tanks and piping, and most of the facilities had used asbestos for insulation. Transformers contained oil that was often contaminated with PCBs. As plant and equipment deteriorated, these types of hazardous substances migrated into the environment and contaminated the land and the ground water. The cost of cleanup became astronomical.

In addition to the possible impact on human health and the environment, it is abundantly clear that the cost of doing business must include surveillance, maintenance, and safe closure of contaminated facilities. In the long run, it saves money to act early to responsibly comply with CERCLA. In Chapter 2, you will learn about many techniques that are useful for estimating the costs associated with environmental cleanup.

Decisions, both great and small, depend in part on estimates. "Looking down the barrel" need not be an embarrassment for the engineer if newer techniques, professional staffing, and a greater awareness are assigned to the engineering cost estimating function.

—Phillip F. Ostwald (1992)

2.1 Introduction

In this chapter, we address Step 3 of the seven steps of the engineering economic analysis procedure, development of the outcomes and cash flows for each alternative. Because engineering economy studies deal with outcomes that extend into the future, estimating the future cash flows for feasible alternatives is a critical step in the analysis procedure. Often, the most difficult, expensive, and time-consuming part of an engineering economy study is the estimation of costs, revenues, useful lives, residual values, and other data pertaining to the alternatives being analyzed. A decision based on the analysis is economically sound only to the extent that these cost and revenue estimates are representative of what subsequently will occur. In this chapter, we introduce the role of *cost estimating* in engineering practice. Definitions and examples of important cost concepts were provided in Chapter 1.

Whenever an engineering economic analysis is performed for a major capital investment, the cost-estimating effort for that analysis should be an integral part of a comprehensive planning and design process requiring the active participation of not only engineering designers but also personnel from marketing, manufacturing, finance, and top management. Results of cost estimating are used for a variety of purposes, including the following:

1. Providing information used in setting a selling price for quoting, bidding, or evaluating contracts
2. Determining whether a proposed product can be made and distributed at a profit (for simplicity, price = cost + profit)

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3. Evaluating how much capital can be justified for process changes or other improvements
4. Establishing benchmarks for productivity improvement programs

There are two fundamental approaches to cost estimating: the "top-down" approach and the "bottom-up" approach. The top-down approach basically uses historical data from similar engineering projects to estimate the costs, revenues, and other data for the current project by modifying these data for changes in inflation or deflation, activity level, weight, energy consumption, size, and other factors. This approach is best used early in the estimating process when alternatives are still being developed and refined.

The bottom-up approach is a more detailed method of cost estimating. This method breaks down a project into small, manageable units and estimates their economic consequences. These smaller unit costs are added together with other types of costs to obtain an overall cost estimate. This approach usually works best when the detail concerning the desired output (a product or a service) has been defined and clarified.

EXAMPLE 2.1 ESTIMATING THE COST OF A COLLEGE DEGREE

A simple example of cost estimating is to forecast the expense of getting a Bachelor of Science (B.S.) from the university you are attending. In our solution, we outline the two basic approaches just discussed for estimating these costs.

Solution

A top-down approach would take the published cost of a four-year degree at the same (or a similar) university and adjust it for inflation and extraordinary items that an incoming student might encounter, such as fraternity/sorority membership, scholarships, and tutoring. For example, suppose that the published cost of attending your university is \$15,750 for the current year. This figure is anticipated to increase at the rate of 6% per year and includes full-time tuition and fees, university housing, and a weekly meal plan. Not included are the costs of books, supplies, and other personal expenses. For our initial estimate, these "other" expenses are assumed to remain constant at \$5,000 per year.

Year	Tuition, Fees, Room and Board	"Other" Expenses	Total Estimated Cost for Year
1	\$15,750 × 1.06 = \$16,695	\$5,000	\$21,695
2	16,695 × 1.06 = 17,697	5,000	22,697
3	17,697 × 1.06 = 18,759	5,000	23,759
4	18,759 × 1.06 = 19,885	5,000	24,885
		Grand Total	\$93,036

The total estimated cost for four years can now be computed. We simply need to adjust the published cost for inflation each year and add in the cost of "other" expenses.

In contrast with the top-down approach, a bottom-up approach to the same cost estimate would be to first break down anticipated expenses into the typical categories shown in Figure 2.1 for each of the four years at the university. Tuition and fees can be estimated fairly accurately in each year, as can books and supplies. For example, suppose

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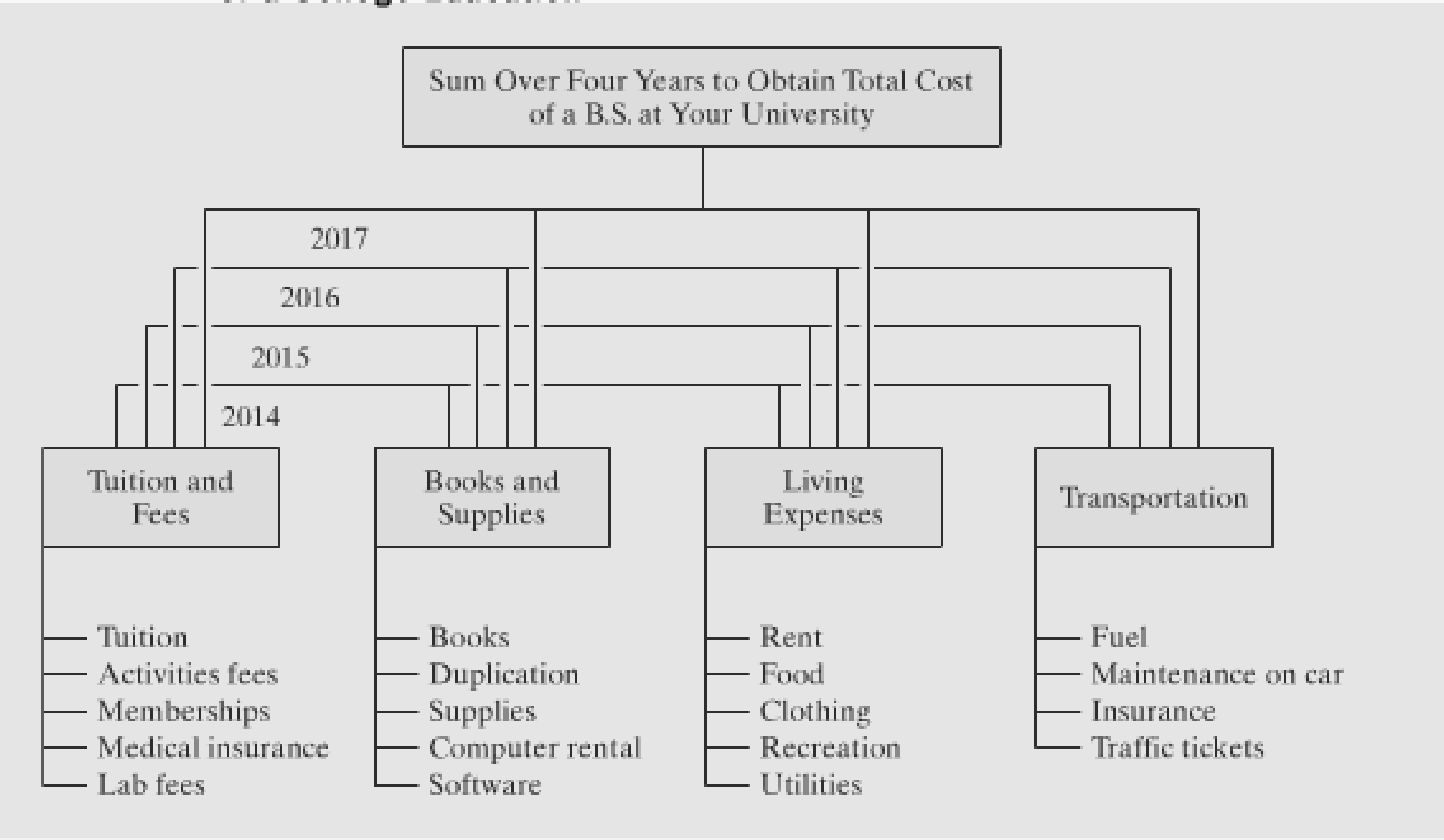
Figure 2.1 Bottom-Up Approach to Determining the Cost of a College Education



that the average cost of a college textbook is \$100. You can estimate your annual textbook cost by simply multiplying the average cost per book by the number of courses you plan to take. Assume that you plan on taking five courses each semester during the first year. Your estimated textbook costs would be

$$\left(\frac{5 \text{ courses}}{\text{semester}}\right)(2 \text{ semesters})\left(\frac{1 \text{ book}}{\text{course}}\right)\left(\frac{\$100}{\text{book}}\right) = \$1{,}000.$$

The other two categories, living expenses and transportation, are probably more dependent on your lifestyle. For example, whether you own and operate an automobile and live in a "high-end" apartment off-campus can dramatically affect the estimated expenses during your college years. ■

2.2 An Integrated Approach

An integrated approach to developing the net cash flows for feasible project alternatives is shown in Figure 2.2. This integrated approach includes three basic components:

1. ***Work breakdown structure (WBS)*** This is a technique for explicitly defining, at successive levels of detail, the work elements of a project and their interrelationships (sometimes called a *work element structure*).
2. ***Cost and revenue structure (classification)*** Delineation of the cost and revenue categories and elements is made for estimates of cash flows at each level of the WBS.
3. ***Estimating techniques (models)*** Selected mathematical models are used to estimate the future costs and revenues during the analysis period.

These three basic components, together with integrating procedural steps, provide an organized approach for developing the cash flows for the alternatives.

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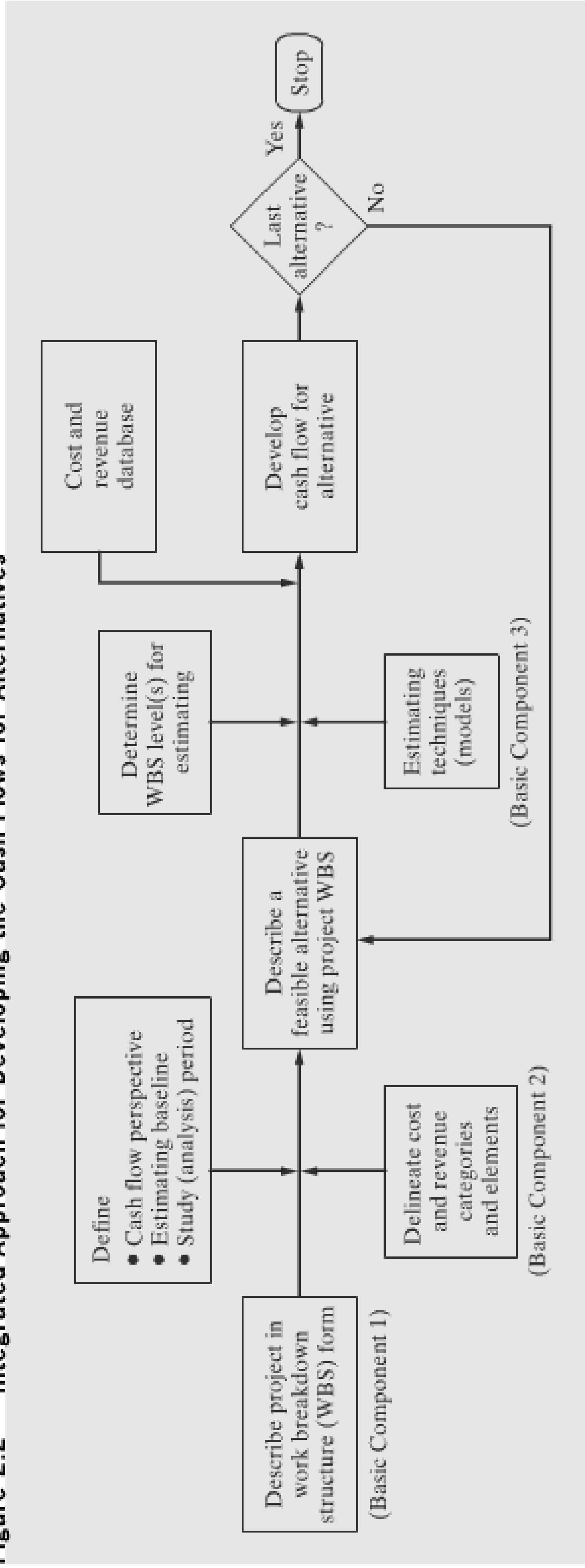
Figure 2.2 Integrated Approach for Developing the Cash Flows for Alternatives



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As shown in Figure 2.2, the integrated approach begins with a description of the project in terms of a WBS. WBS is used to describe the project and each alternative's unique characteristics in terms of design, labor, material requirements, and so on. Then these variations in design, resource requirements, and other characteristics are reflected in the estimated future costs and revenues (net cash flow) for that alternative.

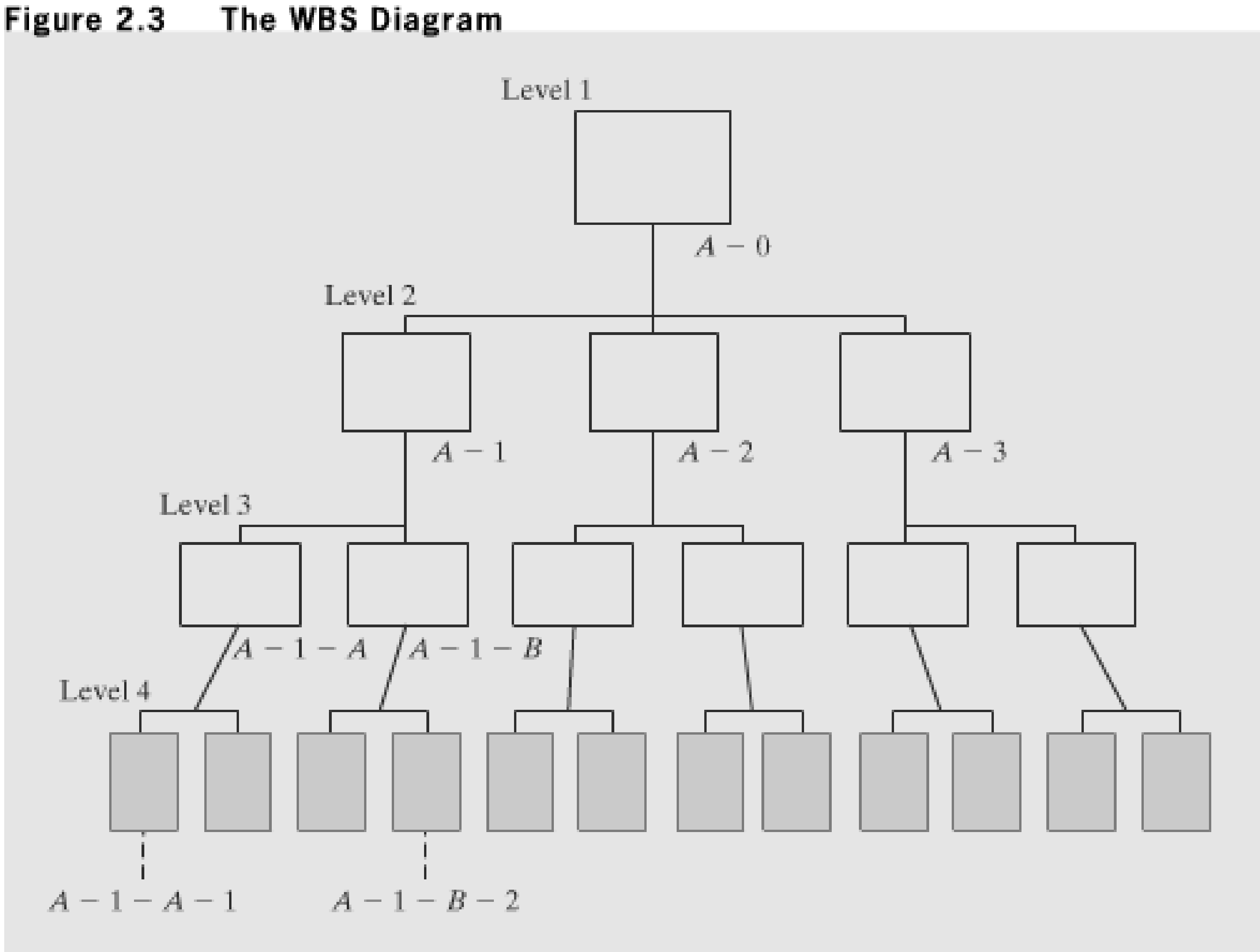
To estimate future costs and revenues for an alternative, the perspective (viewpoint) of the cash flow must be established and an estimating baseline and analysis period defined. Normally, cash flows are developed from the owner's viewpoint. The net cash flow for an alternative represents what is estimated to happen to future revenues and costs from the perspective being used. Therefore, the estimated changes in revenues and costs associated with an alternative have to be relative to a baseline that is consistently used for all the alternatives being compared.

2.2.1 The Work Breakdown Structure (WBS)

The first basic component in an integrated approach to developing cash flows is the work breakdown structure (WBS). The WBS is a basic tool in project management and is a vital aid in an engineering economy study. The WBS serves as a framework for defining all project work elements and their interrelationships, collecting and organizing information, developing relevant cost and revenue data, and integrating project management activities.

Figure 2.3 shows a diagram of a typical four-level WBS. It is developed from the top (project level) down in successive levels of detail. The project is divided into its major work

Figure 2.3 The WBS Diagram



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elements (Level 2). These major elements are then divided to develop Level 3, and so on. For example, an automobile (first level of the WBS) can be divided into second-level components (or work elements) such as the chassis, drive train, and electrical system. Then each second-level component of the WBS can be subdivided further into third-level elements. The drive train, for example, can be subdivided into third-level components such as the engine, differential, and transmission. This process is continued until the desired detail in the definition and description of the project or system is achieved.

Different numbering schemes may be used. The objectives of numbering are to indicate the interrelationships of the work elements in the hierarchy. The scheme illustrated in Figure 2.3 is an alphanumeric format. Another scheme often used is all numeric—Level 1: 1-0; Level 2: 1-1, 1-2, 1-3; Level 3: 1-1-1, 1-1-2, 1-2-1, 1-2-2, 1-3-1, 1-3-2; and so on (i.e., similar to the organization of this book). Usually, the level is equal (except for Level 1) to the number of characters indicating the work element.

Other characteristics of a project WBS are as follows:

1. Both functional (e.g., planning) and physical (e.g., foundation) work elements are included in it:
   (a) Typical functional work elements are logistical support, project management, marketing, engineering, and systems integration.
   (b) Physical work elements are the parts that make up a structure, product, piece of equipment, or similar item; they require labor, materials, and other resources to produce or construct.
2. The content and resource requirements for a work element are the sum of the activities and resources of related subelements below it.
3. A project WBS usually includes recurring (e.g., maintenance) and nonrecurring (e.g., initial construction) work elements.

EXAMPLE 2.2 A WBS FOR A CONSTRUCTION PROJECT

You have been appointed by your company to manage a project involving construction of a small commercial building with two floors of 15,000 gross square feet each. The ground floor is planned for small retail shops, and the second floor is planned for offices. Develop the first three levels of a representative WBS adequate for all project efforts from the time the decision was made to proceed with the design and construction of the building until initial occupancy is completed.

Solution

There would be variations in the WBSs developed by different individuals for a commercial building. A representative three-level WBS is shown in Figure 2.4. Level 1 is the total project. At Level 2, the project is divided into seven major physical work elements and three major functional work elements. Then each of these major elements is divided into subelements as required (Level 3). The numbering scheme used in this example is all numeric.

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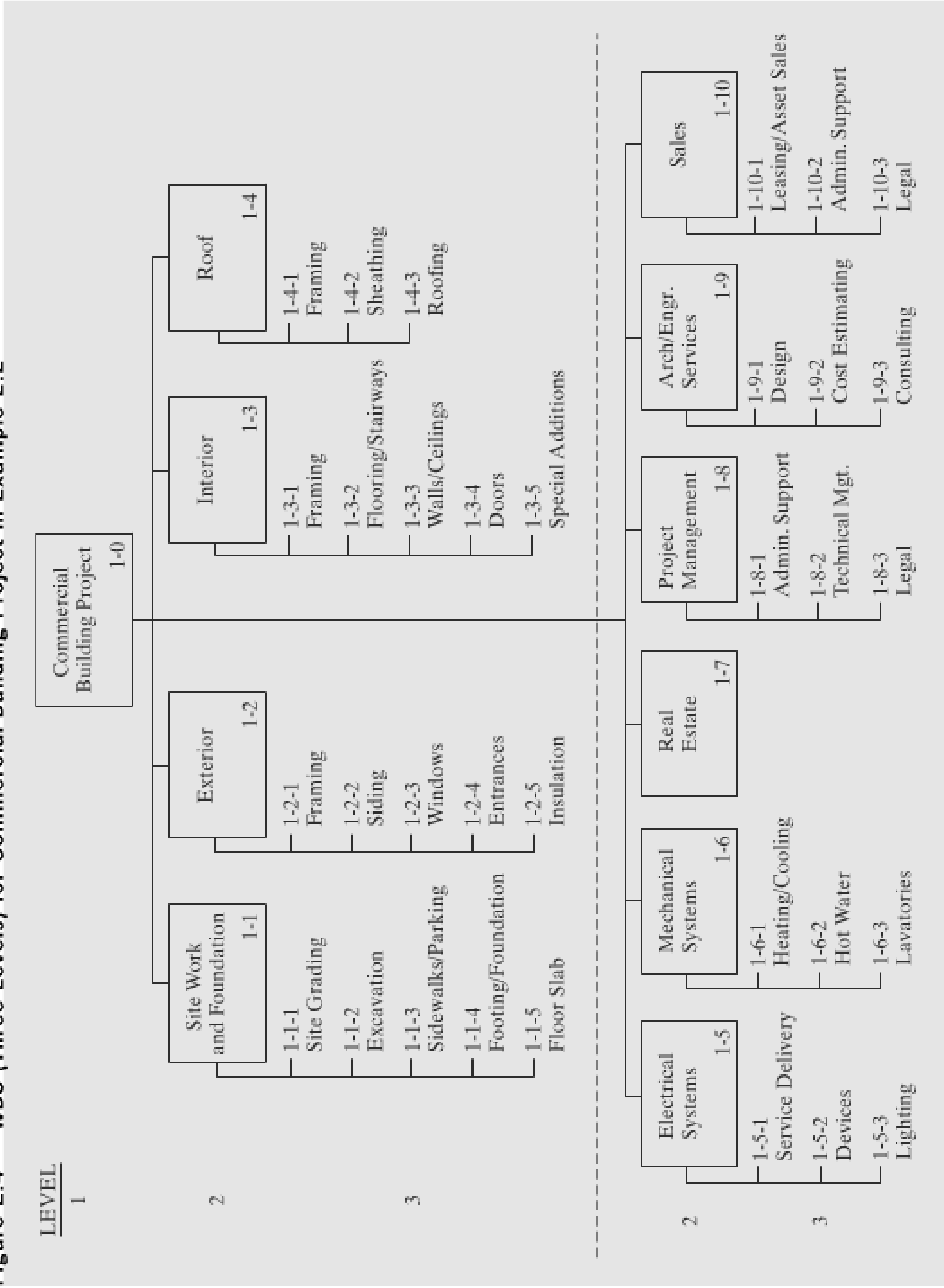
Figure 2.4 **WBS (Three Levels) for Commercial Building Project in Example 2.2**



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2.2.2 The Cost and Revenue Structure

The second basic component of the integrated approach for developing cash flows (Figure 2.2) is the cost and revenue structure. This structure is used to identify and categorize the costs and revenues that need to be included in the analysis. Detailed data are developed and organized within this structure for use with the estimating techniques of Section 2.3 to prepare the cash-flow estimates.

The life-cycle concept and the WBS are important aids in developing the cost and revenue structure for a project. The life cycle defines a maximum time period and establishes a range of cost and revenue elements that need to be considered in developing cash flows. The WBS focuses the analyst's effort on the specific functional and physical work elements of a project and on its related costs and revenues.

Perhaps the most serious source of errors in developing cashflows is overlooking important categories of costs and revenues. The cost and revenue structure, prepared in tabular or checklist form, is a good means of preventing such oversights. Technical familiarity with the project is essential in ensuring the completeness of the structure, as are using the life-cycle concept and the WBS in its preparation.

The following is a brief listing of some categories of costs and revenues that are typically needed in an engineering economy study:

1. Capital investment (fixed and working)
2. Labor costs
3. Material costs
4. Maintenance costs
5. Property taxes and insurance
6. Overhead costs
7. Disposal costs
8. Revenues based on sales, etc.
9. Quality (and scrap) costs
10. Market (or salvage) values

2.2.3 Estimating Techniques (Models)

The third basic component of the integrated approach (Figure 2.2) involves estimating techniques (models). These techniques, together with the detailed cost and revenue data, are used to develop individual cash-flow estimates and the overall net cash flow for each alternative.

The purpose of estimating is to develop cash-flow projections—*not to produce exact data* about the future, which is virtually impossible. Neither a preliminary estimate nor a final estimate is expected to be exact; rather, it should adequately suit the need at a reasonable cost and is often presented as a range of numbers.

Cost and revenue estimates can be classified according to detail, accuracy, and their intended use as follows:

1. ***Order-of-magnitude estimates:*** used in the planning and initial evaluation stage of a project.

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2. ***Semidetailed, or budget, estimates:*** used in the preliminary or conceptual design stage of a project.
3. ***Definitive (detailed) estimates:*** used in the detailed engineering/construction stage of a project.

Order-of-magnitude estimates are used in selecting the feasible alternatives for the study. They typically provide accuracy in the range of ±30 to 50% and are developed through semiformal means such as conferences, questionnaires, and generalized equations applied at Level 1 or 2 of the WBS.

Budget (semidetailed) estimates are compiled to support the preliminary design effort and decision making during this project period. Their accuracy usually lies in the range of ±15%. These estimates differ in the fineness of cost and revenue breakdowns and the amount of effort spent on the estimate. Estimating equations applied at Levels 2 and 3 of the WBS are normally used.

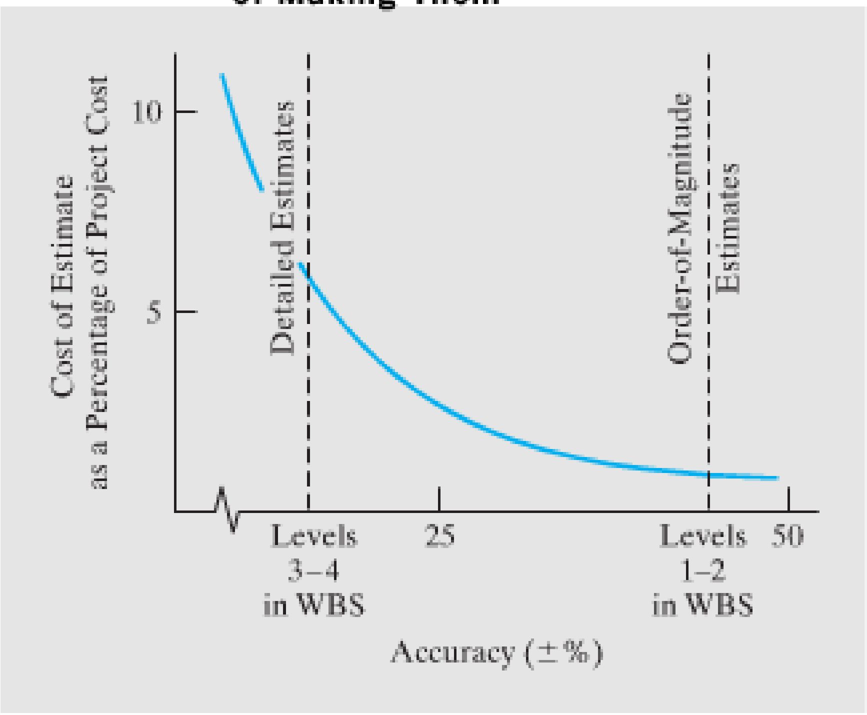
Detailed estimates are used as the basis for bids and to make detailed design decisions. Their accuracy is ±5%. They are made from specifications, drawings, site surveys, vendor quotations, and in-house historical records and are usually done at Level 3 and successive levels in the WBS.

Thus, it is apparent that a cost or revenue estimate can vary from a "back of the envelope" calculation by an expert to a very detailed and accurate prediction of the future prepared by a project team. The level of detail and accuracy of estimates should depend on the following:

1. Time and effort available as justified by the importance of the study
2. Difficulty of estimating the items in question
3. Methods or techniques employed
4. Qualifications of the estimator(s)
5. Sensitivity of study results to particular factor estimates

As estimates become more detailed, accuracy typically improves, but the cost of making the estimate increases dramatically. This general relationship is shown in Figure 2.5 and illustrates the idea that cost and revenue estimates should be prepared with full recognition of how accurate a particular study requires them to be.

Figure 2.5 Accuracy of Cost and Revenue Estimates versus the Cost of Making Them



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2.2.3.1 Sources of Estimating Data

The information sources useful in cost and revenue estimating are too numerous to list completely. The following four major sources of information are listed roughly in order of importance:

1. ***Accounting records.*** Accounting records are a prime source of information for economic analyses; however, they are often not suitable for direct, unadjusted use.

   A brief discussion of the accounting process and information was given in Appendix 1.A. In its most basic sense, accounting consists of a series of procedures for keeping a detailed record of monetary transactions between established categories of assets. Accounting records are a good source of historical data but have some limitations when used in making prospective estimates for engineering economic analyses. Moreover, accounting records rarely contain direct statements of incremental costs or opportunity costs, both of which are essential in most engineering economic analyses. Incremental costs are decision specific for one-of-a-kind investments and are unlikely to be available from the accounting system.
2. ***Other sources within the firm.*** The typical firm has a number of people and records that may be excellent sources of estimating information. Examples of functions within firms that keep records useful to economic analyses are engineering, sales, production, quality, purchasing, and personnel.
3. ***Sources outside the firm.*** There are numerous sources outside the firm that can provide helpful information. The main problem is in determining those that are most beneficial for particular needs. The following is a listing of some commonly used outside sources:
   (a) *Published information.* Technical directories, buyer indexes, U.S. government publications, reference books, and trade journals offer a wealth of information. For instance, *Standard and Poor's Industry Surveys* gives monthly information regarding key industries. *The Statistical Abstract of the United States* is a remarkably comprehensive source of cost indexes and data. The Bureau of Labor Statistics publishes many periodicals that are good sources of labor costs, such as the *Monthly Labor Review*, *Employment and Earnings*, *Current Wage Developments*, *Handbook of Labor Statistics*, and the *Chartbook on Wages, Prices and Productivity.*
   (b) *Personal contacts* are excellent potential sources. Vendors, salespeople, professional acquaintances, customers, banks, government agencies, chambers of commerce, and even competitors are often willing to furnish needed information on the basis of a serious and tactful request.
4. ***Research and development (R&D).*** If the information is not published and cannot be obtained by consulting someone, the only alternative may be to undertake R&D to generate it. Classic examples are developing a pilot plant and undertaking a test market program.

The Internet can also be a source of cost-estimating data, though you should assure yourself that the information is from a reputable source. The following Web sites may be useful to you both professionally and personally.

www.enr.com	*Engineering News-Record*	Construction and labor costs
www.kbb.com	Kelley Blue Book	Automobile pricing
www.factsonfuel.com	American Petroleum Institute	Fuel costs

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2.2.3.2 How Estimates Are Accomplished

Estimates can be prepared in a number of ways, such as the following examples:

1. A *conference* of various people who are thought to have good information or bases for estimating the quantity in question. A special version of this is the *Delphi method*, which involves cycles of questioning and feedback in which the opinions of individual participants are kept anonymous.
2. *Comparison* with similar situations or designs about which there is more information and from which estimates for the alternatives under consideration can be extrapolated. This is sometimes called *estimating by analogy*. The comparison method may be used to approximate the cost of a design or product that is new. This is done by taking the cost of a more complex design for a similar item as an upper bound and the cost of a less complex item of similar design as a lower bound. The resulting approximation may not be very accurate, but the comparison method does have the virtue of setting bounds that might be useful for decision making.
3. *Using quantitative techniques*, which do not always have standardized names. Some selected techniques, with the names used being generally suggestive of the approaches, are discussed in the next section.

2.3 Selected Estimating Techniques (Models)

The estimating models discussed in this section are applicable for order-of-magnitude estimates and for many semidetailed or budget estimates. They are useful in the initial selection of feasible alternatives for further analysis and in the conceptual or preliminary design phase of a project. Sometimes, these models can be used in the detailed design phase of a project.

2.3.1 Indexes

Costs and prices* vary with time for a number of reasons, including (1) technological advances, (2) availability of labor and materials, and (3) inflation. An *index* is a dimensionless number that indicates how a cost or a price has changed with time (typically escalated) with respect to a base year. Indexes provide a convenient means for developing present and future cost and price estimates from historical data. An estimate of the cost or selling price of an item in year n can be obtained by multiplying the cost or price of the item at an earlier point in time (year k) by the ratio of the index value in year n ($\bar{I}_n$) to the index value in year k ($\bar{I}_k$);† that is,

$$C_n = C_k\left(\frac{\bar{I}_n}{\bar{I}_k}\right), \tag{2.1}$$

where k = reference year (e.g., 2000) for which cost or price of item is known;
n = year for which cost or price is to be estimated ($n > k$);
C_n = estimated cost or price of item in year n;
C_k = cost or price of item in reference year k.

* The terms *cost* and *price* are often used together. The cost of a product or service is the total of the resources, direct and indirect, required to produce it. The price is the value of the good or service in the marketplace. In general, price is equal to cost plus a profit.

† In this section only, k is used to denote the reference year.

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Equation (2.1) is sometimes referred to as the *ratio technique* of updating costs and prices. Use of this technique allows the cost or potential selling price of an item to be taken from historical data with a specified base year and updated with an index. This concept can be applied at the lower levels of a WBS to estimate the cost of equipment, materials, and labor, as well as at the top level of a WBS to estimate the total project cost of a new facility, bridge, and so on.

EXAMPLE 2.3 INDEXING THE COST OF A NEW BOILER

A certain index for the cost of purchasing and installing utility boilers is keyed to 1988, where its baseline value was arbitrarily set at 100. Company XYZ installed a 50,000-lb/hour boiler for $525,000 in 2000 when the index had a value of 468. This same company must install another boiler of the same size in 2014. The index in 2014 is 542. What is the approximate cost of the new boiler?

Solution

In this example, n is 2014 and k is 2000. From Equation (2.1), an approximate cost of the boiler in 2014 is

$$C_{2014} = \$525{,}000(542/468) = \$608{,}013. \quad \blacksquare$$

Indexes can be created for a single item or for multiple items. For a single item, the index value is simply the ratio of the cost of the item in the current year to the cost of the same item in the reference year, multiplied by the reference year factor (typically, 100). A composite index is created by averaging the ratios of selected item costs in a particular year to the cost of the same items in a reference year. The developer of an index can assign different weights to the items in the index according to their contribution to total cost. For example, a general weighted index is given by

$$\overline{I}_n = \frac{W_1(C_{n1}/C_{k1}) + W_2(C_{n2}/C_{k2}) + \cdots + W_M(C_{nM}/C_{kM})}{W_1 + W_2 + \cdots + W_M} \times \overline{I}_k, \tag{2.2}$$

where M = total number of items in the index ($1 \le m \le M$);
C_{nm} = unit cost (or price) of the mth item in year n;
C_{km} = unit cost (or price) of the mth item in year k;
W_m = weight assigned to the mth item;
$\overline{I}_k$ = composite index value in year k.

The weights $W_1, W_2, \ldots, W_M$ can sum to any positive number, but typically sum to 1.00 or 100. Almost any combination of labor, material, products, services, and so on can be used for a composite cost or price index.

EXAMPLE 2.4 WEIGHTED INDEX FOR GASOLINE COST

Based on the following data, develop a weighted index for the price of a gallon of gasoline in 2014, when 1996 is the reference year having an index value of 99.2. The weight placed on *regular unleaded* gasoline is three times that of either premium or unleaded plus, because roughly three times as much regular unleaded is sold compared with premium or unleaded plus.

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	Price (Cents/Gal) in Year		
	1996	2010	2014
Premium	114	240	315
Unleaded plus	103	230	305
Regular unleaded	93	221	285

Solution

In this example, k is 1996 and n is 2014. From Equation (2.2), the value of $\bar{I}_{2014}$ is

$$\frac{(1)(315/114) + (1)(305/103) + (3)(285/93)}{1+1+3} \times 99.2 = 296.$$

Now, if the index in 2016, for example, is estimated to be 327, it is a simple matter to determine the corresponding 2016 prices of gasoline from $\bar{I}_{2014} = 296$:

$$\text{Premium: } 315 \text{ cents/gal} \left(\frac{327}{296}\right) = 348 \text{ cents/gal},$$

$$\text{Unleaded plus: } 305 \text{ cents/gal} \left(\frac{327}{296}\right) = 337 \text{ cents/gal},$$

$$\text{Regular unleaded: } 285 \text{ cents/gal} \left(\frac{327}{296}\right) = 315 \text{ cents/gal.}$$ ■

Many indexes are periodically published, including the *Engineering News Record* Construction Index (www.enr.com), which incorporates labor and material costs and the Marshall and Swift cost index.

2.3.2 Unit Technique

The *unit technique* involves using a per unit factor that can be estimated effectively. Examples are as follows:

1. Capital cost of plant per kilowatt of capacity
2. Revenue per mile
3. Capital cost per installed telephone
4. Revenue per customer served
5. Temperature loss per 1,000 feet of steam pipe
6. Operating cost per mile
7. Construction cost per square foot

Such factors, when multiplied by the appropriate unit, give a total estimate of cost, savings, or revenue.

As a simple example of the unit technique, suppose the Air Force's B-2 aircraft costs \$68,000 per hour to own, operate, and maintain. A certain mission requires two B-2 aircrafts to fly a total round-trip time of 45 hours. Thus, the total cost of this mission is (2 planes) (45 hours per mission per plane) (\$68,000 per hour) = \$6,120,000 per mission.

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While the unit technique is very useful for preliminary estimating purposes, such average values can be misleading. In general, more detailed methods will result in greater estimation accuracy.

2.3.3 Factor Technique

The *factor technique* is an extension of the unit method in which we sum the product of several quantities or components and add these to any components estimated directly. That is,

$$C = \sum_d C_d + \sum_m f_m U_m, \tag{2.3}$$

where C = cost being estimated;
C_d = cost of the selected component d that is estimated directly;
f_m = cost per unit of component m;
U_m = number of units of component m.

As a simple example, suppose that we need a slightly refined estimate of the cost of a house consisting of 2,000 square feet, two porches, and a garage. Using a unit factor of \$85 per square foot, \$10,000 per porch, and \$8,000 per garage for the two directly estimated components, we can calculate the total estimate as

$$(\$10{,}000 \times 2) + \$8{,}000 + (\$85 \times 2{,}000) = \$198{,}000.$$

The factor technique is particularly useful when the complexity of the estimating situation does not require a WBS,but several different parts are involved. Example 2.5 and the cost-estimating example to be presented in Section 2.5 further illustrate this technique.

EXAMPLE 2.5 ANALYSIS OF BUILDING SPACE COST ESTIMATES

The detailed design of the commercial building described in Example 2.2 affects the utilization of the gross square feet (and, thus, the net rentable space) available on each floor. Also, the size and location of the parking lot and the prime road frontage available along the property may offer some additional revenue sources. As project manager, analyze the potential revenue impacts of the following considerations.

The first floor of the building has 15,000 gross square feet of retail space, and the second floor has the same amount planned for office use. Based on discussions with the sales staff, develop the following additional information:

(a) The retail space should be designed for two different uses—60% for a restaurant operation (utilization = 79%, yearly rent = \$23/sq.ft.) and 40% for a retail clothing store (utilization = 83%, yearly rent = \$18/sq.ft.).
(b) There is a high probability that all the office space on the second floor will be leased to one client (utilization = 89%, yearly rent = \$14/sq.ft.).
(c) An estimated 20 parking spaces can be rented on a long-term basis to two existing businesses that adjoin the property. Also, one spot along the road frontage can be leased to a sign company, for erection of a billboard, without impairing the primary use of the property.

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Solution

Based on this information, you estimate annual project revenue ($\hat{R}$) as

$$\hat{R} = W(r_1)(12) + \Upsilon(r_2)(12) + \sum_{j=1}^{3} S_j(u_j)(d_j),$$

where W = number of parking spaces;
Υ = number of billboards;
r_1 = rate per month per parking space = \$22;
r_2 = rate per month per billboard = \$65;
j = index of type of building space use;
S_j = space (gross square feet) being used for purpose j;
u_j = space j utilization factor (% net rentable);
d_j = rate per (rentable) square foot per year of building space used for purpose j.

Then,

$$\hat{R} = [20(\$22)(12) + 1(\$65)(12)] + [9{,}000(0.79)(\$23) + 6{,}000(0.83)(\$18) + 15{,}000(0.89)(\$14)]$$

$$\hat{R} = \$6{,}060 + \$440{,}070 = \$446{,}130.$$

A breakdown of the annual estimated project revenue shows that

1.4% is from miscellaneous revenue sources;
98.6% is from leased building space.

From a detailed design perspective, changes in annual project revenue due to changes in building space utilization factors can be easily calculated. For example, an average 1% improvement in the ratio of rentable space to gross square feet would change the annual revenue ($\Delta\hat{R}$) as follows:

$$\begin{aligned}\Delta\hat{R} &= \sum_{j=1}^{3} S_j(u_j + 0.01)(d_j) - (\$446{,}130 - \$6{,}060) \\ &= \$445{,}320 - \$440{,}070 \\ &= \$5{,}250 \text{ per year.}\end{aligned}$$

2.4 Parametric Cost Estimating

Parametric cost estimating is the use of historical cost data and statistical techniques to predict future costs. Statistical techniques are used to develop cost estimating relationships (CERs) that tie the cost or price of an item (e.g., a product, good, service, or activity) to one or more independent variables (i.e., cost drivers). Recall from Chapter 1 that cost drivers are design variables that account for a large portion of total cost behavior. Table 2.1 lists a variety of items and associated cost drivers. The unit technique described in the previous section is a simple example of parametric cost estimating.

Parametric models are used in the early design stages to get an idea of how much the product (or project) will cost, on the basis of a few physical attributes (such as weight,

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Table 2.1 Examples of Cost Drivers Used in Parametric Cost Estimates

Product	Cost Driver (Independent Variable)
Construction	Floor space, roof surface area, wall surface area
Trucks	Empty weight, gross weight, horsepower
Passenger car	Curb weight, wheel base, passenger space, horsepower
Turbine engine	Maximum thrust, cruise thrust, specific fuel consumption
Reciprocating engine	Piston displacement, compression ratio, horsepower
Aircraft	Empty weight, speed, wing area
Electrical power plants	Kilowatts
Motors	Horsepower
Software	Number of lines of code

volume, and power). The output of the parametric models (an estimated cost) is used to gauge the impact of design decisions on the total cost.

Various statistical and other mathematical techniques are used to develop the CERs. For example, simple linear regression and multiple linear regression models, which are standard statistical methods for estimating the value of a dependent variable (the unknown quantity) as a function of one or more independent variables, are often used to develop estimating relationships. This section describes two commonly used estimating relationships, the power-sizing technique and the learning curve, followed by an overview of the procedure used to develop CERs.

2.4.1 Power-Sizing Technique

The *power-sizing technique*, which is sometimes referred to as an *exponential model*, is frequently used for developing capital investment estimates for industrial plants and equipment. This CER recognizes that cost varies as some power of the change in capacity or size. That is,

$$\frac{C_A}{C_B} = \left(\frac{S_A}{S_B}\right)^X,$$

$$C_A = C_B\left(\frac{S_A}{S_B}\right)^X, \tag{2.4}$$

where C_A = cost for plant A, C_B = cost for plant B (both in \$ as of the point in time for which the estimate is desired);

S_A = size of plant A, S_B = size of plant B (both in same physical units);

X = *cost-capacity factor* to reflect economies of scale.*

* This may be calculated or estimated from experience by using statistical techniques. For typical factors, see W. R. Park, *Cost Engineering Analysis* (New York: John Wiley & Sons, 1973), p. 137.

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The value of the cost-capacity factor will depend on the type of plant or equipment being estimated. For example, $X = 0.68$ for nuclear generating plants and 0.79 for fossil-fuel generating plants. Note that $X < 1$ indicates decreasing economies of scale (each additional unit of capacity costs less than the previous unit), $X > 1$* indicates increasing economies of scale (each additional unit of capacity costs more than the previous unit), and $X = 1$ indicates a linear cost relationship with size.

EXAMPLE 2.6 POWER-SIZING MODEL FOR COST ESTIMATING

Suppose that an aircraft manufacturer desires to make a preliminary estimate of the cost of building a 600-MW fossil-fuel plant for the assembly of its new long-distance aircraft. It is known that a 200-MW plant cost $100 million 20 years ago when the approximate cost index was 400, and that cost index is now 1,200. The cost-capacity factor for a fossil-fuel power plant is 0.79.

Solution

Before using the power-sizing model to estimate the cost of the 600-MW plant (C_A), we must first use the cost index information to update the known cost of the 200-MW plant 20 years ago to a current cost. Using Equation (2.1), we find that the current cost of a 200MW plant is

$$C_B = \$100 \text{ million} \left(\frac{1{,}200}{400}\right) = \$300 \text{ million}.$$

So, using Equation (2.4), we obtain the following estimate for the 600-MW plant:

$$C_A = \$300 \text{ million} \left(\frac{600\text{-MW}}{200\text{-MW}}\right)^{0.79}$$

$$C_A = \$300 \text{ million} \times 2.38 = \$714 \text{ million}.$$ ■

Note that Equation (2.4) can be used to estimate the cost of a larger plant (as in Example 2.6) or the cost of a smaller plant. For example, suppose we need to estimate the cost of building a 100-MW plant. Using Equation (2.4) and the data for the 200-MW plant in Example 2.6, we find that the current cost of a 100-MW plant is

$$\text{CA} = \$300 \text{ million} \left(\frac{100 \text{ MW}}{200 \text{ MW}}\right)^{0.79}$$

$$\text{CA} = \$300 \text{ million} \times 0.58 = \$174 \text{ million}.$$

Cost-capacity factors can also have a role in figuring the costs associated with environmental cleanup. The cost of cleaning up an oil spill in the Gulf of Mexico is $10 billion when the spilled oil amounts to 18 million gallons. The cleanup cost is $14 billion when the amount of spilled oil is 32 million gallons. We can use Equation (2.4) to estimate the value of the cost-capacity factor in this situation.

$$\frac{\$10 \text{ billion}}{\$14 \text{ billion}} = \left(\frac{18 \text{ million gallons}}{32 \text{ million gallons}}\right)^X$$

$$\log(0.7143) = X \log(0.5625)$$

$$X = 0.58$$

* Precious gems are an example of increasing economies of scale. For example, a one-carat diamond typically costs more than four quarter-carat diamonds.

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2.4.2 Learning and Improvement

A *learning curve* is a mathematical model that explains the phenomenon of increased worker efficiency and improved organizational performance with repetitive production of a good or service. The learning curve is sometimes called an *experience curve* or a *manufacturing progress function*; fundamentally, it is an estimating relationship. The learning (improvement) curve effect was first observed in the aircraft and aerospace industries with respect to labor hours per unit. However, it applies in many different situations. For example, the learning curve effect can be used in estimating the professional hours expended by an engineering staff to accomplish successive detailed designs within a family of products, as well as in estimating the labor hours required to assemble automobiles.

The basic concept of learning curves is that some input resources (e.g., energy costs, labor hours, material costs, engineering hours) decrease, on a per-output-unit basis, as the number of units produced increases. Most learning curves are based on the assumption that a constant percentage reduction occurs in, say, labor hours, as the number of units produced is *doubled*. For example, if 100 labor hours are required to produce the first output unit and a 90% learning curve is assumed, then $100(0.9) = 90$ labor hours would be required to produce the second unit. Similarly, $100(0.9)^2 = 81$ labor hours would be needed to produce the fourth unit, $100(0.9)^3 = 72.9$ hours to produce the eighth unit, and so on. Therefore, a 90% learning curve results in a 10% reduction in labor hours each time the production quantity is doubled.

Equation (2.5) can be used to compute resource requirements assuming a constant percentage reduction in input resources each time the output quantity is doubled.

$$Z_u = K(u^n), \tag{2.5}$$

where u = the output unit number;
Z_u = the number of input resource units needed to produce output unit u;
K = the number of input resource units needed to produce the first output unit;
s = the learning curve slope parameter expressed as a decimal ($s = 0.9$ for a 90% learning curve);

$$n = \frac{\log s}{\log 2} = \text{the learning curve exponent.}$$

EXAMPLE 2.7 LEARNING CURVE FOR A FORMULA CAR DESIGN TEAM

The Mechanical Engineering department has a student team that is designing a formula car for national competition. The time required for the team to assemble the first car is 100 hours. Their improvement (or learning rate) is 0.8, which means that as output is doubled, their time to assemble a car is reduced by 20%. Use this information to determine

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(a) the time it will take the team to assemble the 10th car.
(b) the *total time* required to assemble the first 10 cars.
(c) the estimated *cumulative average* assembly time for the first 10 cars.

Solve by hand and by spreadsheet.

Solution by Hand

(a) From Equation (2.5), and assuming a proportional decrease in assembly time for output units between doubled quantities, we have

$$\begin{aligned} Z_{10} &= 100(10)^{\log 0.8/\log 2} \\ &= 100(10)^{-0.322} \\ &= \frac{100}{2.099} = 47.6 \text{ hours} \end{aligned}$$

(b) The total time to produce x units, T_x, is given by

$$T_x = \sum_{u=1}^{x} Z_u = \sum_{u=1}^{x} K(u^n) = K \sum_{u=1}^{x} u^n. \tag{2.6}$$

Using Equation (3-6), we see that

$$T_{10} = 100 \sum_{u=1}^{10} u^{-0.322} = 100[1^{-0.322} + 2^{-0.322} + \cdots + 10^{-0.322}] = 631 \text{ hours.}$$

(c) The cumulative average time for x units, C_x, is given by

$$C_x = T_x/x \tag{2.7}$$

Using Equation (2.7), we get

$$C_{10} = T_{10}/10 = 631/10 = 63.1 \text{ hours.}$$

Spreadsheet Solution

Figure 2.6 shows the spreadsheet solution for this example problem. For each unit number, the unit time to complete the assembly, the cumulative total time, and the cumulative average time are computed with the use of Equations (2.5), (2.6), and (2.7), respectively. Note that these formulas are entered once in row 6 of the spreadsheet and are then simply copied into rows 7 through 15.

A plot of unit time and cumulative average time is easily created with the spreadsheet software. This spreadsheet model can be used to examine the impact of a different learning slope parameter (e.g., $s = 90\%$) on predicted car assembly times by changing the value of cell B2.

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Figure 2.6 Spreadsheet Solution, Example 2.7

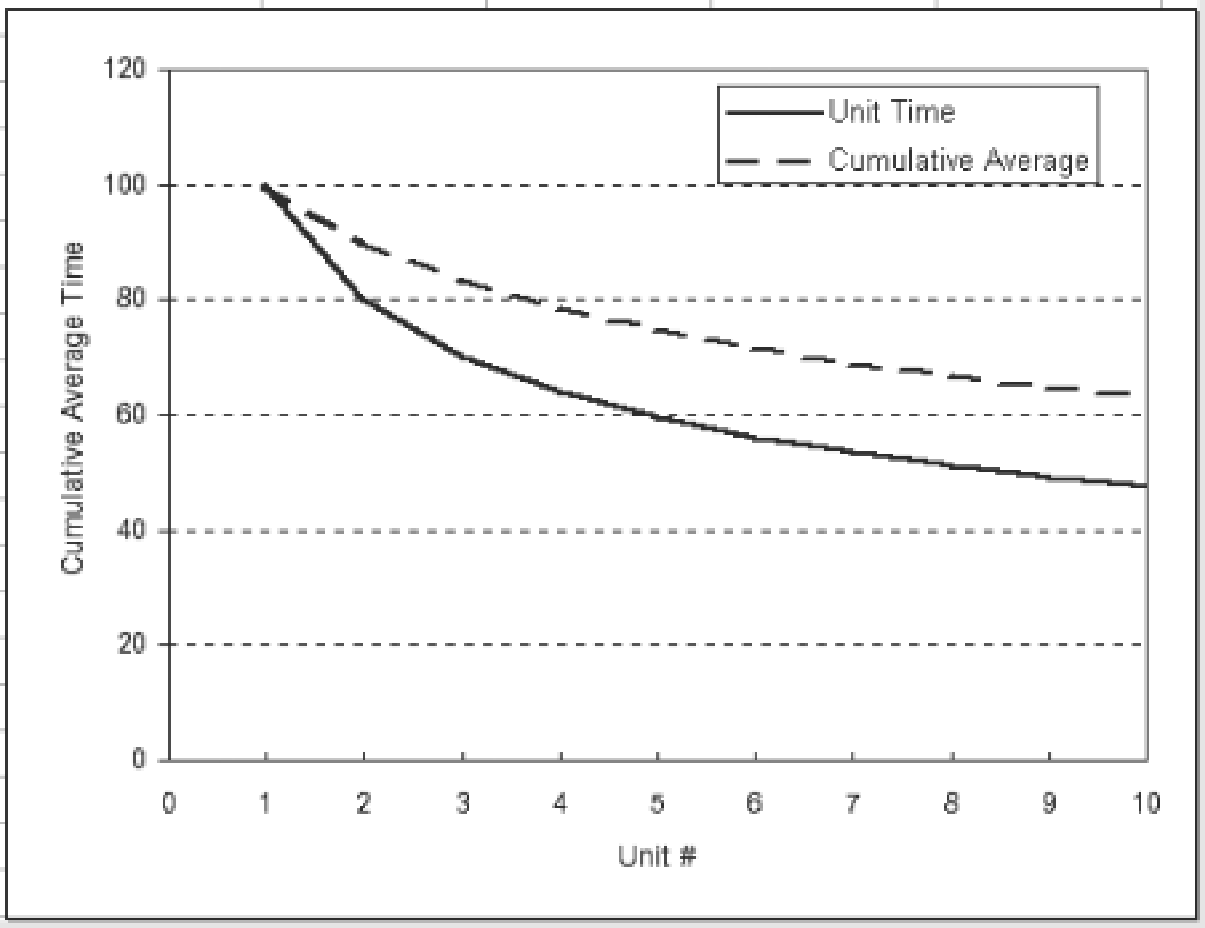
= LOG(B2) / LOG(2)

= $B$1 * A6 ^ $B$4

= SUM($B$6:B6)

= AVERAGE($B$6:B6)

	A	B	C	D	E
1	K =	100			
2	s =	80.0%			
3					
4	**n =**	-0.322			
5	**Unit #**	**Unit Time**	**Cumulative Total**	**Cumulative Average**	
6	**1**	100.00	100.00	100.00	
7	**2**	80.00	180.00	90.00	
8	**3**	70.21	250.21	83.40	
9	**4**	64.00	314.21	78.55	
10	**5**	59.56	373.77	74.75	
11	**6**	56.17	429.94	71.66	
12	**7**	53.45	483.39	69.06	
13	**8**	51.20	534.59	66.82	
14	**9**	49.29	583.89	64.88	
15	**10**	47.65	631.54	63.15	



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2.4.3 Developing a Cost Estimating Relationship (CER)

A CER is a mathematical model that describes the cost of an engineering project as a function of one or more design variables. CERs are useful tools because they allow the estimator to develop a cost estimate quickly and easily. Furthermore, estimates can be made early in the design process before detailed information is available. As a result, engineers can use CERs to make early design decisions that are cost effective in addition to meeting technical requirements.

There are four basic steps in developing a CER:

1. Problem definition
2. Data collection and normalization
3. CER equation development
4. Model validation and documentation

2.4.3.1 Problem Definition

The first step in any engineering analysis is to define the problem to be addressed. A well-defined problem is much easier to solve. For the purposes of cost estimating, developing a WBS is an excellent way of describing the elements of the problem. A review of the completed WBS can also help identify potential cost drivers for the development of CERs.

2.4.3.2 Data Collection and Normalization

The collection and normalization of data is the most critical step in the development of a CER.We're all familiar with the adage "garbage in—garbage out." Without reliable data, the cost estimates obtained by using the CER would be meaningless. The WBS is also helpful in the data collection phase. The WBS helps to organize the data and ensure that no elements are overlooked.

Data can be obtained from both internal and external sources. Costs of similar projects in the past are one source of data. Published cost information is another source of data. Once collected, data must be normalized to account for differences due to inflation, geographical location, labor rates, and so on. For example, cost indexes or the price inflation techniques can be used to normalize costs that occurred at different times. Consistent definition of the data is another important part of the normalization process.

2.4.3.3 CER Equation Development

The next step in the development of a CER is to formulate an equation that accurately captures the relationship between the selected cost driver(s) and project cost. Table 2.2 lists four general equation types commonly used in CER development. In these equations, b_0, b_1, b_2, and b_3 are constants, while x_1, x_2, and x_3 represent design variables.

A simple, yet very effective, way to determine an appropriate equation form for the CER is to plot the data. If a plot of the data on regular graph paper appears to follow a straight line, then a linear relationship is suggested. If a curve is suggested, then try plotting the data on semilog or log-log paper. If a straight line results on semilog paper, then the relationship is logarithmic or exponential. If a straight line results on log-log paper, then the relationship is a power curve.

Once we have determined the basic equation form for the CER, the next step is to determine the values of the coefficients in the CER equation. The most common

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Table 2.2 Typical Equation Forms

Type of Relationship	Generalized Equation
Linear	Cost $= b_0 + b_1x_1 + b_2x_2 + b_3x_3 + \cdots$
Power	Cost $= b_0 + b_1x_1^{b_{11}}x_2^{b_{12}} + \cdots$
Logarithmic	Cost $= b_0 + b_1\log(x_1) + b_2\log(x_2) + b_3\log(x_3) + \cdots$
Exponential	Cost $= b_0 + b_1\exp^{b_{11}x_1} + b_2\exp^{b_{22}x_2} + \cdots$

technique used to solve for the coefficient values is the method of least squares. Basically, this method seeks to determine a straight line through the data that minimizes the total deviation of the actual data from the predicted values. (The line itself represents the CER.) This method is relatively easy to apply manually and is also available in many commercial software packages. (Most spreadsheet packages are capable of performing a least-squares fit of data.) The primary requirement for the use of the least-squares method is a linear relationship between the independent variable (the cost driver) and the dependent variable (project cost).*

All of the equation forms presented in Table 2.2 can easily be transformed into a linear form. The following equations can be used to calculate the values of the coefficients b_0 and b_1 in the simple linear equation $y = b_0 + b_1x$:

$$b_1 = \frac{n\sum_{i=1}^{n}x_iy_i - \left(\sum_{i=1}^{n}x_i\right)\left(\sum_{i=1}^{n}y_i\right)}{n\sum_{i=1}^{n}x_i^2 - \left(\sum_{i=1}^{n}x_i\right)}, \tag{2.8}$$

$$b_0 = \frac{\sum_{i=1}^{n}y_i - b_1\sum_{i=1}^{n}x_i}{n}. \tag{2.9}$$

Note that the variable n in the foregoing equations is equal to the number of data sets used to estimate the values of b_0 and b_1.

EXAMPLE 2.8 COST ESTIMATING RELATIONSHIP (CER) FOR A SPACECRAFT

In the early stages of design, it is believed that the cost of a Martian rover spacecraft is related to its weight. Cost and weight data for six spacecraft have been collected and normalized and are shown in the next table. A plot of the data suggests a linear relationship. Use a spreadsheet model to determine the values of the coefficients for the CER.

* In addition, the observations should be independent. The difference between predicted and actual values is assumed to be normally distributed with an expected value of zero. Furthermore, the variance of the dependent variable is assumed to be equal for each value of the independent variable.

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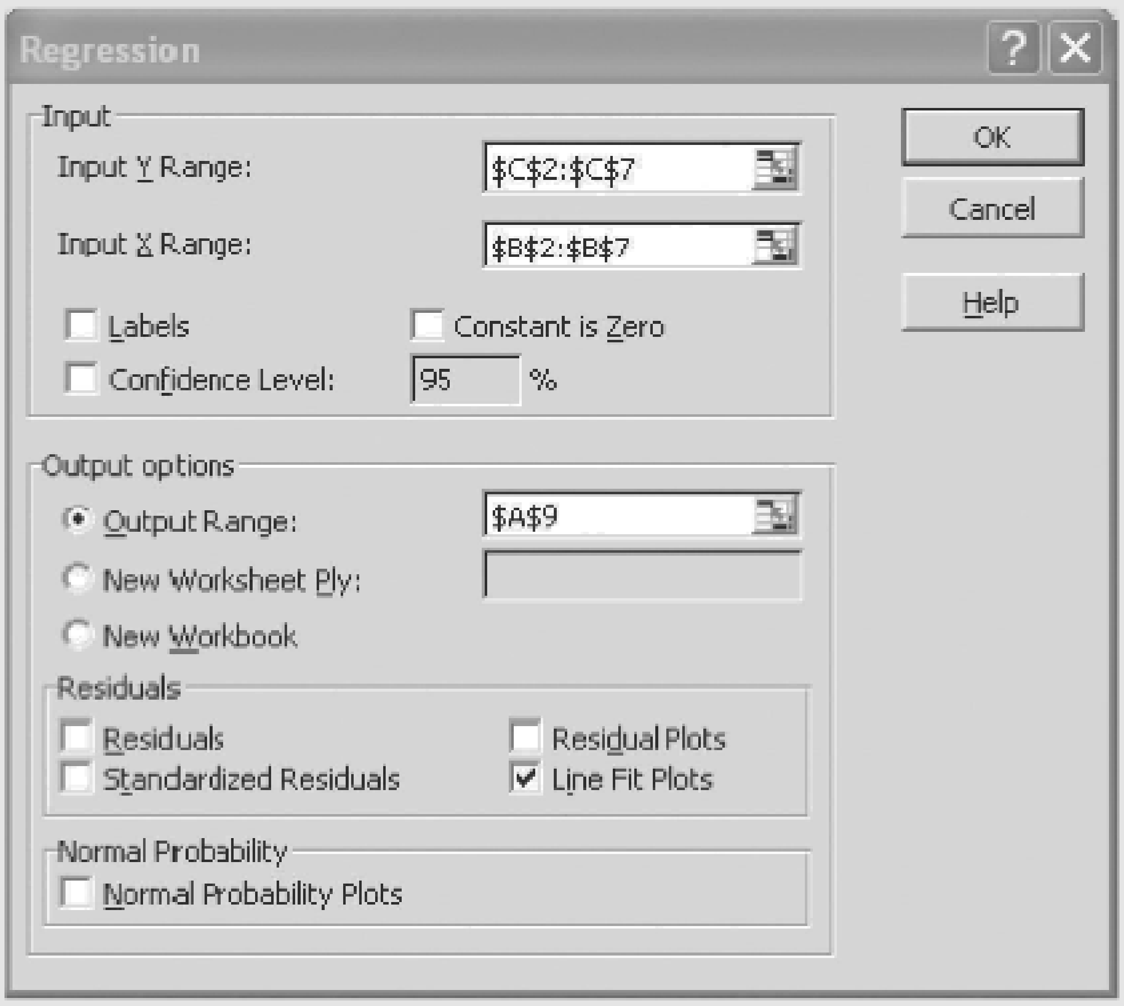
Spacecraft i	Weight (lb) x_i	Cost ($ million) y_i
1	400	278
2	530	414
3	750	557
4	900	689
5	1,130	740
6	1,200	851

Spreadsheet Solution

Figure 2.7 displays the spreadsheet model for determining the coefficients of the CER. This example illustrates the basic regression features of Excel. No formulas are entered, only the cost and weight data for the spacecraft. The challenge in spreadsheet regression lies in making sure that the underlying regression assumptions are satisfied and in interpreting the output properly.

The *Tools* | *Data Analysis* | *Regression* menu command brings up the Regression dialog box shown in Figure 2.7(a) and shows the values used for this model. The results of the analysis are generated by Excel and are displayed beginning in cell A9 of Figure 2.7(b). For the purposes of this example, the coefficients b_0 and b_1 of the CER are found in cells B25 and B26, respectively.

Figure 2.7 Spreadsheet Solution, Example 2.8



(a) Regression Dialog Box

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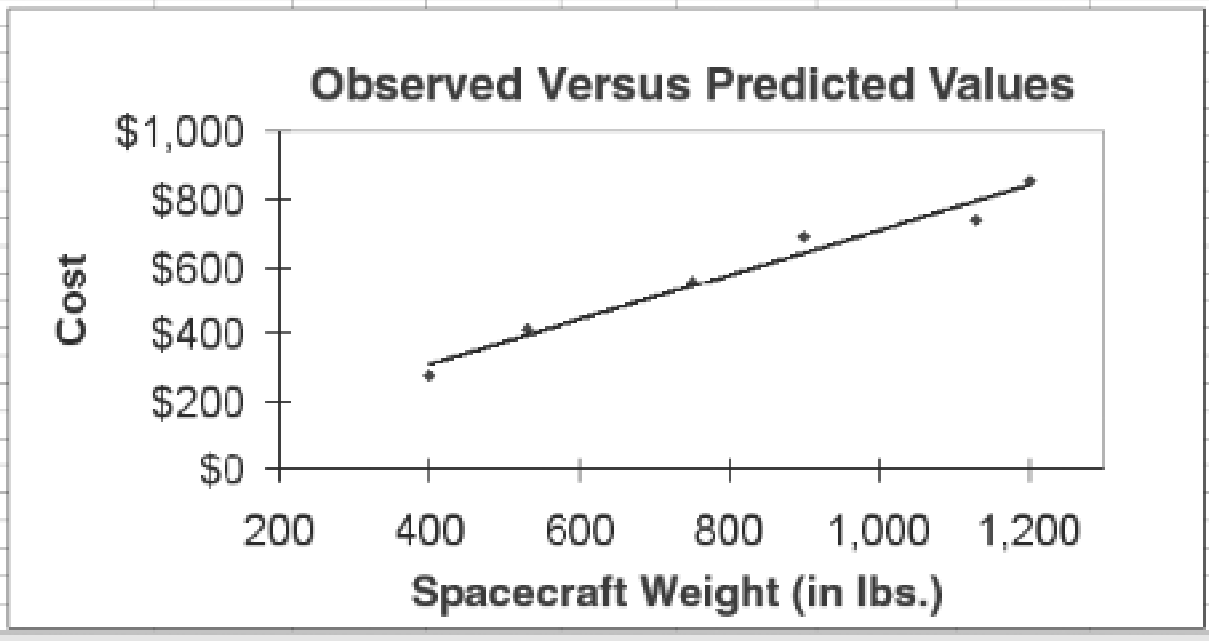
Figure 2.7 ***(continued)***

	A	B	C	D	E	F	G	H	I
1	Spacecraft	Weight	Cost						
2	1	400	$ 278						
3	2	530	$ 414						
4	3	750	$ 557						
5	4	900	$ 689						
6	5	1,130	$ 720						
7	6	1,200	$ 851						
8									
9	SUMMARY OUTPUT								
10									
11	*Regression Statistics*								
12	Multiple R	0.98500839							
13	R Square	0.97024154							
14	Adjusted R Square	0.96280192							
15	Standard Error	41.3485719							
16	Observations	6							
17									
18	ANOVA								
19		*df*	*SS*	*MS*	*F*	*Significance F*			
20	Regression	1	222972.02	222972.02	130.4155	0.00033544			
21	Residual	4	6838.8176	1709.7044					
22	Total	5	229810.83						
23									
24		*Coefficients*	*Standard Erro*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
25	Intercept	48.2828513	50.198791	0.961833	0.390601	-91.091625	187.657327	-91.091625	187.657327
26	X Variable 1	0.65973582	0.0577704	11.419962	0.000335	0.49933914	0.82013251	0.4993391	0.82013251



b) Regression Results

The resulting CER relating spacecraft cost (in millions of dollars) to spacecraft weight is

$$\text{Cost} = 48.28 + 0.6597x,$$

where x represents the weight of the spacecraft in pounds, and $400 \leq x \leq 1,200$. ■

2.4.3.4 Model Validation and Documentation

Once the CER equation has been developed, we need to determine how well the CER can predict cost (i.e., model validation) and document the development and appropriate use of the CER. Validation can be accomplished with statistical "goodness of fit" measures such as standard error and the correlation coefficient. Analysts must use goodness of fit measures to infer how well the CER predicts cost as a function of the selected cost

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driver(s). Documenting the development of the CER is important for future use of the CER. It is important to include in the documentation the data used to develop the CER and the procedures used for normalizing the data.

The standard error (SE) measures the average amount by which the actual cost values and the predicted cost values vary. The SE is calculated by

$$SE = \sqrt{\frac{\sum_{i=1}^{n}(y_i - \text{Cost}_i)^2}{n-2}}, \tag{2.10}$$

where Cost_i is the cost predicted by using the CER with the independent variable values for data set i and y_i is the actual cost. A small value of SE is preferred.

The correlation coefficient (R) measures the closeness of the actual data points to the regression line ($y = b_0 + b_1x$). It is simply the ratio of explained deviation to total deviation.

$$R = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\left[\sum_{i=1}^{n}(x_i - \bar{x})^2\right]\left[\sum_{i=1}^{n}(y_i - \bar{y})^2\right]}}, \tag{2.11}$$

where $\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$ and $\bar{y} = \frac{1}{n}\sum_{i=1}^{n} y_i$. The sign (+/−) of R will be the same as the sign of the slope (b_1) of the regression line. Values of R close to one (or minus one) are desirable in that they indicate a strong linear relationship between the dependent and independent variables.

In cases where it is not clear which is the "best" cost driver to select or which equation form is best, you can use the goodness of fit measures to make a selection. In general, all other things being equal, the CER with better goodness of fit measures should be selected.

EXAMPLE 2.9 REGRESSION STATISTICS FOR THE SPACECRAFT CER

Determine the SE and the correlation coefficient for the CER developed in Example 2.8.

Solution

From the spreadsheet for Example 2.8 (Figure 2.7), we find that the SE is 41.35 (cell B15) and that the correlation coefficient is 0.985 (cell B12). The value of the correlation coefficient is close to one, indicating a strong positive linear relationship between the cost of the spacecraft and the spacecraft's weight. ■

In summary, CERs are useful for a number of reasons. First, given the required input data, they are quick and easy to use. Second, a CER usually requires very little detailed information, making it possible to use the CER early in the design process. Finally, a CER is an excellent predictor of cost if correctly developed from good historical data.

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CASE STUDY 2.5

Demanufacturing of Computers

Let's consider a case that deals with a timely and important issue concerning environmental economics. What are companies to do with all of the old computers that typically accumulate at their facilities?

As one possible solution to this problem, a number of states and companies have jointly established "resource recovery" facilities to process the handling of old electronic equipment, such as used computers. Demanufacturing of computers involves disassembly, refurbishing, and either donating or reselling the units. However, there are some residuals, or remaining components, that cannot be reused, are harmful to the environment, and contribute to the cost of demanufacturing.

Let's consider the case of one resource recovery center in the Northeast that currently handles approximately 2,000 computers per year. Of these computers, approximately 50% are refurbished and donated, 40% are remanufactured and resold, and 10% are "residuals." What to do with the residuals is a challenging problem.

The facility currently has a contract with an outside source to take the monitors and CPUs. This leads to storage requirements in their facility, and there are issues concerning the determination of the optimal truckload capacity. The labor costs for the outside contractor are $10.00 per unit, and transportation costs are $1.70 per unit, for a total of $11.70 per unit, based on a full capacity truck load.

The recovery facility is seeking an alternative solution to the handling of residuals. One alternative under consideration is to establish a method for demanufacturing of the computers that will consider the CPUs only, since there are environmental issues associated with computer monitors.

The recovery facility recently completed a work measurement study to develop a method for demanufacture of the CPUs. The method is as follows:

1. Remove fasteners or screws.
2. Remove metal casing.
3. Remove power and data cables from CD drive.
4. Unfasten CD drive.
5. Unfasten supporting bar.
6. Remove support and floppy drive.
7. Remove power and data cables from power supply.
8. Remove motherboard.
9. Unfasten and remove power supply.
10. Unfasten drive housing.
11. Remove rubber feet.

From the predetermined time study, it is determined that the demanufacturing rate is 7.35 minutes/unit. The facility uses an internal labor rate of $12.00/hour, and it is estimated that training costs for the demanufacturing method will be 10% of total labor costs. Setup costs and transportation costs are estimated at 150% and 20% of total labor costs, respectively. The facility's goal is to demanufacture 200 units during regular operations. Determine the estimated cost per unit for the proposed demanufacturing method. What percentage reduction is this over the per unit cost of using the outside contractor?

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Solution

As one possible solution, the industrial engineer performs the following calculations. For 200 units, the labor quantity is estimated as

$$7.35 \text{ minutes/unit} \times 200 \text{ units} = 1{,}470 \text{ minutes} = 24.5 \text{ hours.}$$

The engineer develops the cost template provided below:

Demanufacturing Cost Elements	Unit Elements		Factor Estimates		Row Total
	Units	Cost/Unit	Factor	of Row	
A: Factory labor	24.5 hrs	$12.00/hr			$294.00
B: Quality costs—Training			10%	A	$29.40
C: Total labor					$323.40
D: Factory overhead—Setup costs			150%	C	$485.10
E: Transportation cost			20%	C	$64.68
F: Total direct charge					$550.08
G: Facility rental					—
H: Total demanufacturing cost					$873.48
I: Quantity—Lot size					200
J: Demanufacturing cost per unit					$4.37
Outside cost per unit	$11.70				

The per unit cost of the proposed internal demanufacturing method is $4.37, while the per unit cost of using the outside contractor is $11.70. Should the proposed demanufacturing method be adopted, the estimated per unit cost savings is $7.33 for a 62.6% reduction over the per unit cost for the outside contractor.

This case illustrates that developing creative solutions for internal demanufacturing methods not only results in cost savings of approximately 63% from current practices for the case company, but proper demanufacturing methods will minimize the number of computer residuals entering the waste stream. What makes economic sense is also good for the environment!

2.6 Electronic Spreadsheet Modeling: Learning Curve

Regardless of its form, modeling is an integral part of every engineering discipline. It is important to establish good skills early in your career and then to continually refine them as you gain experience. Using the guidelines in Appendix A and the learning curve formulation in Equation (2.5), we will illustrate the electronic spreadsheet modeling process. This simple spreadsheet can stand on its own or be incorporated into a work breakdown structure as part of a more detailed estimate.

Spreadsheet modeling begins by identifying the decision criteria, the fundamental relationships defining the decision criteria, the parameter values required in the

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equations, and then creating an infrastructure within the worksheet to support these calculations and present the results. A good model should make it easy for the user to know what input is required, where it goes, and where to find the results.

Equation (2.5) contains four parameters and one intermediate calculation. For maximum flexibility, we will allow the user to provide any three parameters, and the model will return the value for the unspecified parameter. Basic algebraic manipulation is used to create three additional equations, resulting in one equation for each of the parameters.

The preliminary model is shown in Figure 2.8. Column A identifies the four parameters that can be estimated and the intermediate calculation for n, column B holds the user-specified values for the parameters, and column C contains the equations for the final result. We will solve for Z_u to validate the model by providing parameter values for K, s, and u in column B.

Once the infrastructure is created, we enter the equations. The intermediate equation for the learning curve exponent, n, is in cell B8:

= LOG(B5)/LOG(2)

We could have incorporated this calculation directly into each of the equations in column C, but it is better to separate intermediate calculations to aid in troubleshooting and validating the model.

The newly derived learning curve equations are inserted in column C. For example, cell C4 is:

= B7/(B6^B8)

The other equations go into cells C5, C6, and C7. Note the results of these equations: cell C4 displays the value 0, which conflicts with the value of 100 specified in cell B4. Cells C5 and C6 return the error code *#NUM!*, indicating an invalid parameter value in each formula. In both cases, the formula is trying to evaluate log(0) because cell B7 is blank. In this format, the answer in cell C7 is difficult to spot.

Model usability is improved by adding an IF function to each equation in column C to check if the corresponding cell in column B is blank. Recall that the user can enter three of the four parameters, and the model will solve for the unspecified parameter. The modified equation for cell C4 is shown below. The IF function returns the equation result if cell B4 is empty, or a blank (indicated by the two consecutive double quotes) if B4 contains a value. This approach eliminates the conflicting values and error codes.

= IF(ISBLANK(B4),B7/(B6^B9),"")

Figure 2.8 Preliminary Learning Curve Model

	A	B	C
1	Learning Curve Estimation Mode		
2			
3		given	find
4	K	100	0
5	s	0.8	#NUM!
6	u	10	#NUM!
7	Zu		47.65099
8	n	-0.32193	

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Model usability is further enhanced with some simple formatting. We add a title for the parameter names and then set the column titles *Parameters*, *Value*, and *RESULT* in bold and center them for emphasis. The last header is in uppercase for additional emphasis. The parameter names are added in column A, in addition to their symbols, and the names are right justified with a trailing equal sign to further link them to the adjacent column values.

The *value* cells are outlined to clearly delineate them from their names in column A. The *result* area in column C is shaded, and the corresponding color used in the column title. Finally, a *key* is provided at the bottom of the spreadsheet for additional clarification. The revised spreadsheet is in Figure 2.9. The final answer is now obvious.

Significant digits play a critical role in estimation. Implied precision through extraneous digits is very common in spreadsheet modeling. Indeed, our answer implies that we are capable of measuring time to the nearest millionth of an hour. Our next enhancement is to incorporate a mechanism for specifying the number of significant digits in the result. For additional emphasis, the input cell for the number of digits is placed at the top of the model, still using column B as the input region. The column C results are retained, since these values may be intermediate calculations in a larger model.

Spreadsheet software contains a wealth of guidance for using functions and improving usability. Microsoft *Excel* help provides an approach for incorporating significant digits in our answer. The newly revised formula in cell D6 is shown below.

= IF(ISBLANK(B6),ROUND(C6,$B$3-LEN(INT(C6))),"")

The equation in C6 still provides the actual calculation; cell D6 simply reports this result to the number of significant digits specified in cell B3. This approach reduces the length of the equation in D6, making troubleshooting easier. The ISBLANK function is retained so that only one cell in column D displays results. The ROUND function uses the number of significant digits specified in B3 and the number of digits in the initial answer to provide the final answer with the appropriate number of significant digits. The dollar signs in the B3 cell address represent absolute addressing. The final model is shown in Figure 2.10.

We see that modeling is an iterative process—we begin with the basics, validate the results by hand, then enhance the results for usability. The level of sophistication is a function of how often the model will be used and who will be using it.

Figure 2.9 Revised Learning Curve Spreadsheet Model

	A	B	C
1	Learning Curve Estimation Model		
2			
3	**Parameters**	**Value**	**RESULT**
4	**K** (first unit resources) =	100	
5	**s** (slope parameter) =	0.8	
6	**u** (Unit #) =	10	
7	**Zu** (Unit Time) =		47.650987
8			
9	n (learning curve exponent) =	-0.321928	
10			
11			
12	**Key:**		
13	Input values		
14	Intermediate result		
15	Result		

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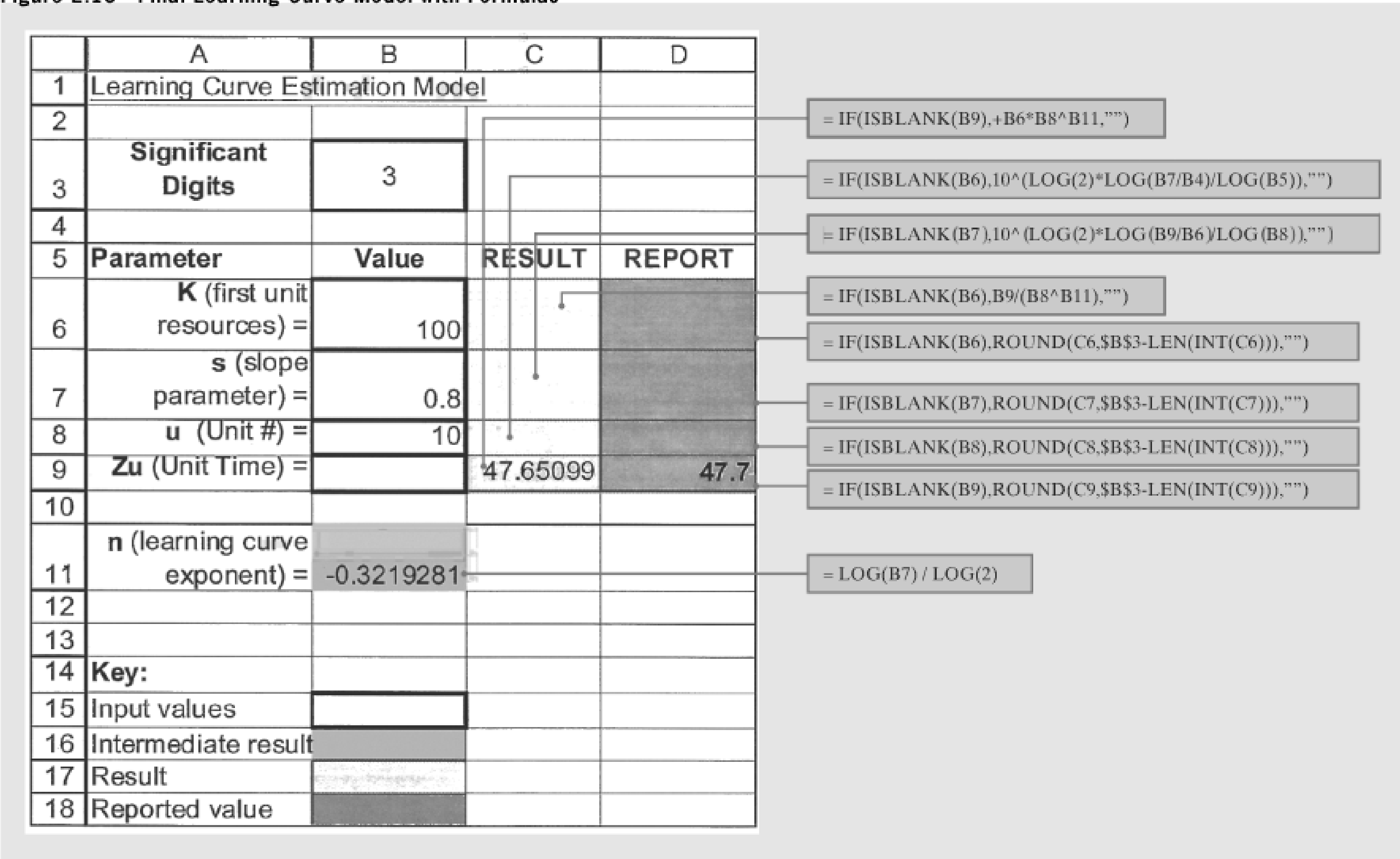
Figure 2.10 Final Learning Curve Model with Formulas



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2.7 Try Your Skills

The number in parentheses that follows each problem refers to the section from which the problem is taken.

2.A. Develop an estimate for the cost of washing and drying a 12-pound load of laundry. Remember to consider all the costs. Your time is worth nothing unless you have an opportunity to use it for making (or saving) money on other activities. **(2.2)**

2.B. The manufacturer of commercial jets has a cost index equal to 94.9 per aircraft in 2013. The anticipated cost index for the airplane in 2018 is 106.8. The average compound rate of growth should hold steady for the next 15 years. If an aircraft costs $10.2 million to build in 2014, what is its expected cost in 2016? State your assumptions. **(2.3)**

2.C. Four hundred pounds of copper go into a 2,000-square-foot, newly constructed house. Today's price of copper is $3.50 per pound. If the cost of copper is expected to increase 4.5% per year into the foreseeable future, what is the cost of copper going to be in a new 2,400-square-foot house 10 years from now? Assume the cost capacity factor for increases of copper in houses equals 1.0. **(2.4)**

SUMMARY

Developing the cash flow for each alternative in a study is a pivotal, and usually the most difficult, step in the engineering economic analysis procedure. An integrated approach for developing cash flows includes three major components: (1) a WBS definition of the project, (2) a cost and revenue structure that identifies all the cost and revenue elements involved in the study, and (3) estimating techniques (models).

Estimating techniques (models) are used to develop the cash flows for the alternatives as they are defined by the WBS. Thus, the estimating techniques form a bridge between the WBS and detailed cost and revenue data and the estimated cash flows for the alternatives.

The results of the cost-estimating process are a set of cash flows for a proposed engineering project. Since these cash flows will occur at different points in time over the life cycle of the project, we will demonstrate how to account for the time value of money in our analysis. Then, we will learn procedures for determining the profitability, or economic feasibility, of the proposed project.

PROBLEMS

The number in parentheses that follows each problem refers to the section from which the problem is taken.

2.1 A "green" (environmentally friendly) office building costs an average of $3.50 per square foot each year to heat and cool. What is the total annual heating and cooling cost of an office building that has 10,000 square meters of space? **(2.3)**

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2.2 You are planning to build a new home with approximately 2,000–2,500 gross square feet of living space on one floor. In addition, you are planning an attached two-car garage (with storage space) of approximately 450 gross square feet. Develop a cost and revenue structure for designing and constructing, operating (occupying) for 10 years, and then selling the home at the end of the 10th year. **(2.2)**

2.3 Estimate the cost of an oil change (5 quarts of oil) and a new oil filter for your automobile at a local service station. It takes a technician 20 minutes to do this job. Compare your estimate with the actual cost of an oil change at the service station. What percent markup is being made by the service station? **(2.3)**

2.4 A large electric utility company releases 62 million tons of greenhouse gases (mostly carbon dioxide) into the environment each year. This company has committed to spending \$1.2 billion in capital over the next five years to reduce its annual emissions by 5%. More will be spent after five years to reduce greenhouse gases further. **(2.3)**

(a) What is the implicit cost of a ton of greenhouse gas?

(b) If the United States produces 3 billion tons of greenhouse gases per year, how much capital must be spent to reduce total emissions by 3% over the next five years based on your answer in Part (a)?

2.5. The proposed small office building in Example 2.2 had 24,000 net square feet of area heated by a natural gas furnace. The owner of the building wants to know the approximate cost of heating the structure from October through March (6 months) because she will lease heated space to the building's occupants. During the heating season, the building will require roughly 60,000 Btu per cubic foot of heated area. Natural gas has 1,000 Btu per cubic foot, and natural gas costs \$10.50 per thousand cubic foot. What will the owner pay to heat her building? **(2.3)**

2.6 An electric power distributor charges residential customers \$0.10 per kilowatt-hour (kWh). The company advertises that "green power" is available in 150 kWh blocks for an additional \$4 per month. (Green power is generated from solar, wind power, and methane sources.) **(2.3)**

(a) If a certain customer uses an average of 400 kWh per month and commits to one monthly 150 kWh block of green power, what is her annual power bill?

(b) What is the average cost per kWh with green power during the year?

(c) Why does green power cost more than conventional power?

2.7 Suppose that your brother-in-law has decided to start a company that produces synthetic lawns for senior homeowners. He anticipates starting production in 18 months. In estimating future cash flows of the company, which of the following items would be relatively easy versus relatively difficult to obtain? Also, suggest how each might be estimated with reasonable accuracy. **(2.2)**

(a) Cost of land for a 10,000-square-foot building.

(b) Cost of the building (cinder block construction).

(c) Initial working capital.

(d) Total capital investment cost.

(e) First year's labor and material costs.

(f) First year's sales revenues.

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2.8 A water filtration system in an industrial process was purchased in 2014 for $250,000. It will be replaced at the end of year 2019. What is the estimated cost of the replacement, based on the following equipment cost index? **(2.3)**

Year	Index	Year	Index
2014	220	2017	257
2015	238	2018	279
2016	247	2019	298

2.9 Prepare a composite (weighted) index for housing construction costs in 2014, using the following data: **(2.3)**

Type of Housing	Percent	Reference Year ($I = 100$)		2014	
Single units	70	41		62	
Duplex units	5	38	$/ft^2	57	$/ft^2
Multiple	25	33		53	

2.10 A microbrewery was built in 2012 at a total cost of $650,000. Additional information is given in the accompanying table (all 2000 indices = 100). **(2.3)**

Cost Element	Average Percentage of Total Brewery Cost	Index (2012)	Index (2016)
Labor	30	160	200
Materials	20	145	175
Equipment	50	135	162

(a) Calculate a weighted index for microbrewery construction in 2016.

(b) Prepare a budget estimate for a microbrewery in 2016.

2.11 The purchase price of a natural gas-fired commercial boiler (capacity X) was $181,000 eight years ago. Another boiler of the same basic design, except with capacity $1.42X$, is currently being considered for purchase. If it is purchased, some optional features presently costing $28,000 would be added for your application. If the cost index was 162 for this type of equipment when the capacity X boiler was purchased and is 221 now, and the applicable cost capacity factor is 0.8, what is your estimate of the purchase price for the new boiler? **(2.3, 2.4)**

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2.12 Today (year 0) a new 7-megaWatt (MW) solar panel farm is constructed at a cost of $14 million. Four years from today, a smaller 6-MW solar farm will be added to the existing farm. The inflation rate on solar panel construction projects averages 8% per year. If the cost-capacity factor is 0.85 for solar panel construction, what is the estimated capital investment for the smaller 6-MW solar farm? **(2.4)**

2.13 Six years ago, an 80-kW diesel electric set cost $160,000. The cost index for this class of equipment six years ago was 187 and is now 194. The cost-capacity factor is 0.6. **(2.4)**

(a) The plant engineering staff is considering a 120-kW unit of the same general design to power a small isolated plant. Assume we want to add a precompressor, which (when isolated and estimated separately) currently costs $18,000. Determine the total cost of the 120-kW unit.

(b) Estimate the cost of a 40-kW unit of the same general design. Include the cost of the $18,000 precompressor.

2.14 The capital investment cost for a switchgrass-fueled ethanol plant with a capacity of 250,000 gallons per year is $3 million. The cost-capacity factor for this particular plant technology is 0.59 for capacities ranging from 200,000 gallons per year to 500,000 gallons per year. What is the estimated capital investment for a similar ethanol plant with a capacity of 500,000 gallons per year? **(2.4)**

2.15 In a building construction project, 7,500 feet of insulated ductwork is required. The ductwork is made from 14-gauge steel costing $8.50 per pound. The 24-inch-diameter duct weighs 15 pounds per foot. Insulation for the ductwork costs $10 per foot. Engineering design will cost $16,000, and labor to install the ductwork will amount to $180,000. What is the total cost of the installed ductwork for this project? **(2.3)**

2.16 A biotech firm is considering abandoning its old plant, built 23 years ago, and constructing a new facility that has 50% more square footage. The original cost of the old facility was $300,000, and its capacity in terms of standardized production units is 250,000 units per year. The capacity of the new laboratory is to be 400,000 units per year. During the past 23 years, costs of laboratory construction have risen by an average of 5% per year. If the cost-capacity factor, based on square footage, is 0.80, what is the estimated cost of the new laboratory? **(2.4)**

2.17 The structural engineering design section within the engineering department of a regional electrical utility corporation has developed several standard designs for a group of similar transmission line towers. The detailed design for each tower is based on one of the standard designs. A transmission line project involving 50 towers has been approved. The estimated number of engineering hours needed to accomplish the first detailed tower design is 126. Assuming a 95% learning curve,

(a) What is your estimate of the number of engineering hours needed to design the eighth tower and to design the last tower in the project?

(b) What is your estimate of the cumulative average hours required for the first five designs? **(2.4)**

2.18 The overhead costs for a company are presently $\$X$ per month. The management team of the company, in cooperation with the employees, is ready to implement a comprehensive improvement program to reduce these costs. If you (a) consider an observation of

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actual overhead costs for one month analogous to an output unit, (b) estimate the overhead costs for the first month of program implementation to be $1.15X$ due to extra front-end effort, and (c) consider a 90% improvement curve applicable to the situation, what is your estimate of the percentage reduction in present overhead costs per month after 30 months of program implementation? **(2.4)**

2.19 In a learning curve application, 658.5 work hours are required for the third production unit and 615.7 work hours are required for the fourth production unit. Determine the value of n (and therefore s) in Equation (2.5). **(2.4)**

2.20 You have been asked to estimate the cost of 100 prefabricated structures to be sold to a local school district. Each structure provides 1,000 square feet of floor space, with 8-feet ceilings. In 2003, you produced 70 similar structures consisting of the same materials and having the same ceiling height, but each provided only 800 square feet of floor space. The material cost for each structure was $25,000 in 2003, and the cost capacity factor is 0.65. The cost index values for 2003 and 2014 are 200 and 289, respectively. The estimated manufacturing cost for the first 1,000-square-foot structure is $12,000. Assume a learning curve of 88% and use the cost of the 50th structure as your standard time for estimating manufacturing cost. Estimate the total material cost and the total manufacturing cost for the 100 prefabricated structures. **(2.3, 2.4)**

2.21 The cost of building a supermarket is related to the total area of the building. Data for the last 10 supermarkets built for Regork, Inc., are shown in the accompanying table.

Building	Area (ft^2)	Cost ($)
1	14,500	800,000
2	15,000	825,000
3	17,000	875,000
4	18,500	972,000
5	20,400	1,074,000
6	21,000	1,250,000
7	25,000	1,307,000
8	26,750	1,534,000
9	28,000	1,475,500
10	30,000	1,525,000

(a) Develop a CER for the construction of supermarkets. Use the CER to estimate the cost of Regork's next store, which has a planned area of 23,000 square feet. **(2.4)**

(b) Compute the standard error and correlation coefficient for the CER developed in Part (a). **(2.4)**

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2.22 In the packaging department of a large aircraft parts distributor, a fairly reliable estimate of packaging and processing costs can be determined by knowing the weight of an order. Thus, the weight is a cost driver that accounts for a sizable fraction of the packaging and processing costs at this company. Data for the past 10 orders are given as follows: **(2.4)**

Packaging and Processing Costs ($), y	Weight (Pounds), x
97	230
109	280
88	210
86	190
123	320
114	300
112	280
102	260
107	270
86	190

(a) Estimate the b_0 and b_1 coefficients, and determine the linear regression equation to fit these data.

(b) What is the correlation coefficient (R)?

(c) If an order weighs 250 lb, how much should it cost to package and process it?

2.23 A 250 square foot shell and tube heat exchanger was purchased for $15,250 in 2004 when the index value was 830. Estimate the cost of 150 square foot shell and tube heat exchanger in 2014 when the index value is 1,059 and the appropriate cost-capacity factor is 0.6. **(2.4)**

2.24 Today a proposed community college is estimated to cost $34.6 million, which is $127 per square foot of space multiplied by 272,310 square feet. If construction costs are expected to increase by 19% per year because of high demand for construction labor and materials, how much would a 320,000-square-foot community college cost five years from now? The cost capacity factor is 1.0. **(2.3)**

2.25 Your FICO score is a commonly used measure of credit risk (see www.myfico.com). A score of 850 is the best (highest) score possible. Thirty-five percent of the FICO score is based on payment history for credit cards, car loans, home mortgages, and so on. Suppose your current FICO score is 720 and you have just missed a credit card payment due date and have incurred a late payment fee! If your FICO score will drop 10% in the "payment history" category because of the late payment on your credit card, what is your new FICO score? **(2.3)**

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Table P2.26 Table for Problem 2.26

Equipment	Reference Size	Unit Reference Cost	Cost-Capacity Factor	New Design Size
Two boilers	6 MW	$300,000	0.80	10 MW
Two generators	6 MW	$400,000	0.60	9 MW
Tank	80,000 gal	$106,000	0.66	91,500 gal

2.26 A small plant has been constructed and the costs are known. A new plant is to be estimated with the use of the exponential (power sizing) costing model. Major equipment, costs, and factors are as shown in Table P2.26. (Note MW = 10^6 Watts.)

If ancillary equipment will cost an additional $200,000, find the cost for the proposed plant. **(2.4)**

2.27 *Extended Learning Exercise.* You have been asked to prepare a quick estimate of the construction cost for a coal-fired electricity generating plant and facilities. A work breakdown structure (levels one through three) is shown is Table P2.27. You have the following information available:

- A coal-fired generating plant twice the size of the one you are estimating was built in 1993. The 1993 boiler (1.2) and boiler support system (1.3) cost $110 million. The cost index for boilers was 110 in 1993, it is 492 in 2016. The cost capacity factor for similar boilers and support systems is 0.9. The 600-acre site is on property you already own, but improvements (1.1.1) and roads (1.1.2) will cost $2,000 per acre, and railroads (1.1.3) will cost $3,000,000. Project integration (1.9) is projected to cost 3% of all other construction costs.
- The security systems (1.5.4) are expected to cost $1,500 per acre, according to recent (2016) construction of similar plants. All other support facilities and equipment (1.5) elements are to be built by Viscount Engineering. Viscount Engineering has built the support facilities and equipment elements for two similar generating plants. Their experience is expected to reduce labor requirements substantially; a 90% learning curve can be assumed. Viscount built the support facilities and equipment on their first job in 95,000 hours. For this project, Viscount's labor will be billed to you at $60 per hour. Viscount estimates that materials for the construction of the support facilities and equipment elements (except 1.5.4) will cost you $15,000,000.
- The coal storage facility (1.4) for the coal-fired generating plant built in 1993 cost $5 million. Although your plant is smaller, you require the same size coal storage facility as the 1993 plant. You assume you can apply the cost index for similar boilers to the coal storage facility.

  What is your estimated 2016 cost for building the coal-fired generating facility? Summarize your calculations in a cost estimating worksheet, and state the assumptions you make.

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Table P2.27 Work Breakdown Structure for Problem 2.27

PROJECT: Coal-Fired Electricity Generating Plant and Facilities		
Line No.	**Title**	**WBS Element Code**
001	Coal-fired power plant	1.
002	Site	1.1
003	Land improvements	1.1.1
004	Roads, parking, and paved areas	1.1.2
005	Railroads	1.1.3
006	Boiler	1.2
007	Furnace	1.2.1
008	Pressure vessel	1.2.2
009	Heat exchange system	1.2.3
010	Generators	1.2.4
011	Boiler support system	1.3
012	Coal transport system	1.3.1
013	Coal pulverizing system	1.3.2
014	Instrumentation and control	1.3.3
015	Ash disposal system	1.3.4
016	Transformers and distribution	1.3.5
017	Coal storage facility	1.4
018	Stockpile reclaim system	1.4.1
019	Rail car dump	1.4.2
020	Coal handling equipment	1.4.3
021	Support facilities and equipment	1.5
022	Hazardous waste systems	1.5.1
023	Support equipment	1.5.2
024	Utilities and communications system	1.5.3
025	Security systems	1.5.4
026	Project integration	1.9
027	Project management	1.9.1
028	Environmental management	1.9.2
029	Project safety	1.9.3
030	Quality assurance	1.9.4
031	Test, start-up, and transition management	1.9.5

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SPREADSHEET EXERCISES

2.28 Refer to Example 2.7. Construct a graph to show how the time to complete the 10th car changes as the learning curve slope parameter is varied from 75% to 95%. **(2.4)**

2.29 The Betterbilt Construction Company designs and builds residential mobile homes. The company is ready to construct, in sequence, 16 new homes of 2,400 square feet each. The successful bid for the construction materials in the first home is $64,800, or $27 per square foot. The purchasing manager believes that several actions can be taken to reduce material costs by 8% each time the number of homes constructed doubles. Based on this information,

(a) What is the estimated cumulative average material cost per square foot for the first five homes?

(b) What is the estimated material cost per square foot for the last (16th) home? **(2.4)**

2.30 Refer to Example 2.8. While cleaning out an old file, someone uncovers the first spacecraft manufactured by your company—30 years ago! It weighed 100 pounds and cost $600 million. Extend the spreadsheet to include this data point. How does adding this observation affect R and the standard error? How about the regression coefficients? Should this new data point be included in the model used for predicting future costs? **(2.4)**

CASE STUDY EXERCISES

2.31 What other cost factors might you include in such an economic analysis? **(2.5)**

2.32 What cost factor is the per unit demanufacturing cost most sensitive to and why? **(2.5)**

2.33 What is the projected impact on the per unit demanufacturing cost of a 50% increase in training costs coupled with a 90% increase in transportation costs? What is the revised cost reduction percentage? **(2.5)**

Use the cost template presented in Section 2.5 to solve Problems **(2.34)** and **(2.35)**.

2.34 You have been asked to *estimate the per unit selling price* of a new line of clothing. Pertinent data are as follows:

Direct labor rate:	$15.00 per hour
Production material:	$375 per 100 items
Factory overhead:	125% of direct labor
Packing costs:	75% of direct labor
Desired profit:	20% of total manufacturing cost

Past experience has shown that an 80% learning curve applies to the labor required for producing these items. The time to complete the first item has been estimated to be 1.76 hours. Use the estimated time to complete the 50th item as your standard time for the purpose of estimating the unit selling price. **(2.4, 2.5)**

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2.35 Given the following information, how many units must be sold to achieve a profit of $25,000? [Note that the units sold must account for total production costs (direct and overhead) plus desired profit.] **(2.4, 2.5)**

Direct labor hours:	0.2 hour/unit
Direct labor costs:	$21.00/hour
Direct materials cost:	$4.00/unit
Overhead costs:	120% of direct labor
Packaging and shipping:	$1.20/unit
Selling price:	$20.00/unit

FE PRACTICE PROBLEMS

2.36 Find the average time per unit required to produce the first 30 units, if the slope parameter of the learning rate is 92% and the first unit takes 460 hours.

(a) −3.30693E-11

(b) 305.5404

(c) 245

(d) 347.3211

2.37 A student is considering the purchase of two alternative cars. Car A initially costs $1,500 more than Car B, but uses 0.05 gallons per mile, versus 0.07 gallons per mile for Car B. Both cars will last for 10 years, and B's market value is $800 less than A's. Fuel costs $4.00 per gallon. If all else is equal, at how many miles driven per year does Car A become preferable to Car B?

(a) 875

(b) 1,167

(c) 1,723

(d) 1,892

2.38 An automatic process controller will eliminate the current manual control operation. Annual cost of the current method is $4,000. If the controller has a service life of 13 years and an expected market value of 11% of the first cost, what is the maximum economical price for the controller? Ignore interest.

(a) $28,869

(b) $58,426

(c) $26,358

(d) $25,694

(e) $53,344

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2.39 A foreman supervises A, B, and eight other employees. The foreman states that he spends twice as much time supervising A and half as much time supervising B, compared with the average time spent supervising his other subordinates. All employees have the same production rate. On the basis of equal cost per unit production, what monthly salary is justified for B if the foreman gets \$3,800 per month and A gets \$3,000 per month?

(a) \$3,543

(b) \$3,800

(c) \$3,000

(d) \$2,457

(e) \$3,400

2.40 A car rental agency is considering a modification in its oil change procedure. Currently, it uses a Type X filter, which costs \$5 and must be changed every 7,000 miles along with the oil (5 quarts). Between each oil change, one quart of oil must be added after each 1,000 miles. The proposed filter (Type Y) has to be replaced every 5,000 miles (along with 5 quarts of oil) but does not require any additional oil between filter changes. If the oil costs \$1.08 per quart, what is the maximum acceptable price for the Type Y filter?

(a) \$12.56

(b) \$7.43

(c) \$11.48

(d) \$6.66

2.41 A small textile plant was constructed in 2004. The major equipment, costs, and factors are shown below.

Estimate the cost to build a new plant in 2014 if the index for this type of equipment has increased at an average rate of 12% per year for the past 10 years. Select the closest answer. **(2.4)**

(a) \$4,618,000

(b) \$10,623,000

(c) \$14,342,000

(d) \$14,891,000

Equipment	Reference Size	Reference Cost	Cost-Capacity Factor	New Design Size
Finishing machine	150 yd/min	\$900,000	0.92	200 yd/min
Jet dyer	200 yd/min	\$1,125,000	0.87	450 yd/min
Steam dyer	100 yd/min	\$750,000	0.79	175 yd/min

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Time Value of Money

Taken from *Engineering Economics: Financial Decision Making for Engineers,* Fifth Edition by Niall M. Fraser and Elizabeth M. Jewkes.

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ENGINEERING ECONOMICS IN ACTION, PART 3A

A Steal For Steel

"Naomi, can you check this for me?" Terry's request broke the relative silence as Naomi and Terry worked together one Tuesday afternoon. "I was just reviewing our J-class line for Clem, and it seems to me that we could save a lot of money there."

"Okay, tell me about it." Since Naomi and Terry had met two weeks earlier, just after Naomi started her job, things had being going very well. Terry, an engineering student at the local university, was on a four-month co-op work term industrial placement at Canadian Widgets.

"Well, mostly we use the heavy rolled stock on that line. According to the pricing memo we have for that kind of steel, there is a big price break at a volume that could supply our needs for six months. We've been buying this stuff on a week-by-week basis. It just makes sense to me to take advantage of that price break."

"Interesting idea, Terry. Have you got data about how we have ordered before?"

"Yep, right here."

"Let's take a closer look."

"Well," Terry said, as he and Naomi looked over his figures, "the way we have been paying doesn't make too much sense. We order about a week's supply. The cost of this is added to our account. Every six months we pay off our account. Meanwhile, the supplier is charging us 2 percent of our outstanding amount at the end of each month!"

"Well, at least it looks as if it might make more sense to pay off our bills more often," Naomi replied.

"Now look at this. In the six months ending last December, we ordered steel for a total cost of $1 600 000. If we had bought this steel at the beginning of July, it would have only cost $1 400 000. That's a saving of $200 000!"

"Good observation, Terry, but I don't think buying in advance is the right thing to do. If you think about it . . ."

3.1 Introduction

Engineering decisions frequently involve evaluating tradeoffs among costs and benefits that occur at different times. A typical situation is when we invest in a project today in order to obtain benefits from the project in the future. This chapter discusses the economic methods used to compare benefits and costs that occur at different times. The key to making these comparisons is the use of an interest rate. In Sections 3.2 to 3.5, we illustrate the comparison process with examples and introduce some interest and interest rate terminology. Section 3.6 deals with cash flow diagrams, which are graphical representations of the magnitude and timing of cash flows over time. Section 3.7 explains the equivalence of benefits and costs that occur at different times.

3.2 Interest and Interest Rates

Everyone is familiar with the idea of interest from their everyday activities:

From a furniture store ad: *Pay no interest until next year!*

From a bank: *Now 2.6 percent daily interest on passbook accounts!*

Why are there interest rates? If people are given the choice between having money today and the same amount of money one year from now, most would prefer the money today. If they had the money today, they could do something productive with it in hopes of benefit in the future. For example, they could buy an asset like a machine today, and could

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NET VALUE 3.1

Prime Interest Rates

When you hear about the interest rate going up or down in the news, it usually refers to the *prime rate*—the interest rate charged by banks to their most creditworthy customers, such as prominent businesspeople. It attracts people's attention because it is the reference point for interest rates charged on many mortgage, personal, and business loans. The prime rate is almost always the same among major banks. The internet makes it easy to collect and compare interest rate information from banks and other financial institutions.

Contrary to what many people may think, the prime rate is *not* set by the Bank of Canada, the country's central bank. Its role, as defined in the original *Bank of Canada Act* of 1934, is to promote the economic and financial well-being of Canada, but setting the prime rate on behalf of all Canadian banks is not one of its jobs. This doesn't mean that the Bank of Canada is not interested in having control over what the prime rate should be. It does try to influence the rate by setting the target for the short-term interest rates called *overnight rates*, which represent the average interest rates that the Bank of Canada would like to see in the marketplace and are representative of what the prime rate should be. Find more on the Bank of Canada and its role in setting or influencing various interest rates at its website at www.bankofcanada.ca.

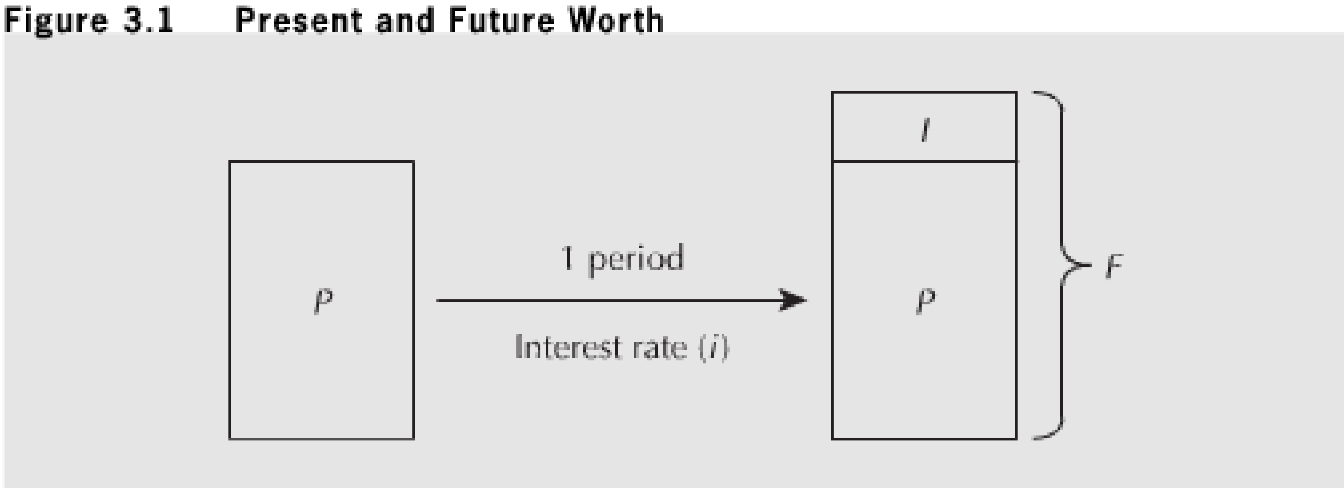
use it to make money from their initial investment. Or they may want to buy a consumer good like a new home theatre system and start enjoying it immediately. What this means is that one dollar today is worth more than one dollar in the future. This is because a dollar today can be invested for productive use, while that opportunity is lost or diminished if the dollar is not available until some time in the future.

The observation that a dollar today is worth more than a dollar in the future means that people must be compensated for lending money. They are giving up the opportunity to invest their money for productive purposes now on the promise of getting more money in the future. The compensation for loaning money is in the form of an interest payment—say, I. More formally, **interest** is the difference between the amount of money lent and the amount of money later repaid. It is the compensation for giving up the use of the money for the duration of the loan.

An amount of money today, P (also called the *principal amount*), can be related to a *future amount* F by the interest amount I or interest rate i. This relationship is illustrated graphically in Figure 3.1 and can be expressed as $F = P + I$. The interest I can also be expressed as an interest rate i with respect to the principal amount so that $I = Pi$. Thus

$$\begin{aligned} F &= P + Pi \\ &= P(1 + i) \end{aligned}$$

Figure 3.1 Present and Future Worth



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EXAMPLE 3.1

Samuel bought a one-year guaranteed investment certificate (GIC) for \$5000 from a bank on May 15 last year. The bank was paying 10 percent on one-year guaranteed investment certificates at the time. One year later, Samuel cashed in his certificate for \$5500.

We may think of the interest payment that Samuel got from the bank as compensation for giving up the use of money. When Samuel bought the GIC for \$5000, he gave up the opportunity to use the money in some other way during the following year. On the other hand, the bank got use of the money for the year. In effect, Samuel lent \$5000 to the bank for a year. The \$500 interest was payment by the bank to Samuel for the loan. The bank wanted the loan so that it could use the money for the year. (It may have lent the money to someone else at a higher interest rate.) ■

This leads to a formal definition of interest rates. Divide time into periods like days, months, or years. If the right to P at the beginning of a time period exchanges for the right to F at the end of the period, where $F = P(1 + i)$, i is the **interest rate** per time period. In this definition, P is called the **present worth** of F, and F is called the **future worth** of P.

EXAMPLE 3.1 RESTATED

Samuel invested \$5000 with the bank on May 15 last year. The bank was paying 10 percent on one-year fixed term investments at the time. The agreement gave Samuel the right to claim \$5500 from the bank one year later.

Notice in this example that there was a transaction between Samuel and the bank on May 15 last year. There was an exchange of \$5000 on May 15 a year ago for the right to collect \$5500 on May 15 this year. The bank got the \$5000 last year and Samuel got the right to collect \$5500 one year later. Evidently, having a dollar on May 15 last year was worth more than the right to collect a dollar a year later. Each dollar on May 15 last year was worth the right to collect $5500/5000 = 1.1$ dollars a year later. This 1.1 may be written as $1 + 0.1$, where 0.1 is the interest rate. The interest rate, then, gives the rate of exchange between money at the beginning of a period (one year in this example) and the right to money at the end of the period. ■

The dimension of an interest rate is currency/currency/time period. For example, a 9 percent interest rate means that for every dollar lent, 0.09 dollars (or other unit of money) is paid in interest for each time period. The value of the interest rate depends on the length of the time period. Usually, interest rates are expressed on a yearly basis, although they may be given for periods other than a year, such as a month or a quarter. This base unit of time over which an interest rate is calculated is called the **interest period**. Interest periods are described in more detail in Close-Up 3.1. The longer the interest period, the higher the interest rate must be to provide the same return.

Interest concerns the lending and borrowing of money. It is a parameter that allows an exchange of a larger amount of money in the future for a smaller amount of money in the present, and vice versa. As we will see in Chapter 4, it also allows us to evaluate very complicated exchanges of money over time.

Interest also has a physical basis. Money can be invested in financial instruments that pay interest, such as a bond or a savings account, and money can also be invested directly in industrial processes or services that generate wealth. In fact, the money invested in financial instruments is also indirectly invested in productive activities by the organization

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CLOSE-UP 3.1 Interest Periods

The most commonly used interest period is one year. If we say, for example, "6 percent interest" without specifying an interest period, the assumption is that 6 percent interest is paid for a one-year period. However, interest periods can be of any duration. Here are some other common interest periods:

Interest Period	Interest Is Calculated:
Semiannually	Twice per year, or once every six months
Quarterly	Four times a year, or once every three months
Monthly	12 times per year
Weekly	52 times per year
Daily	365 times per year
Continuous	For infinitesimally small periods

providing the instrument. Consequently, the root source of interest is the productive use of money, as this is what makes the money actually increase in value. The actual return generated by a specific productive investment varies enormously, as will be seen in Chapter 5.

3.3 Compound and Simple Interest

We have seen that if an amount, P, is lent for one interest period at the interest rate, i, the amount that must be repaid at the end of the period is $F = P(1 + i)$. But loans may be for several periods. How is the quantity of money that must be repaid computed when the loan is for N interest periods? The usual way is one period at a time. Suppose that the amount P is borrowed for N periods at the interest rate i. The amount that must be repaid at the end of the N periods is $P(1 + i)^N$; that is

$$F = P(1 + i)^N \tag{3.1}$$

This is derived as shown in Table 3.1.

This method of computing interest is called *compounding*. Compounding assumes that there are N sequential one-period loans. At the end of the first interest period, the borrower owes $P(1 + i)$. This is the amount borrowed for the second period. Interest is

Table 3.1 Compound Interest Computations

Beginning of Period	Amount Lent		Interest Amount	Amount Owed at Period End
1	P	+	Pi	$= P + Pi = P(1 + i)$
2	$P(1 + i)$	+	$P(1 + i)i$	$= P(1 + i) + P(1 + i)i = P(1 + i)^2$
3	$P(1 + i)^2$	+	$P(1 + i)^2 i$	$= P(1 + i)^2 + P(1 + i)^2 i = P(1 + i)^3$
$\vdots$	$\vdots$			
N	$P(1 + i)^{N-1}$	+	$[P(1 + i)^{N-1}]i$	$= P(1 + i)^N$

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required on this larger amount. At the end of the second period $[P(1 + i)](1 + i)$ is owed. This is the amount borrowed for the third period. This continues so that at the end of the $(N - 1)$th period, $P(1 + i)^{N-1}$ is owed. The interest on this over the Nth period is $[P(1 + i)^{N-1}]i$. The total interest on the loan over the N periods is

$$I_c = P(1 + i)^N - P \tag{3.2}$$

I_c is called **compound interest**. It is the standard method of computing interest where interest accumulated in one interest period is added to the principal amount used to calculate interest in the next period. The interest period used with the compound interest method is called the **compounding period**.

EXAMPLE 3.2

If you were to lend \$100 for three years at 10 percent per year compound interest, how much interest would you get at the end of the three years?

If you lend \$100 for three years at 10 percent compound interest per year, you will earn \$10 in interest in the first year. That \$10 will be lent, along with the original \$100, for the second year. Thus, in the second year, the interest earned will be \$11 = \$110(0.10). The \$11 is lent for the third year. This makes the loan for the third year \$121, and \$12.10 = \$121(0.10) in interest will be earned in the third year. At the end of the three years, the amount you are owed will be \$133.10. The interest received is then \$33.10. This can also be calculated from Equation (3.2):

$$I_c = F - P = 100(1 + 0.1)^3 - 100 = 33.10$$ **= 100*(1 + 0.1)^3 − 100**

Table 3.2 summarizes the compounding process.

An Excel spreadsheet corresponding to Table 3.2 along with instructions for creating it are provided in the Spreadsheet Savvy box on page 98. ■

Table 3.2 Compound Interest Computations for Example 3.2

Beginning of Year	Amount Lent		Interest Amount		Amount Owed at Year-End
1	100	+	100 × 0.1	=	\$110
2	110	+	110 × 0.1	=	\$121
3	121	+	121 × 0.1	=	\$133.10

If the interest payment for an N-period loan at the interest rate i per period is computed without compounding, the interest amount, I_s, is called *simple interest*. It is computed as

$$I_s = PiN$$

Simple interest is a method of computing interest where interest earned during an interest period is not added to the principal amount used to calculate interest in the next period. Simple interest is rarely used in practice, except as a method of calculating approximate interest.

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SPREADSHEET SAVVY

One of the most common uses of spreadsheets is to compute the value of formulas. The formulas written into a cell of a worksheet can be as complicated as necessary to write out the calculation desired. It's a good idea to use parentheses often, both to indicate the order of execution of the operations within the formula and to make error checking easier. Use + and − for addition and subtraction, * for multiplication, / for division, and ^ for exponentiation. Within a formula, you can refer to values that are stored in other cells. For example, if the value for P is in cell B1, the value for i is in cell B2, and the value for N is in cell A8, the expression $P(1 + i)^{N-1}$ is entered into a worksheet cell as "=B1*(1 + B2)^(A8 − 1)." Note that the = sign is used to indicate that the expression is to be evaluated by Excel.

Worksheets such as the one shown in Table 3.2 are particularly easy to create in a spreadsheet program. It is a good idea to designate one area of the spreadsheet for parameters and to document each. For example, the values for P and i are entered into cells B1 and B2. For documentation, cells A1 and A2 have text indicating what cells B1 and B2 mean. Calculations in other cells of the worksheet can reference the values of P and i, and these calculations can be easily updated simply by changing the contents of cells B1 or B2 as needed.

In the example worksheet below, Table 3.2 is reproduced for five periods for a principal amount P = \$100 and an interest rate of i = 10 percent. The values are shown in the left-hand table and the formulas used are shown in the right. Start by entering "=B1" into cell B4. C4 is computed as the product of cells B4 and B2, and D4 as the sum of B4 and C4. Cell B5, the amount owed at the beginning of period 2, is the amount owed at the end of period 1, D4. Once cells C5 and D5 are entered, rows 6 through 8 can be completed by using the Fill Down function: Highlight cells B5:D5 to B8:D8, and under the Home tab in Excel, select Fill Down. This will copy the formulas from cells B5 to D5 down to rows 6 through 8, making the appropriate row number adjustments automatically. Copying and pasting will achieve the same effect.

Important: the "\$" entered in cell C4 in reference to B\$2 tells Excel not to adjust the row reference to the interest rate when cell B2 is filled down or pasted.

	A	B	C	D
1	P =	\$100.00		
2	i =	10.00%		
3	Beginning of Period	Amount Lent	Interest Amount	Amount Owed at Period End
4	1	\$100.00	\$10.00	\$110.00
5	2	\$110.00	\$11.00	\$121.00
6	3	\$121.00	\$12.10	\$133.10
7	4	\$133.10	\$13.31	\$146.41
8	5	\$146.41	\$14.64	\$161.05

	A	B	C	D
1	P =	100		
2	i =	0.1		
3	Beginning of Period	Amount Lent	Interest Amount	Amount Owed at Period End
4	1	=B1	=B4*B\$2	=B4+C4
5	2	=D4	=B5*B\$2	=B5+C5
6	3	=D5	=B6*B\$2	=B6+C6
7	4	=D6	=B7*B\$2	=B7+C7
8	5	=D7	=B8*B\$2	=B8+C8

EXAMPLE 3.3

If you were to lend \$100 for three years at 10 percent per year simple interest, how much interest would you get at the end of the three years?

The total amount of interest earned on the \$100 over the three years would be \$30. This can be calculated by using $I_s = PiN$:

$$I_s = PiN = 100(0.10)(3) = 30$$ ■

Interest amounts computed with simple interest and compound interest will yield the same results only when the number of interest periods is one. As the number of periods increases, the difference between the accumulated interest amounts for the two methods increases exponentially.

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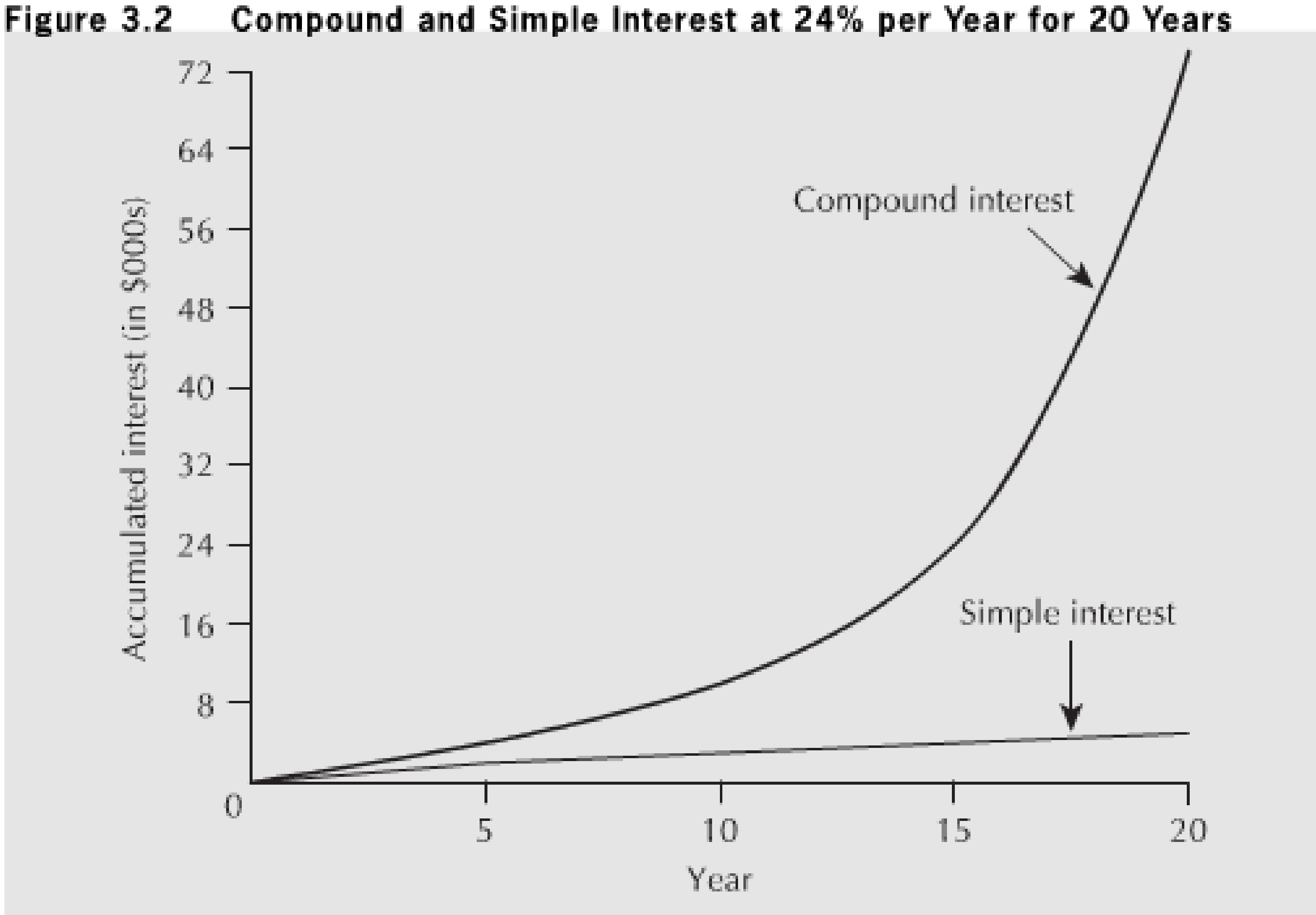
Figure 3.2 Compound and Simple Interest at 24% per Year for 20 Years



When the number of interest periods is significantly greater than one, the difference between simple interest and compound interest can be very great. In April 1993, a couple in Nevada presented the state government with a $1000 bond issued by the state in 1865. The bond carried an annual interest rate of 24 percent. The couple claimed the bond was now worth several trillion dollars (*Newsweek*, August 9, 1993, p. 8). If one takes the length of time from 1865 to the time the couple presented the bond to the state as 128 years, the value of the bond could have been $908 trillion = $1000(1 + 0.24)^{128}$. As of 2012, the value would have been $54 quadrillion!

If, instead of compound interest, a simple interest rate given by $iN = (24\%)(128) = 3072$ percent were used, the bond would be worth only $31 720 = $1000(1 + 30.72). Thus, the difference between compound and simple interest can be dramatic, especially when the interest rate is high and the number of periods is large. The graph in Figure 3.2 shows the difference between compound interest and simple interest for the first 20 years of the bond example. As for the couple in Nevada, the $1000 bond was worthless after all—a state judge ruled that the bond had to have been cashed by 1872.

The conventional approach for computing interest is the compound interest method rather than simple interest. Simple interest is rarely used, except perhaps as an intuitive (yet incorrect!) way of thinking of compound interest. We mention simple interest primarily to contrast it with compound interest and to indicate that the difference between the two methods can be large.

3.4 Effective and Nominal Interest Rates

Interest rates may be stated for some period, such as a year, while the computation of interest is based on shorter compounding subperiods such as months. In this section we consider the relation between the *nominal* interest rate that is stated for the full period and the *effective* interest rate that results from the compounding based on the subperiods. This relation between nominal and effective interest rates must be understood to

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answer questions such as: How would you choose between two investments, one bearing 12 percent per year interest compounded yearly and another bearing 1 percent per month interest compounded monthly? Are they the same?

Nominal interest rate is the conventional method of stating the annual interest rate. It is calculated by multiplying the interest rate per compounding period by the number of compounding periods per year. Suppose that a time period is divided into m equal subperiods. Let there be stated a nominal interest rate, r, for the full period. By convention, for nominal interest, the interest rate for each subperiod is calculated as $i_s = r/m$. For example, a nominal interest rate of 18 percent per year, compounded monthly, is the same as

$$0.18/12 = 0.015 \text{ or } 1.5 \text{ percent per month}$$

Effective interest rate is the actual but not usually stated interest rate, found by converting a given interest rate with an arbitrary compounding period (normally less than a year) to an equivalent interest rate with a one-year compounding period. What is the effective interest rate, i_e, for the full period that will yield the same amount as compounding at the end of each subperiod, i_s? If we compound interest every subperiod, we have

$$F = P(1 + i_s)^m$$

We want to find the effective interest rate, i_e, that yields the same future amount F at the end of the full period from the present amount P. Set

$$P(1 + i_s)^m = P(1 + i_e)$$

Then

$$(1 + i_s)^m = 1 + i_e$$

$$i_e = (1 + i_s)^m - 1 \tag{3.3}$$

Note that Equation (3.3) allows the conversion between the interest rate over a compounding subperiod, i_s, and the effective interest rate over a longer period, i_e, by using the number of subperiods, m, in the longer period.

EXAMPLE 3.4

What is the annual effective interest rate equivalent to a nominal rate of 12 percent a year?

The nominal interest rate is given as r = 12 percent, and the number of corresponding periods per year is $m = 12$. This gives $i_s = r/m = 0.12/12 = 0.01$. Then:

$$\begin{aligned} i_e &= (1 + i_s)^m - 1 \\ &= (1 + 0.01)^{12} - 1 \\ &= 0.126825 \\ &\approx 0.127 \text{ or } 12.7\% \end{aligned}$$

= (1 + 0.01)^12 − 1

An interest rate of 1 percent per month, compounded monthly, is equivalent to an effective rate of approximately 12.7 percent per year, compounded yearly. ■

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Interest rates are normally given as nominal rates. We may get the effective (yearly) rate by substituting $i_s = r/m$ into Equation (3.3). We then obtain a direct means of computing an effective interest rate, given a nominal rate and the number of compounding periods per year:

$$i_e = \left(1 + \frac{r}{m}\right)^m - 1 \tag{3.4}$$

This formula is suitable only for converting from a nominal rate r to an annual effective rate. If the effective rate desired is for a period longer than a year, then Equation (3.3) must be used.

EXAMPLE 3.5

Leona the loan shark lends money to clients at a rate of 5 percent interest per week! What is the nominal interest rate for these loans? What is the effective annual interest rate?

The nominal interest rate is 5 percent × 52 = 260 percent. Recall that nominal interest rates are usually expressed on a yearly basis. The effective yearly interest rate can be found by substitution into Equation (3.3):

$$i_e = (1 + 0.05)^{52} - 1 = 12.64$$

Leona charges an effective annual interest rate of about 1264 percent on her loans. ■

EXAMPLE 3.6

The Cardex Credit Card Company charges a nominal 24 percent interest on overdue accounts, compounded daily. What is the effective interest rate?

Assuming that there are 365 days per year, we can calculate the interest rate per day using either Equation (3.3) with $i_s = r/m = 0.24/365 = 0.0006575$ or by the use of Equation (3.4) directly. The effective interest rate (per year) is

$$i_e = (1 + 0.0006575)^{365} - 1 \qquad \mathbf{= (1 + 0.24/365)\verb|^|365 - 1}$$

$$= 0.271 \text{ or } 27.1\%$$

With a nominal rate of 24 percent compounded daily, the Cardex Credit Card Company is actually charging an effective rate of about 27.1 percent per year. ■

Although there are laws that may require that the effective interest rate be disclosed for loans and investments, it is still very common for nominal interest rates to be quoted. Since the nominal rate will be less than the effective rate whenever the number of compounding periods per year exceeds one, there is an advantage to quoting loans using the nominal rates, since it makes the loan look more attractive. This is particularly true when interest rates are high and compounding occurs frequently.

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3.5 Continuous Compounding

As has been seen, compounding can be done yearly, quarterly, monthly, or daily. The periods can be made even smaller—as small as desired; the main disadvantage in having very small periods is having to do more calculations. If the period is made infinitesimally small, we say that interest is compounded *continuously*. There are situations in which very frequent compounding makes sense. For instance, an improvement in materials handling may reduce downtime on machinery. There will be benefits in the form of increased output that may be used immediately. If there are several additional runs a day, there will be benefits several times a day. Another example is trading on the stock market. Personal and corporate investments are often in the form of mutual funds. Mutual funds represent a changing set of stocks and bonds in which transactions occur very frequently, often many times a day.

A formula for **continuous compounding** can be developed from Equation (3.3) by allowing the number of compounding periods per year to become infinitely large:

$$i_e = \lim_{m \to \infty}\left(1 + \frac{r}{m}\right)^m - 1$$

By noting from a definition of the natural exponential function, e, that

$$\lim_{m \to \infty}\left(1 + \frac{r}{m}\right)^m = e^r$$

we get

$$i_e = e^r - 1 \tag{3.5}$$

EXAMPLE 3.7

Cash flow at the Arctic Oil Company is continuously reinvested. An investment in a new data logging system is expected to return a nominal interest of 40 percent, compounded continuously. What is the effective interest rate earned by this investment?

The nominal interest rate is given as $r = 0.40$. From Equation (3.5),

$i_e = e^{0.4} - 1$ **= exp(0.4) − 1**

$= 1.492 - 1 \cong 0.492$ or 49.2%

The effective interest rate earned on this investment is about 49.2 percent. ■

Although continuous compounding makes sense in some circumstances, it is rarely used. As with effective interest and nominal interest, in the days before calculators and computers, calculations involving continuous compounding were difficult to do. Consequently, discrete compounding is, by convention, the norm. As illustrated in Figure 3.3, the difference between continuous compounding and discrete compounding is relatively insignificant, even at a fairly high interest rate.

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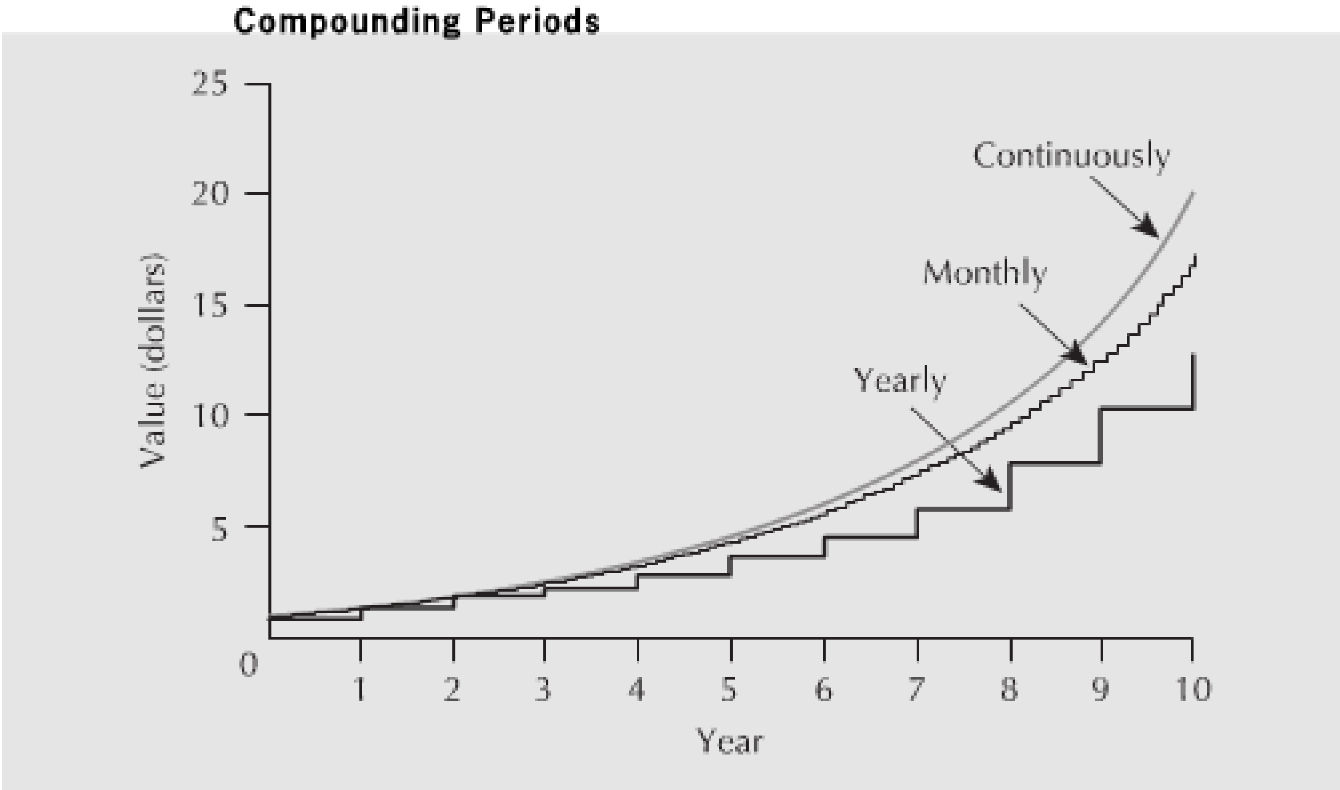
Figure 3.3 Growth in Value of $1 at 30% Interest for Various Compounding Periods

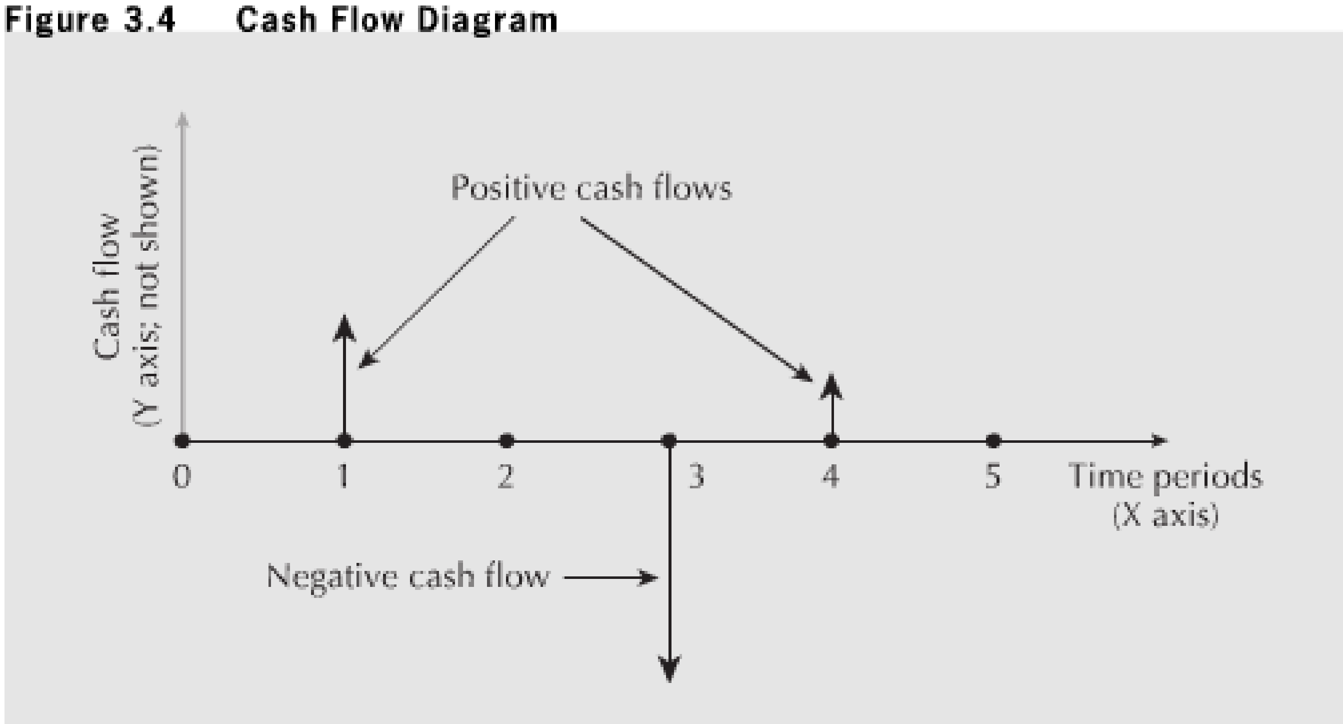


3.6 Cash Flow Diagrams

Sometimes a set of cash flows can be sufficiently complicated that it is useful to have a graphical representation. A **cash flow diagram** is a graph that summarizes the timing and magnitude of cash flows as they occur over time.

On a cash flow diagram, the graph's vertical axis is not shown explicitly. The horizontal (X) axis represents time, measured in periods, and the vertical (Y) axis represents the size and direction of the cash flows. Individual cash flows are indicated by arrows pointing up or down from the horizontal axis, as indicated in Figure 3.4. The arrows that point up represent positive cash flows, or receipts. The downward-pointing arrows represent negative cash flows, or disbursements. See Close-Up 3.2 for some conventions pertaining to the beginning and ending of periods.

Figure 3.4 Cash Flow Diagram



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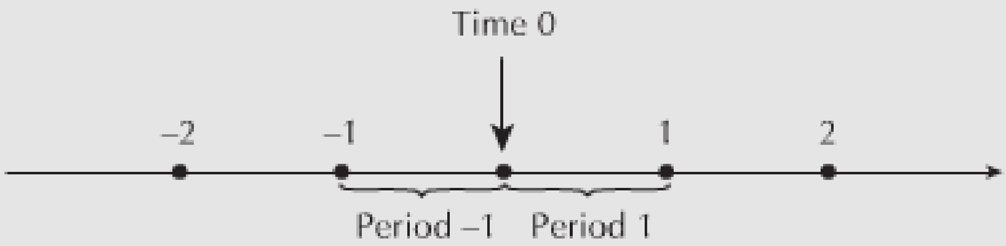
CLOSE-UP 3.2 Beginning and Ending of Periods

As illustrated in a cash flow diagram (see Figure 3.4), the end of one period is exactly the same point in time as the beginning of the next period. Now is time 0, which is the end of period –1 and also the beginning of period 1. The end of period 1 is the same as the beginning of period 2, and so on. N years from now is the end of period N and the beginning of period (N + 1).

Figure 3.5 Beginning and Ending of Periods



EXAMPLE 3.8

Consider Ashok, a recent university graduate who is trying to summarize typical cash flows for each month. His monthly income is \$2200, received at the end of each month. Out of this he pays for rent, food, entertainment, telephone charges, and a credit card bill for all other purchases. Rent is \$700 per month (including utilities), due at the end of each month. Weekly food and entertainment expenses total roughly \$120, a typical telephone bill is \$40 (due at the end of the first week in the month), and his credit card purchases average \$300. Credit card payments are due at the end of the second week of each month.

Figure 3.6 shows the timing and amount of the disbursements and the single receipt over a typical month. It assumes that there are exactly four weeks in a month, and it is now just past the end of the month. Each arrow, which represents a cash flow, is labelled with the amount of the receipt or disbursement.

When two or more cash flows occur in the same time period, the amounts may be shown individually, as in Figure 3.6, or in summary form, as in Figure 3.7. The level of detail used depends on personal choice and the amount of information the diagram is intended to convey.

We suggest that the reader make a practice of using cash flow diagrams when working on a problem with cash flows that occur at different times. Just going through the steps in setting up a cash flow diagram can make the problem structure clearer. Seeing the pattern of cash flows in the completed diagram gives a "feel" for the problem. ■

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Figure 3.6 Cash Flow Diagram for Example 3.8

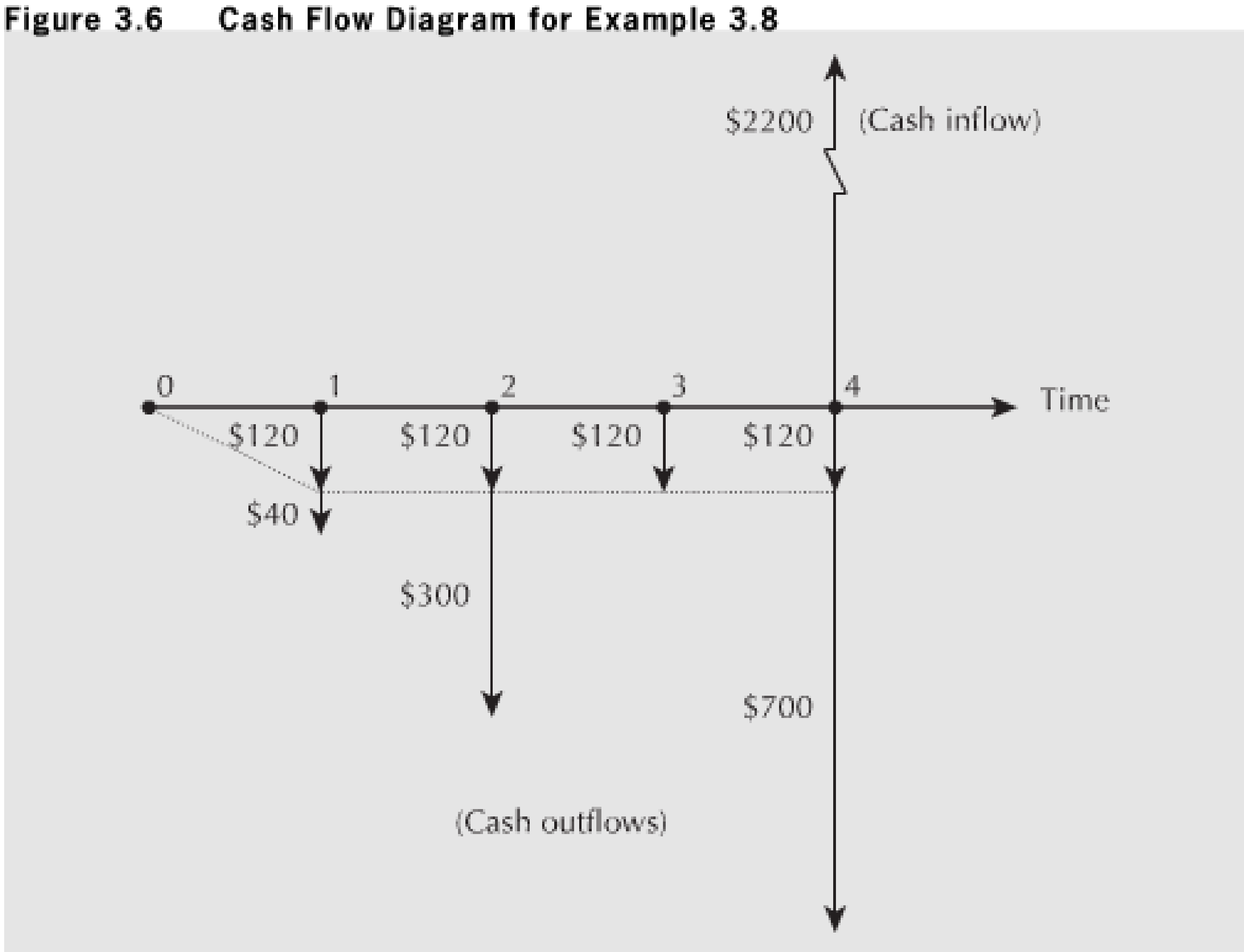
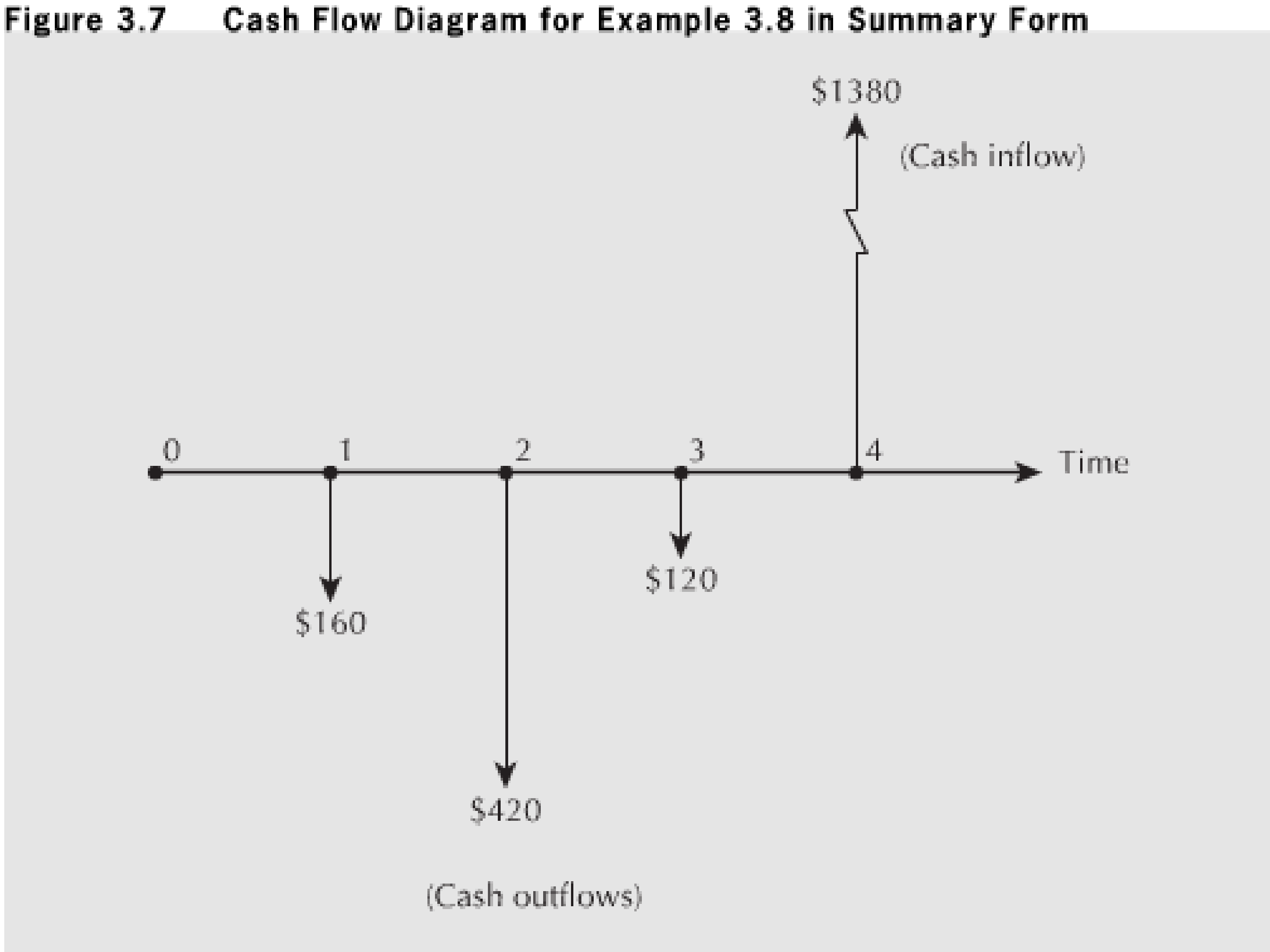


Figure 3.7 Cash Flow Diagram for Example 3.8 in Summary Form



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3.7 Equivalence

We started this chapter by pointing out that many engineering decisions involve costs and benefits that occur at different times. Making these decisions requires that the costs and benefits at different times be compared. To make these comparisons, we must be able to say that certain values at different times are *equivalent*. **Equivalence** is a condition that exists when the value of a cost at one time is equivalent to the value of the related benefit received at a different time. In this section we distinguish three concepts of equivalence that may underlie comparisons of costs and benefits at different times.

With **mathematical equivalence**, equivalence is a consequence of the mathematical relationship between time and money. This is the form of equivalence used in $F = P(1 + i)^N$.

With **decisional equivalence**, equivalence is a consequence of indifference on the part of a decision maker among available choices.

With **market equivalence**, equivalence is a consequence of the ability to exchange one cash flow for another at zero cost.

Although the mathematics governing money is the same regardless of which form of equivalence is most appropriate for a given situation, it can be important to be aware of what assumptions must be made for the mathematical operations to be meaningful.

3.7.1 Mathematical Equivalence

Mathematical equivalence is simply a mathematical relationship. It says that two cash flows, P_t at time t and F_{t+N} at time $t + N$, are equivalent with respect to the interest rate, i, if $F_{t+N} = P_t(1 + i)^N$. Notice that if F_{t+N+M} (where M is a second number of periods) is mathematically equivalent to P_t, then

$$
\begin{aligned}
F_{t+N+M} &= P_t(1 + i)^{N+M} \\
&= F_{t+N}(1 + i)^M
\end{aligned}
$$

so that F_{t+N} and F_{t+N+M} are also equivalent to each other. The fact that mathematical equivalence has this property permits complex comparisons to be made among many cash flows that occur over time.

3.7.2 Decisional Equivalence

For any individual, two cash flows, P_t at time t and F_{t+N} at time $t + N$, are equivalent if the individual is indifferent between the two. Here, the implied interest rate relating P_t and F_{t+N} can be calculated from the decision that the cash flows are equivalent, as opposed to mathematical equivalence, in which the interest rate determines whether the cash flows are equivalent. This can be illustrated best through an example.

EXAMPLE 3.9

Bildmet is an extruder of aluminum shapes used in construction. The company buys aluminum from Alpure, an outfit that recovers aluminum from scrap. When Bildmet's purchasing manager, Greta Kehl, called in an order for 1000 kilograms of metal on August 15, she was told that Alpure was having production difficulties and was running behind schedule. Alpure's manager, Masaaki Sawada, said that he could ship the order immediately if Bildmet required it. However, if Alpure shipped Bildmet's order, it would

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not be able to fill an order for another user whom Mr. Sawada was anxious to impress with Alpure's reliability. Mr. Sawada suggested that, if Ms. Kehl would wait a week until August 22, he would show his appreciation by shipping 1100 kilograms then at the same cost to Bildmet as 1000 kilograms now. In either case, payment would be due at the end of the month. Should Ms. Kehl accept Alpure's offer?

The rate of exchange, 1100 to 1000 kilograms, may be written as $(1 + 0.1)$ to 1, where the $0.1 = 10$ percent is an interest rate for the one-week period. (This is equivalent to an effective interest rate of more than 14 000 percent per year!) Whether or not Ms. Kehl accepts the offer from Alpure depends on her situation. There is some chance of Bildmet's running out of metal if it doesn't get supplied for a week. This would require Ms. Kehl to do some scrambling to find other sources of metal in order to ship to her own customers on time. Clearly, Ms. Kehl would prefer the 1000 kilograms on the 15th to 1000 kilograms on the 22nd. But there is some minimum amount, larger than 1000 kilograms, that she would accept on the 22nd in exchange for 1000 kilograms on the 15th. This amount would take into account both measurable costs and immeasurable costs such as inconvenience and anxiety.

Let the minimum rate at which Ms. Kehl would be willing to make the exchange be 1 kilogram on the 15th for $(1 + x)$ kilograms on the 22nd. In this case, if $x < 10$ percent, Ms. Kehl should accept Alpure's offer of 1100 kilograms on the 22nd. ■

In Example 3.9, the aluminum is a capital good that can be used productively by Bildmet. There is value in that use, and that value can be measured by Greta's willingness to postpone receiving the aluminum. It can be seen that interest is not necessarily a function of exchanges of money at different points in time. However, money is a convenient measure of the worth of a variety of goods, and so interest is usually expressed in terms of money.

3.7.3 Market Equivalence

Market equivalence is based on the idea that there is a market for money that permits cash flows in the future to be exchanged for cash flows in the present, and vice versa. Converting a future cash flow, F, to a present cash flow, P, is called borrowing money, while converting P to F is called lending or investing money. The market equivalence of two cash flows P and F means that they can be exchanged, one for the other, at zero cost.

The interest rate associated with an individual's borrowing money is usually a lot higher than the interest rate applied when that individual lends money. For example, the interest rate a bank pays on deposits is lower than what it charges to lend money to clients. The difference between these interest rates provides the bank with income. This means that, for an individual, market equivalence does not exist. An individual can exchange a present worth for a future worth by investing money, but if he or she were to try to borrow against that future worth to obtain money now, the resulting present worth would be less than the original amount invested. Moreover, every time either borrowing or lending occurred, transaction costs (the fees charged or cost incurred) would further diminish the capital.

EXAMPLE 3.10

This morning, Averill bought a \$5000 one-year guaranteed investment certificate (GIC) at his local bank. It has an effective interest rate of 7 percent per year. At the end of a year, the GIC will be worth \$5350. On the way home from the bank, Averill unexpectedly

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discovered a valuable piece of art he had been seeking for some time. He wanted to buy it, but all his spare capital was tied up in the GIC. He went back to the bank, this time to negotiate a one-year loan for \$5000, the cost of the piece of art. He figured that if the loan came due at the same time as the GIC, he would simply pay off the loan with the proceeds of the GIC.

Unfortunately, Averill found out that the bank charges 10 percent effective interest per year on loans. Considering the proceeds from the GIC of \$5350 one year from now, the amount the bank would give him today is only \$5350/1.1 = \$4864 (roughly), less any fees applicable to the loan. He discovered that for him, market equivalence does not hold. He cannot exchange \$5000 today for \$5350 one year from now, and vice versa, at zero cost. ■

Large companies with good records have opportunities that differ from those of individuals. Large companies borrow and invest money in so many ways, both internally and externally, that the interest rates for borrowing and for lending are very close to being the same, and the transaction costs are negligible. They can shift funds from the future to the present by raising new money or by avoiding investment in a marginal project that would earn only the rate that they pay on new money. They can shift funds from the present to the future by undertaking an additional project or investing externally.

But how large is a "large company"? Established businesses of almost any size, and even individuals with some wealth and good credit, can acquire cash and invest at about the same interest rate, provided that the amounts are small relative to their total assets. For these companies and individuals, market equivalence is a reasonable model, assuming that market equivalence makes calculations easier and still generally results in good decisions.

For most of the remainder of this book, we will be making two broad assumptions with respect to equivalence: first, that market equivalence holds, and second, that decisional equivalence can be expressed entirely in monetary terms. If these two assumptions are reasonably valid, mathematical equivalence can be used as an accurate model of how costs and benefits relate to one another over time. In several sections of the book, when we cover how firms raise capital and how to incorporate non-monetary aspects of a situation into a decision, we will discuss the validity of these two assumptions. In the meantime, mathematical equivalence is used to relate cash flows that occur at different points in time.

REVIEW PROBLEMS

REVIEW PROBLEM 3.1

Atsushi has had \$800 stashed under his mattress for 30 years. How much money has he lost by not putting it in a bank account at 8 percent annual compound interest all these years?

ANSWER

Since Atsushi has kept the \$800 under his mattress, he has not earned any interest over the 30 years. Had he put the money into an interest-bearing account, he would have far more today. We can think of the \$800 as a present amount and the amount in 30 years as the future amount.

Given: $P = \$800$

$i = 0.08$ per year

$N = 30$ years

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Formula: $F = P(1 + i)^N$

$$= 800(1 + 0.08)^{30}$$

$$= 8050.13$$

Atsushi would have \$8050.13 in the bank account today if he had deposited his \$800 at 8 percent annual compound interest. Instead, he has only \$800. He suffered an opportunity cost of \$8050.13 – \$800 = \$7250.13 by not investing the money.■

REVIEW PROBLEM 3.2

You want to buy a new computer, but you are \$1000 short of the amount you need. Your aunt has agreed to lend you the \$1000 you need now, provided you pay her \$1200 two years from now. She compounds interest monthly. Another place from which you can borrow \$1000 is the bank. There is, however, a loan processing fee of \$20, which will be included in the loan amount. The bank is expecting to receive \$1220 two years from now based on monthly compounding of interest.

(a) What monthly rate is your aunt charging you for the loan? What is the bank charging?

(b) What effective annual rate is your aunt charging? What is the bank charging?

(c) Would you prefer to borrow from your aunt or from the bank?

ANSWER

(a) *Your aunt*

Given: $P = \$1000$

$F = \$1200$

$N = 24$ months (since compounding is done monthly)

Formula: $F = P(1 + i)^N$

The formula $F = P(1 + i)^N$ must be solved in terms of i to answer the question.

$$i = \sqrt[N]{F/P} - 1$$

$$= \sqrt[24]{1200/1000} - 1$$ **= (1200/1000)^(1/24) – 1**

$$= 0.007626$$

Your aunt is charging interest at a rate of approximately 0.76 percent per month.

The bank

Given: $P = \$1020$ (since the fee is included in the loan amount)

$F = \$1220$

$N = 24$ months (since compounding is done monthly)

$$i = \sqrt[N]{F/P} - 1$$

$$= \sqrt[24]{1220/1020} - 1$$

$$= 0.007488$$

The bank is charging interest at a rate of approximately 0.75 percent per month.

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(b) The effective annual rate can be found with the formula $i_e = (1 + r/m)^m - 1$, where r is the nominal rate per year and m is the number of compounding periods per year. Since the number of compounding periods per year is 12, notice that r/m is simply the interest rate charged per month.

Your aunt

$i = 0.007626$ per month

Then

$$\begin{aligned} i_e &= (1 + r/m)^m - 1 \\ &= (1 + 0.007626)^{12} - 1 \\ &= 0.095445 \end{aligned}$$

The effective annual rate your aunt is charging is approximately 9.54 percent.

The bank

$i = 0.007488$ per month

Then

$$\begin{aligned} i_e &= (1 + r/m)^m - 1 \\ &= (1 + 0.007488)^{12} - 1 \\ &= 0.09365 \end{aligned}$$

The effective annual rate for the bank is approximately 9.37 percent.

(c) The bank appears to be charging a lower interest rate than that offered by your aunt. This can be concluded by comparing the two monthly rates or the effective annual rates. If you were to base your decision only on who charged the lower interest rate, you would pick the bank, despite the fact that it has a fee. However, although you are borrowing \$1020 from the bank, you are getting only \$1000, since the bank immediately gets its \$20 fee. The cost of money for you from the bank is better calculated as

Given: $P = \$1000$
$F = \$1220$
$N = 24$ months (since compounding is done monthly)

$$\begin{aligned} i &= \sqrt[N]{F/P} - 1 \\ &= \sqrt[24]{1220/1000} - 1 \\ &= 0.00832 \end{aligned}$$

From this point of view, the bank is charging interest at a rate of approximately 0.83 percent per month and you would be better off borrowing from your aunt.■

REVIEW PROBLEM 3.3

At the end of four years, you would like to have \$5000 in a bank account to purchase a used car. What you need to know is how much to deposit in the bank account now. The account pays daily interest. Create a spreadsheet and plot the necessary deposit today as a function of interest rate. Consider nominal interest rates ranging from 5 percent to 15 percent per year, and assume that there are 365 days per year.

ANSWER

From the formula $F = P(1 + i)^N$, we have $5000 = P(1 + i)^{365\times4}$. This gives

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$$P = 5000 \times \frac{1}{(1 + i)^{365\times4}}$$

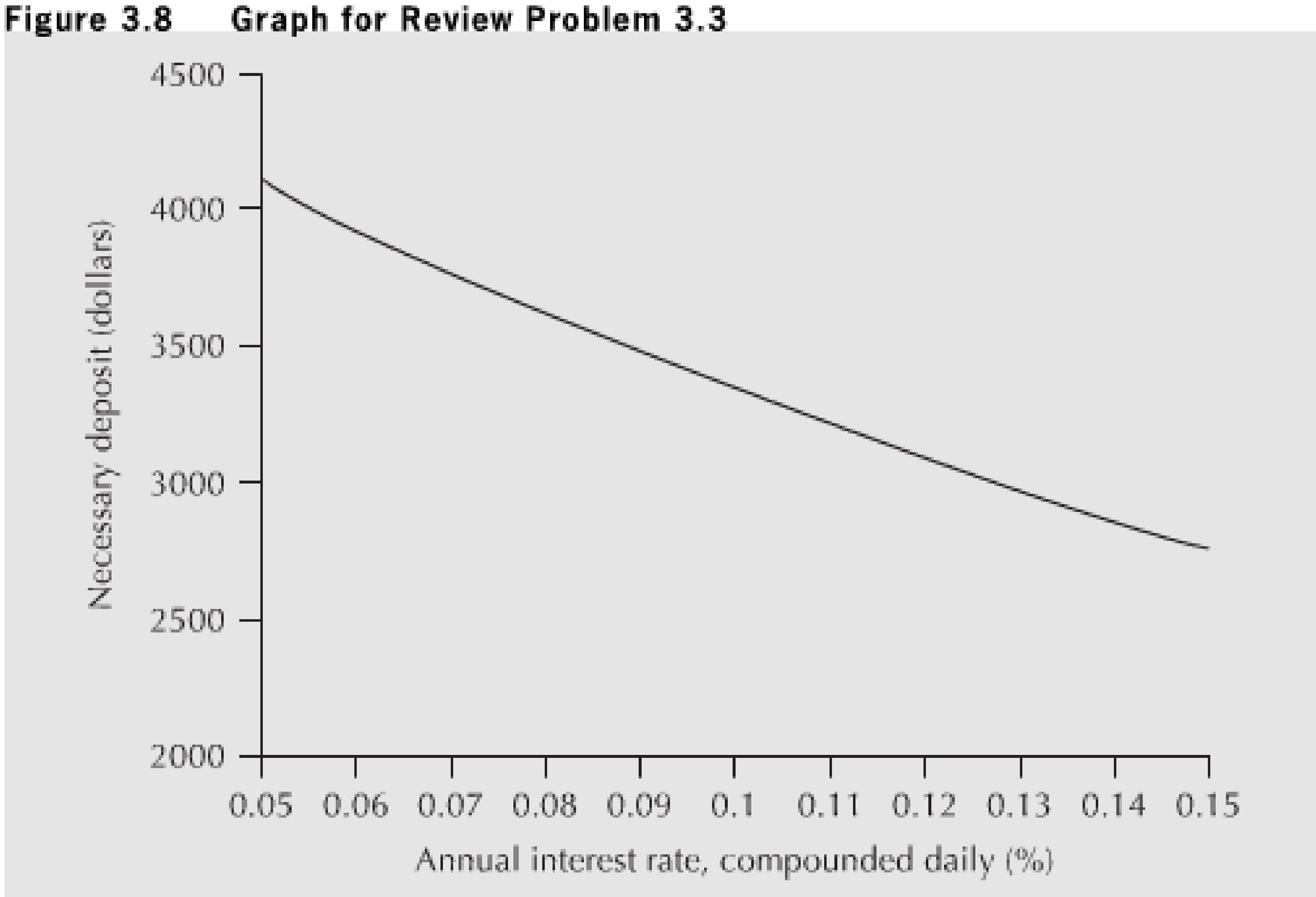
The left spreadsheet in Table 3.3 shows the necessary deposits for a range of interest rates. The right spreadsheet shows the Excel formulas that were used. To construct the spreadsheet, 0.05 was entered into cell A2 and the formula **=A2 + 0.01** was put into cell A3. After then selecting A3 through A12, the Fill Down function was used to complete the remaining cells in column A. Once the formula in cell B2 was entered, the Fill Down function was also used to complete the rest of column B. The references to the interest rates in A3, A4, etc. were automatically incremented by the Fill Down function.

Table 3.3 Necessary Deposits for a Range of Interest Rates

	A	B
1	Interest Rate *i* (%)	Necessary Deposit, P ($)
2	0.05	4094
3	0.06	3933
4	0.07	3779
5	0.08	3631
6	0.09	3489
7	0.10	3352
8	0.11	3220
9	0.12	3094
10	0.13	2973
11	0.14	2856
12	0.15	2744

	A	B
1	Interest Rate *i* (%)	Necessary Deposit, P ($)
2	=0.05	=5000/((1+A2/365)^(365*4))
3	=A2+0.01	=5000/((1+A3/365)^(365*4))
4	=A3+0.01	=5000/((1+A4/365)^(365*4))
5	=A4+0.01	=5000/((1+A5/365)^(365*4))
6	=A5+0.01	=5000/((1+A6/365)^(365*4))
7	=A6+0.01	=5000/((1+A7/365)^(365*4))
8	=A7+0.01	=5000/((1+A8/365)^(365*4))
9	=A8+0.01	=5000/((1+A9/365)^(365*4))
10	=A9+0.01	=5000/((1+A10/365)^(365*4))
11	=A10+0.01	=5000/((1+A11/365)^(365*4))
12	=A11+0.01	=5000/((1+A12/365)^(365*4))

Figure 3.8 Graph for Review Problem 3.3



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The specific implementation of this formula will vary depending on the particular spreadsheet program used. Figure 3.8 is a diagram of the necessary deposits plotted against interest rates.■

SUMMARY

This chapter has provided an introduction to interest, interest rate terminology, and interest rate conventions. Through a series of examples, the mechanics of working with simple and compound interest, nominal and effective interest rates, and continuous compounding were illustrated. Cash flow diagrams were introduced to represent graphically monetary transactions at various points in time. The final part of the chapter contained a discussion of various forms of cash flow equivalence: mathematical, decisional, and market. With the assumption that mathematical equivalence can be used as an accurate model of how costs and benefits relate to one another over time, we now move on to Chapter 4, in which equivalence formulas for a variety of cash flow patterns are presented.

ENGINEERING ECONOMICS IN ACTION, PART 3B

You Just Have to Know When

Naomi and Terry were looking at the steel orders for the J-class line. Terry thought money could be saved by ordering in advance. "Now look at this," Terry said. "In the six months ending last December, we ordered steel for a total cost of $1 600 000. If we had bought this steel at the beginning of July, it would have cost only $1 400 000. That's a savings of $200 000!"

"Good observation, Terry, but I don't think buying in advance is the right thing to do. If you think about it, the rate of return on our $1 400 000 would be 200 000/1 400 000 or about 14.3 percent over six months."

"Yes, but that's over 30 percent effective interest, isn't it? I'll bet we only make 3 percent or 4 percent for money we keep in the bank."

"That's true, but the money we would use to buy the steel in advance we don't have sitting in the bank collecting interest. It would have to come from somewhere else—either money we borrow from the bank, at about 14 percent plus administrative costs, or from our shareholders."

"But it's still a good idea, right?"

"Well, you are right and you are wrong. Mathematically, you could probably show the advantage of buying a six-month supply in advance. But we wouldn't do it for two reasons. The first one has to do with where the money comes from. If we had to pay for six months of steel in advance, we would have a capital requirement beyond what we could cover through normal cash flows. I'm not sure the bank would even lend us that much money, so we would probably have to raise it through equity—that is, selling more shares in the company. This would cost a lot and throw all your calculations way off."

"Just because it's such a large amount of money?"

"That's right. Our regular calculations are based on the assumption that the capital requirements don't take an extraordinary effort."

"You said there were two reasons. What's the other one?"

"The other reason is that we just wouldn't do it."

"Huh?"

"We just wouldn't do it. Right now the steel company's taking the risk—if we can't pay, it is in trouble. If we buy in advance, it's the other way around—if our widget orders dropped, we would be stuck with some pretty expensive raw materials. We would also have the problem of where to store the steel, and other practical difficulties. It makes sense mathematically, but I'm pretty sure we just wouldn't do it."

→

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Terry looked a little dejected. Naomi continued, "But your figures make sense. The first thing to do is find out why we are carrying that account so long before we pay it off. The second thing to do is see if we can't get that price break retroactively. We are good customers and I'll bet we can convince them to give us the price break anyhow, without changing our ordering pattern. Let's talk to Clem about it."

"But, Naomi, why use the mathematical calculations at all, if they don't work?"

"But they do work, Terry. You just have to know when."

PROBLEMS

A. Key Concepts

3.1 Using 12 percent simple interest per year, how much interest will be owed on a loan of $500 at the end of two years?

3.2 If a sum of $3000 is borrowed for six months at 9 percent simple interest per year, what is the total amount due (principal and interest) at the end of six months?

3.3 What principal amount will yield $150 in interest at the end of three months when the interest rate is 1 percent simple interest per month?

3.4 If 2400 rupees in interest is paid on a two-year simple-interest loan of 12 000 rupees, what is the interest rate per year?

3.5 How much will be in a bank account at the end of five years if $2000 is invested today at 12 percent interest per annum, compounded yearly?

3.6 How much is accumulated in each of these savings plans over two years?

(a) Deposit €1000 today at 10 percent compounded annually.

(b) Deposit €900 today at 12 percent compounded monthly.

3.7 Greg wants to have $50 000 in five years. The bank is offering five-year investment certificates that pay 8 percent nominal interest, compounded quarterly. How much money should he invest in the certificates to reach his goal?

3.8 Greg wants to have $50 000 in five years. He has $20 000 today to invest. The bank is offering five-year investment certificates that pay interest compounded quarterly. What is the minimum nominal interest rate he would have to receive to reach his goal?

3.9 Hans now has $6000. In three months, he will receive a cheque for $2000. He must pay $900 at the end of each month (starting exactly one month from now). Draw a single cash flow diagram illustrating all of these payments for a total of six monthly periods. Include his cash on hand as a payment at time 0.

3.10 Margaret is considering an investment that will cost her $500 today. It will pay her $100 at the end of each of the next 12 months, and cost her another $300 one year from today. Illustrate these cash flows in two cash flow diagrams. The first should show each cash flow element separately, and the second should show only the net cash flows in each period.

3.11 Heddy is considering working on a project that will cost her $20 000 today. It will pay her $10 000 at the end of each of the next 12 months and cost her another $15 000 at the end of each quarter. An extra $10 000 will be received at the end of the project, one year from now. Illustrate these cash flows in two cash flow diagrams. The first should show each cash flow element separately, and the second should show only the net cash flow in each period.

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3.12 Illustrate the following cash flows over 12 months in a cash flow diagram. Show only the net cash flow in each period.

Cash Payments	\$20 every three months, starting now
Cash Receipts	Receive \$30 at the end of the first month, and from that point on, receive 10 percent more than the previous month at the end of each month

B. Applications

3.13 Simple interest of \$190.67 is owed on a loan of \$550 after four years and four months. What is the annual interest rate?

3.14 Greg wants to have \$50 000. He will invest \$20 000 today in investment certificates that pay 8 percent nominal interest, compounded quarterly. How long will it take him to reach his goal?

3.15 Greg will invest \$20 000 today in five-year investment certificates that pay 8 percent nominal interest, compounded quarterly. How much money will this be in five years?

3.16 You bought an antique car three years ago for \$500 000. Today it is worth \$650 000.

(a) What annual interest rate did you earn if interest is compounded yearly?

(b) What monthly interest rate did you earn if interest is compounded monthly?

3.17 You have a bank deposit now worth \$5000. How long will it take for your deposit to be worth more than \$8000 if

(a) The account pays 5 percent actual interest every half-year and is compounded every half-year?

(b) The account pays 5 percent nominal interest, compounded semiannually?

3.18 Some time ago, you put £500 into a bank account for a "rainy day." Since then, the bank has been paying you 1 percent per month, compounded monthly. Today, you checked the balance, and found it to be £708.31. How long ago did you deposit the £500?

3.19 **(a)** If you put \$1000 in a bank account today that pays 10 percent interest per year, how much money could be withdrawn 20 years from now?

(b) If you put \$1000 in a bank account today that pays 10 percent *simple* interest per year, how much money could be withdrawn 20 years from now?

3.20 How long will it take any sum to double itself

(a) With an 11 percent simple interest rate?

(b) With an 11 percent interest rate, compounded annually?

(c) With an 11 percent interest rate, compounded continuously?

3.21 Compute the effective annual interest rate on each of these investments.

(a) 25 percent nominal interest, compounded semiannually

(b) 25 percent nominal interest, compounded quarterly

(c) 25 percent nominal interest, compounded continuously

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3.22 For a 15 percent effective annual interest rate, what is the nominal interest rate if

(a) Interest is compounded monthly?

(b) Interest is compounded daily (assume 365 days per year)?

(c) Interest is compounded continuously?

3.23 A Studebaker automobile that cost \$665 in 1934 was sold as an antique car at \$14 800 in 1998. What was the rate of return on this "investment"?

3.24 Clifford has X dollars right now. In five years, X will be \$3500 if it is invested at 7.5 percent, compounded annually. Determine the present value of X. If Clifford invested X dollars at 7.5 percent compounded daily, how much would the value of X be in 10 years?

3.25 The Kovalam Bank advertises savings account interest as 6 percent compounded daily. What is the effective interest rate?

3.26 The Bank of Brisbane is offering a new savings account that pays a nominal 7.99 percent interest, compounded continuously. Will your money earn more in this account than in a daily interest account that pays 8 percent?

3.27 The Crete Credit Union advertises savings account interest as 5.5 percent compounded weekly and chequing account interest at 7 percent compounded monthly. What are the effective interest rates for the two types of accounts?

3.28 Victory Visa, Magnificent Master Card, and Amazing Express are credit card companies that charge different interest on overdue accounts. Victory Visa charges 26 percent compounded daily, Magnificent Master Card charges 28 percent compounded weekly, and Amazing Express charges 30 percent compounded monthly. On the basis of interest rate, which credit card has the best deal?

3.29 April has a bank deposit now worth \$796.25. A year ago, it was \$750. What was the nominal monthly interest rate on her account?

3.30 May has \$2000 in her bank account right now. She wanted to know how much it would be in one year, so she calculated and came up with \$2140.73. Then she realized she had made a mistake. She had wanted to use the formula for monthly compounding, but instead, she had used the continuous compounding formula. Redo the calculation for May and find out how much will actually be in her account a year from now.

3.31 There are two possible investments, A and B. Their cash flows are shown in the table below. Illustrate these cash flows over 12 months in two cash flow diagrams. Show only the net cash flow in each period. Just looking at the diagrams, would you prefer one investment to the other? Comment on this.

	Investment A	Investment B
Payments	\$2400 now and a closing fee of \$200 at the end of month 12	\$500 every two months, starting two months from now
Receipts	\$250 monthly payment at the end of each month	Receive \$50 at the end of the first month, and from that point on, receive \$50 more than the previous month at the end of each month

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3.32 Using a spreadsheet, construct graphs for the loan described in part (a) below.

(a) Plot the amount owed (principal plus interest) on a simple interest loan of \$100 for N years for $N = 1, 2, \ldots 10$. On the same graph, plot the amount owed on a compound interest loan of \$100 for N years for $N = 1, 2, \ldots 10$. The interest rate is 6 percent per year for each loan.

(b) Repeat part (a), but use an interest rate of 18 percent. Observe the dramatic effect compounding has on the amount owed at the higher interest rate.

3.33 (a) At 12 percent interest per annum, how long will it take for a penny to become a million dollars? How long will it take at 18 percent?

(b) Show the growth in values on a spreadsheet using 10-year time intervals.

3.34 Use a spreadsheet to determine how long it will take for a \$100 deposit to double in value for each of the following interest rates and compounding periods. For each, plot the size of the deposit over time, for as many periods as necessary for the original sum to double.

(a) 8 percent per year, compounded monthly

(b) 11 percent per year, compounded semiannually

(c) 12 percent per year, compounded continuously

3.35 Construct a graph showing how the effective interest rate for the following nominal rates increases as the compounding period becomes shorter and shorter. Consider a range of compounding periods of your choice, from daily compounding to annual compounding.

(a) 6 percent per year

(b) 10 percent per year

(c) 20 percent per year

C. More Challenging Problems

3.36 You have just won a lottery prize of \$1 000 000 collectable in 10 yearly installments of \$100 000 starting today. Why is this prize not really \$1 000 000? What is it really worth today if money can be invested at 10 percent annual interest, compounded monthly? Use a spreadsheet to construct a table showing the present worth of each installment and the total present worth of the prize.

3.37 Suppose in Problem 3.36 that you have a large mortgage you want to pay off now. You propose an alternative but equivalent payment scheme. You would like \$300 000 today and the balance of the prize in five years when you intend to purchase a large piece of waterfront property. How much will the payment be in five years? Assume that annual interest is 10 percent, compounded monthly.

3.38 You are looking at purchasing a new computer for your four-year undergraduate program. Brand 1 costs \$4000 now, and you expect it will last throughout your program without any upgrades. Brand 2 costs \$2500 now and will need an upgrade at the end of two years, which you expect to be \$1700. With 8 percent annual interest, compounded monthly, which is the less expensive alternative, if they provide the same level of service and will both be worthless at the end of the four years?

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3.39 You are comparing two investments. The first pays 1 percent interest per month, compounded monthly, and the second pays 6 percent interest per six months, compounded every six months.

(a) What is the effective semiannual interest rate for each investment?

(b) What is the effective annual interest rate for each investment?

(c) On the basis of interest rates, which investment do you prefer? Does your decision depend on whether you make the comparison based on an effective six-month rate or an effective one-year rate?

3.40 You have $50 000 to invest in the stock market and have sought the advice of Adam, an experienced colleague who is willing to advise you, for a fee. Adam has told you that he has found a one-year investment for you that provides 15 percent interest, compounded monthly.

(a) What is the effective annual interest rate based on a 15 percent nominal annual rate and monthly compounding?

(b) Adam says he will make the investment for you for a modest fee of 2 percent of the investment's value one year from now. If you invest the $50 000 today, how much will you have at the end of one year (before Adam's fee)?

(c) What is the effective annual interest rate of this investment, including Adam's fee?

3.41 You are indifferent about whether you receive $100 today or $110 one year from now. The bank pays you 6 percent interest on deposits and charges you 8 percent for loans. Name the three types of equivalence and comment (with one sentence for each) on whether each exists for this situation and why.

3.42 June has a small house on a small street in a small town. If she sells the house now, she will likely get $110 000 for it. If she waits for one year, she will likely get more—say, $120 000. If she sells the house now, she can invest the money in a one-year guaranteed growth bond that pays 8 percent interest, compounded monthly. If she keeps the house, then the interest on the mortgage payments is 8 percent compounded daily. June is indifferent between the two options: selling the house now and keeping the house for another year. Discuss whether each of the three types of equivalence exists in this case.

3.43 Today, an investment you made three years ago has matured and is now worth $3000. It was a three-year deposit that bore an interest rate of 10 percent per year, compounded monthly. You knew at the time that you were taking a risk in making such an investment because interest rates vary over time and you "locked in" at 10 percent for three years.

(a) How much was your initial deposit? Plot the value of your investment over the three-year period.

(b) Looking back over the past three years, interest rates for similar one-year investments did indeed vary. The interest rates were 8 percent the first year, 10 percent the second, and 14 percent the third. Plot the value of your initial deposit over time as if you had invested at this set of rates, rather than at a constant 10 percent rate. Did you lose out by having locked into the 10 percent investment? If so, by how much?

3.44 Marlee has a choice between X dollars today or Y dollars one year from now. X is a fixed value, but Y varies depending on the interest rate. At interest rate i, X and Y are mathematically equivalent for Marlee. At interest rate j, X and Y have decisional equivalence for Marlee. At interest rate k, X and Y have market equivalence for Marlee. What can be said about the origins, nature, and comparative values of i, j, and k?

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MINI-CASE 3.1

Student Credit Cards

Most major banks offer a credit card service for students. In 2011, Canadian credit card interest rates were in the range of 19.5 to 19.9 percent. Credit limits for student cards vary from $500 and up, depending on the type of card. Many have rewards programs that allow the cardholder, for example, to build up points toward free travel on the reward program airline. Annual fees depend on the features of the card. Basic cards have no annual fee; those with a richer feature set charge fees between $30 per year and $120 per year. The approval process for getting a card is relatively simple for university and college students so that they can start building a credit history and enjoy the convenience of having a credit card while still in school.

The printed information does not use the term *nominal* or *effective*, nor does it define the compounding period. However, it is common in the credit card business for the annual interest rate to be divided into daily rates for billing purposes. Hence, the quoted annual rate of 19.7 percent is a nominal rate and the compounding period is daily. The actual effective interest rate is then $(1 + 0.197/365)^{365} - 1 = 0.2177$, or 21.77 percent.

Discussion

Interest information must be disclosed by law, but lenders and borrowers have some latitude as to how and where they disclose it. Moreover, there is a natural desire to make the interest rate look lower than it really is for borrowers, and higher than it really is for lenders.

In the example of student credit cards, the effective interest rate is 21.77 percent, roughly 2 percent higher than the stated interest rate. The actual effective interest rate could even end up being higher if fees such as late fees, over-the-limit fees, and transaction fees are charged.

Questions

1. Go to your local bank branch and find out the interest rate paid for various kinds of savings accounts, chequing accounts, and loans. For each interest rate quoted, determine if it is a nominal or effective rate. If it is nominal, determine the compounding period and calculate the effective interest rate.
2. Have a contest with your classmates to see who can find the organization that will lend money to a student like you at the cheapest effective interest rate, or that will take investments that provide a guaranteed return at the highest effective interest rate. The valid rates must be generally available, not tied to particular behaviour by the client, and not secured to an asset (like a house).
3. If you borrowed $1000 at the best rate you could find and invested it at the best rate you could find, how much money would you make or lose in a year? Explain why the result of your calculation could not have the opposite sign.

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CHAPTER 4

Cash Flow Analysis

Taken from *Engineering Economics: Financial Decision Making for Engineers*, Fifth Edition by Niall M. Fraser and Elizabeth M. Jewkes.

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ENGINEERING ECONOMICS IN ACTION, PART 4A

Apples and Oranges

The flyer was slick, all right. The information was laid out so anybody could see that leasing palletizing equipment through the Provincial Finance Company (PFC) made much more sense than buying it. It was something Naomi could copy right into her report to Clem.

Naomi had been asked to check out options for automating part of the shipping department. Parts were to be stacked and bound on plastic pallets, then loaded onto trucks and sent to one of Canadian Widgets' sister companies. The saleswoman for the company whose equipment seemed most suitable for Canadian Widgets' needs had included the leasing flyer with her quote.

Naomi looked at the figures again. They seemed to make sense, but there was something that didn't seem right to her. For one thing, if it was cheaper to lease, why didn't everybody lease everything? She knew that some things, like automobiles and airplanes, are often leased instead of bought, but generally companies buy assets. Second, where was the money coming from to give the finance company a profit? If the seller was getting the same amount and the buyer was paying less, how could PFC make money?

"Got a recommendation on that palletizer yet, Naomi?" Clem's voice was cheery as he suddenly appeared at her doorway. Naomi knew that the shipping department was the focus of Clem's attention right now and he wanted to get improvements in place as soon as possible.

"Yes, I do. There's really only one that will do the job, and it does it well at a good price. There is something I'm trying to figure out, though. Christine sent me some information about leasing it instead of buying it, and I'm trying to figure out where the catch is. There has got to be one, but I can't see it right now."

"Okay, let me give you a hint: apples and oranges. You can't add them. Now, let's get the paperwork started for that palletizer. The shipping department is just too much of a bottleneck." Clem disappeared as quickly as he had arrived, leaving Naomi musing to herself.

"Apples and *oranges*? *Apples* and oranges? Ahh . . . apples and oranges, of course!"

4.1 Introduction

Chapter 3 showed that interest is the basis for determining whether different patterns of cash flows are equivalent. Rather than comparing patterns of cash flows from first principles, it is usually easier to use functions that define *mathematical* equivalence among certain common cash flow patterns. These functions are called *compound interest factors*. We discuss a number of these common cash flow patterns, along with their associated compound interest factors, in this chapter. These compound interest factors are used throughout the remainder of the book. It is, therefore, particularly important to understand their use before proceeding to subsequent chapters.

This chapter opens with an explanation of how cash flow patterns that engineers commonly use are simplified approximations of complex reality. Next, we discuss four simple, discrete cash flow patterns and the compound interest factors that relate them to each other. There is then a brief discussion of the case in which the number of time periods considered is so large that it is treated as though the relevant cash flows continue indefinitely. Appendix 4A presents mathematical derivations of the compound interest factors.

4.2 Timing of Cash Flows and Modelling

The actual timing of cash flows can be very complicated and irregular. Unless some simple approximation is used, comparisons of different cash flow sequences will be very difficult and impractical. Consider, for example, the cash flows generated by a relatively

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simple operation like a service station that sells gasoline and supplies and also services cars. Some cash flows, like sales of gasoline and minor supplies, will be almost continuous during the time the station is open. Other flows, like receipts for the servicing of cars, will be on a daily basis. Disbursements for wages may be on a weekly basis. Some disbursements, like those for a manager's salary and for purchases of gasoline and supplies, may be monthly. Disbursements for insurance and taxes may be quarterly or semiannually. Other receipts and disbursements, like receipts for major repairs or disbursements for used parts, may be irregular.

An analyst trying to make a comparison of two projects with different, irregular timings of cash flows might have to record each of the flows of the projects, and then, on a one-by-one basis, find summary equivalent values such as present worth that would be used in the comparison. This activity would be very time-consuming and tedious if it could be done, but it probably could not be done because the necessary data would not exist. If the projects were potential rather than actual, the cash flows would have to be predicted. This could not be done with great precision for either size or timing of the flows. Even if the analysis were of the past performances of ongoing operations, it is unlikely that it would be worthwhile to maintain a databank that contained the exact timing of all cash flows.

Because of the difficulties of making precise calculations of complex and irregular cash flows, engineers usually work with fairly simple models of cash flow patterns. The most common type of model assumes that all cash flows and all compounding of cash flows occur at the ends of conventionally defined periods, such as months or years. Models that make this assumption are called **discrete models**. In some cases, analysts use models that assume cash flows and their compounding occur continuously over time; such models are called **continuous models**. Whether the analyst uses discrete modelling or continuous modelling, the model is usually an approximation. Cash flows do not occur only at the ends of conventionally defined periods, nor are they actually continuous. We emphasize discrete models throughout the book because they are more common and more readily understood by persons of varied backgrounds.

4.3 Compound Interest Factors for Discrete Compounding

Compound interest factors are formulas that define mathematical equivalence for specific common cash flow patterns. The compound interest factors permit cash flow analysis to be done more conveniently because tables or spreadsheet functions can be used instead of complicated formulas. This section presents compound interest factors for four discrete cash flow patterns that are commonly used to model the timing of receipts and disbursements in engineering economic analysis. The four patterns are:

1. A single disbursement (money spent) or receipt (money received)
2. A set of equal disbursements or receipts over a sequence of periods, referred to as an **annuity**
3. A set of disbursements or receipts that change by a constant *amount* from one period to the next in a sequence of periods, referred to as an **arithmetic gradient series**
4. A set of disbursements or receipts that change by a constant *proportion* from one period to the next in a sequence of periods, referred to as a **geometric gradient series**

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The principle of discrete compounding requires several assumptions:

1. Compounding periods are of equal length.
2. Each disbursement and receipt occurs at the end of a period. A payment at time 0 can be considered to occur at the end of period -1.
3. Annuities and gradients coincide with the ends of sequential periods. (Section 4.8 suggests several methods for dealing with annuities and gradients that do not coincide with the ends of sequential periods.)

Mathematical derivations of six of the compound interest factors are given in Appendix 4A at the end of this chapter.

4.4 Compound Interest Factors for Single Disbursements or Receipts

In many situations, a single disbursement or receipt is an appropriate model of cash flows. For example, the salvage value of production equipment with a limited service life will be a single receipt at some future date. An investment today to be redeemed at some future date is another example.

Figure 4.1 illustrates the general form of a single disbursement or receipt. Two commonly used factors relate a single cash flow in one period to another single cash flow in a different period. They are the *compound amount factor* and the *present worth factor*.

The **compound amount factor**, denoted by $(F/P,i,N)$, gives the future amount, F, that is equivalent to a present amount, P, when the interest rate is i and the number of periods is N. The value of the compound amount factor is easily seen as coming from Equation (3.1) on page 96, the compound interest equation, which relates present and future values:

$$F = P(1+i)^N$$

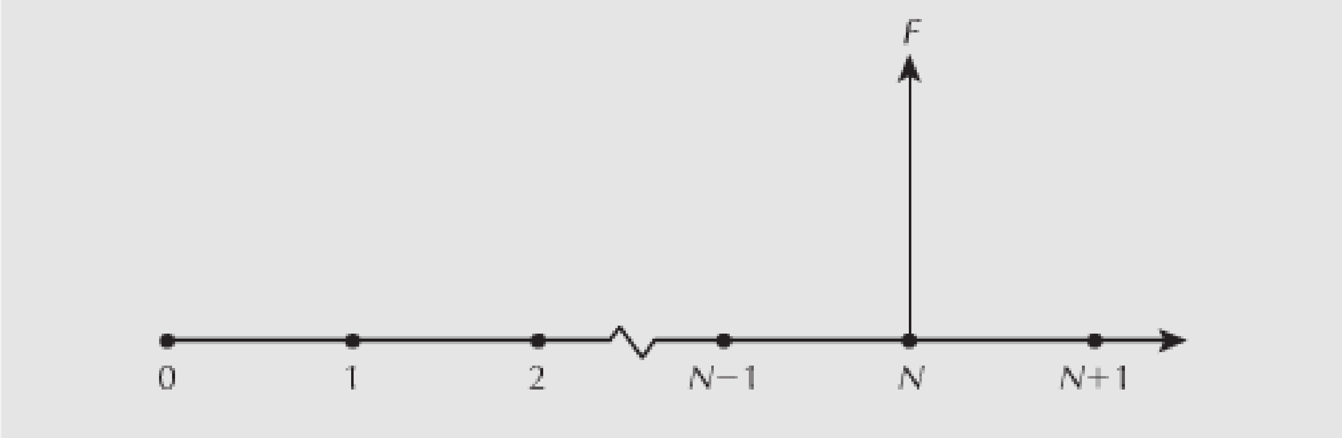
In the symbolic convention used for compound interest factors, this is written

$$F = P(1+i)^N = P(F/P,i,N) \qquad = \boldsymbol{FV(i,N,-P)}$$

so that the compound amount factor is

$$(F/P,i,N) = (1+i)^N$$

Figure 4.1 Single Receipt at End of Period N



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A handy way of thinking of the notation is (reading from left to right): "What is F, given P, i, and N?"

The compound amount factor is useful in determining the future value of an investment made today if the number of periods and the interest rate are known.

The **present worth factor**, denoted by $(P/F,i,N)$, gives the present amount, P, that is equivalent to a future amount, F, when the interest rate is i and the number of periods is N. The present worth factor is the inverse of the compound amount factor, $(F/P,i,N)$. That is, while the compound amount factor gives the future amount, F, that is equivalent to a present amount, P, the present worth factor goes in the other direction. It gives the present worth, P, of a future amount, F. Since $(F/P,i,N) = (1 + i)^N$,

$$(P/F,i,N) = \frac{1}{(1 + i)^N}$$

The compound amount factor and the present worth factor are fundamental to engineering economic analysis. Their most basic use is to convert a single cash flow that occurs at one point in time to an equivalent cash flow at another point in time. When comparing several individual cash flows that occur at different points in time, an analyst would apply the compound amount factor or the present worth factor, as necessary, to determine the equivalent cash flows at a common reference point in time. In this way, each of the cash flows is stated as an amount at one particular time. Example 4.1 illustrates this process.

Although the compound amount factor and the present worth factor are relatively easy to calculate, some of the other factors discussed in this chapter are more complicated, and it is therefore desirable to have an easier way to determine their values. Many of the compound interest factors are available as built-in functions in spreadsheets (see Table 4.3 at the end of the chapter for a summary). They can also be fairly easily programmed into a calculator.

A traditional and still useful method for determining the value of a compound interest factor is to use tables. Appendix A at the back of the book lists values for all the compound interest factors for a selection of interest rates for discrete compounding periods. The desired compound interest factor can be determined by looking in the appropriate table.

EXAMPLE 4.1

How much money will be in a bank account at the end of 15 years if \$100 is invested today and the nominal interest rate is 8 percent compounded semiannually?

Since a present amount is given and a future amount is to be calculated, the appropriate factor to use is the compound amount factor, $(F/P,i,N)$. There are several ways of choosing i and N to solve this problem. The first method is to observe that, since interest is compounded semiannually, the number of compounding periods, N, is 30. The interest rate per six-month period is 4 percent. Then

$$F = 100(F/P,4\%,30) \qquad = \mathbf{FV(0.04,30,-100)}$$
$$= 100(1 + 0.04)^{30}$$
$$= 324.34$$

The bank account will hold \$324.34 at the end of 15 years.

Alternatively, we can obtain the same results by using the interest factor tables.

$$F = 100(3.2434) \qquad \text{(from Appendix A)}$$
$$= 324.34$$

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A second solution to the problem is to calculate the *effective* yearly interest rate and then compound over 15 years at this rate. Recall from Equation (3.4) on page 101 that the effective interest rate per year is

$$i_e = \left(1 + \frac{r}{m}\right)^m - 1$$

where i_e = the effective annual interest rate

r = the nominal rate per year

m = the number of periods in a year

$$i_e = (1 + 0.08/2)^2 - 1 = 0.0816$$

where $r = 0.08$

$m = 2$

When the effective yearly rate for each of 15 years is applied to the future worth computation, the future worth is

$$\begin{aligned} F &= P(F/P,i,N) \\ &= P(1 + i)^N \\ &= 100(1 + 0.0816)^{15} \\ &= 324.34 \end{aligned}$$

Once again, we conclude that the balance will be \$324.34. ■

SPREADSHEET SAVVY

Spreadsheet software applications include a library of built-in functions to make certain types of calculations easier. For example, Excel includes a number of libraries such as statistical, mathematical and trigonometric, and financial. Among the financial functions are several that are useful for economic evaluation of single payment and uniform series cash flow patterns. As an alternative to writing out the full expression to be evaluated using a compound interest factor, the functions can be used to shorten the process. One must take care, however, to fully understand the cash flow pattern captured by each compound interest factor or Excel function so that the structure of the cash flows is not forgotten amid the formulas.

The table below provides a summary of how three Excel functions can be used as alternatives to compound interest factors covered in this chapter. Each function requires a set of arguments that can be either numeric values or references to cells containing numeric values. Warning!: Excel assumes that the cash flows are costs. To get the same signs as the compound interest factors, we have reversed the signs of the amounts A, F, and P in the Excel functions.

Compound Interest Factor	Excel Function
$P = A(P/A,i,N)$	$P = PV(i,N,-A)$
$P = F(P/F,i,N)$	$P = PV(i,N, ,-F)$
$F = A(F/A,i,N)$	$F = FV(i,N,-A)$
$F = P(F/P,i,N)$	$F = FV(i,N, ,-P)$
$A = P(A/P,i,N)$	$A = PMT(i,N,-P)$
$A = F(A/F,i,N)$	$A = PMT(i,N, ,-F)$

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Below are two examples of how Excel functions and compound interest factors can be used to compute the same quantities. The first table shows the formulas, and the second, the results.

	A	B	C	D
1	***Values:***			
2	*i =*	*0.1*	*P =*	2500
3	*N =*	*15*	*F =*	9400
4	***Relation***	***Excel Function***	***Compound Interest Factor***	
5	*A = (A/P,i,N)*	=PMT(B2,B3,-D2)		=D2*(B2*(1+B2)^B3)/((1+B2)^B3-1)
6	*A = (A/F,i,N)*	=PMT(B2,B3,,-D3)		=D3*B2/((1+B2)^B3-1)

	A	B	C	D
1	***Values:***			
2	*i =*	*0.1*	*P =*	2500
3	*N =*	*15*	*F =*	9400
4	***Relation***	***Excel Function***	***Compound Interest Factor***	
5	*A = (A/P,i,N)*	$328.68		$328.68
6	*A = (A/F,i,N)*	$295.85		$295.85

There are several ways to deal with the fact that Excel assumes that the cash flows have the opposite sign to the compound interest factors. The first is to use a minus sign in reference to the cash flows (as on the previous page). This assumes that the reference cell uses a positive sign for a cash receipt and a negative sign for a disbursement. The second way is to refer to the cash flows directly and then reverse the sign of the Excel function (this would be entered as $= -PMT$(B2,B3,,D3) in cell B6 above, for example). The third method is to change the sign of the cash flow referred to (for example, set D2 $= -2500$ and D3 $= -9400$ above). The third method was not used in this example because the compound interest factor computations also make reference to cells D2 and D3.

4.5 Compound Interest Factors for Annuities

The next four factors involve a series of uniform receipts or disbursements that start at the end of the first period and continue over N periods, as illustrated in Figure 4.2. This pattern of cash flows is called an annuity. Mortgage or lease payments and maintenance contract fees are examples of the annuity cash flow pattern. Annuities may also be used to model series of cash flows that fluctuate over time around some average value. Here the average value would be the constant uniform cash flow. This would be done if the fluctuations were unknown or deemed to be unimportant for the problem.

The **sinking fund factor**, denoted by $(A/F,i,N)$, gives the size, A, of a repeated receipt or disbursement that is equivalent to a future amount, F, if the interest rate is i and the number of periods is N. The name of the factor comes from the term **sinking fund**. A sinking fund is an interest-bearing account into which regular deposits are made in order to accumulate some amount.

The equation for the sinking fund factor can be found by decomposing the series of disbursements or receipts made at times 1, 2, . . . , N, and summing to produce a total future value. The formula for the sinking fund factor is

$$(A/F,i,N) = \frac{i}{(1+i)^N - 1}$$

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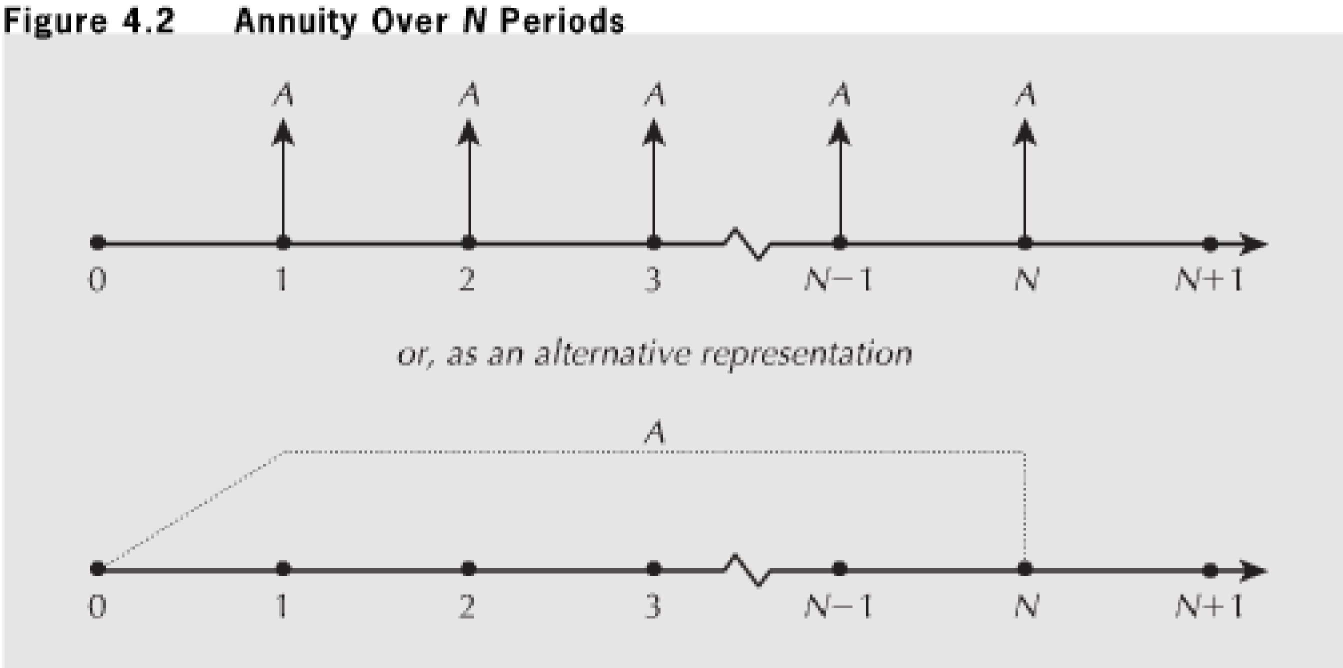
Figure 4.2 Annuity Over *N* Periods



The sinking fund factor is commonly used to determine how much has to be set aside or saved per period to accumulate an amount F at the end of N periods at an interest rate i. The amount F might be used, for example, to purchase new or replacement equipment, to pay for renovations, or to cover capacity expansion costs. In more general terms, the sinking fund factor allows us to convert a single future amount into a series of equal-sized payments, made over N equally spaced intervals, with the use of a given interest rate i.

The **uniform series compound amount factor**, denoted by $(F/A,i,N)$, gives the future value, F, that is equivalent to a series of equal-sized receipts or disbursements, A, when the interest rate is i and the number of periods is N. Since the uniform series compound amount factor is the inverse of the sinking fund factor,

$$(F/A,i,N) = \frac{(1+i)^N - 1}{i}$$

The **capital recovery factor**, denoted by $(A/P,i,N)$, gives the value, A, of the equal periodic payments or receipts that are equivalent to a present amount, P, when the interest rate is i and the number of periods is N. The capital recovery factor is easily derived from the sinking fund factor and the compound amount factor:

$$\begin{aligned}(A/P,i,N) &= (A/F,i,N)(F/P,i,N)\\ &= \frac{i}{(1+i)^N - 1}(1+i)^N\\ &= \frac{i(1+i)^N}{(1+i)^N - 1}\end{aligned}$$

The capital recovery factor can be used to find out, for example, how much money must be saved over N future periods to "recover" a capital investment of P today. The capital recovery factor for the purchase cost of something is sometimes combined with the sinking fund factor for its salvage value after N years to compose the **capital recovery formula**. See Close-Up 4.1.

The **series present worth factor**, denoted by $(P/A,i,N)$, gives the present amount, P, that is equivalent to an annuity with disbursements or receipts in the amount, A, where the interest rate is i and the number of periods is N. It is the reciprocal of the capital recovery factor:

$$(P/A,i,N) = \frac{(1+i)^N - 1}{i(1+i)^N}$$

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CLOSE-UP 4.1 Capital Recovery Formula

Industrial equipment and other assets are often purchased at a cost of P on the basis that they will incur savings of A per period for the firm. At the end of their useful life, they will be sold for some salvage value S. The expression to determine A for a given P and S combines the capital recovery factor (for P) with the sinking fund factor (for S):

$$A = P(A/P,i,N) - S(A/F,i,N)$$

Since

$$(A/F,i,N) = \frac{i}{(1+i)^N - 1} = \frac{i}{(1+i)^N - 1} + i - i$$

$$= \frac{i}{(1+i)^N - 1} + \frac{i[(1+i)^N - 1]}{(1+i)^N - 1} - i$$

$$= \frac{i + i(1+i)^N - i}{(1+i)^N - 1} - i = \frac{i(1+i)^N}{(1+i)^N - 1} - i$$

$$= (A/P,i,N) - i$$

then

$$A = P(A/P,i,N) - S[(A/P,i,N) - i]$$

$$= (P - S)(A/P,i,N) + Si \qquad = \boldsymbol{PMT(i,N,-(P-S)) + Si}$$

This is the **capital recovery formula**, which can be used to calculate the savings necessary to justify a capital purchase of cost P and salvage value S after N periods at interest rate i.

The capital recovery formula is also used to determine an annual amount that captures the loss in value of an asset over the time it is owned. Chapter 8 treats this use of the capital recovery formula more fully.

EXAMPLE 4.2

The Kelowna Go-Kart Klub has decided to build a clubhouse and track five years from now. It must accumulate \$50 000 by the end of five years by setting aside a uniform amount from its dues at the end of each year. If the interest rate is 10 percent, how much must be set aside each year?

Since the problem requires that we calculate an annuity amount given a future value, the solution can be obtained using the sinking fund factor where i = 10 percent, F = \$50 000, N = 5, and A is unknown.

$$A = 50\,000(A/F,10\%,5) \qquad = \boldsymbol{PMT(0.10,5,-50\,000)}$$

$$= 50\,000(0.1638)$$

$$= 8190.00$$

The Go-Kart Klub must set aside \$8190 at the end of each year to accumulate \$50 000 in five years. ■

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EXAMPLE 4.3

A car loan requires 30 monthly payments of $199.00, starting *today*. At an annual rate of 12 percent compounded monthly, how much money is being lent?

This cash flow pattern is referred to as an **annuity due**. It differs from a standard annuity in that the first of the N payments occurs at time 0 (now) rather than at the end of the first time period. Annuities due are uncommon—not often will one make the first payment on a loan on the date the loan is received! Unless otherwise stated, it is reasonable to assume that any annuity starts at the end of the first period.

Two simple methods of analyzing an annuity due will be used for this example.

Method 1. Count the first payment as a present worth and the next 29 payments as an annuity:

$$P = 199 + A(P/A,i,N) \qquad \mathbf{= 199 + \mathit{PV}(\mathit{i},\mathit{N},-\mathit{A})}$$

where $A = 199$, $i = 12\%/12 = 1\%$, and $N = 29$.

$$\begin{aligned} P &= 199 + 199(P/A,1\%,29) \\ &= 199 + 199(25.066) \\ &= 199 + 4988.13 \\ &= 5187.13 \end{aligned}$$

The present worth of the loan is the current payment, $199, plus the present worth of the subsequent 29 payments, $4988.13—a total of about $5187.

Method 2. Determine the present worth of a standard annuity at time −1, and then find its worth at time 0 (now). The worth at time −1 is

$$P_{-1} = A(P/A,i,N) \qquad \mathbf{= \mathit{PV}(\mathit{i},\mathit{N},-\mathit{A})}$$

$$\begin{aligned} &= 199(P/A,1\%,30) \\ &= 199(25.807) \\ &= 5135.79 \end{aligned}$$

Then the present worth now (time 0) is

$$P_0 = P_{-1}(F/P,i,N) \qquad \mathbf{= \mathit{FV}(\mathit{i},\mathit{N},-\mathit{P}_{-1})}$$

$$\begin{aligned} &= 5135.79(F/P,1\%,1) \\ &= 5135.79(1.01) \\ &= 5187.15 \end{aligned}$$

The second method gives the same result as the first, allowing a small margin for the effects of rounding. ■

It is worth noting here that although it is natural to think about the symbol P as meaning a cash flow at time 0, the present, and F as meaning a cash flow in the future, in fact these symbols can be more general in meaning. As illustrated in the last example, we can consider any point in time to be the "present" for calculation purposes, and similarly any point in time to be the "future," provided P is some point in time earlier than F. This observation gives us substantial flexibility in analyzing cash flows.

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EXAMPLE 4.4

Clarence bought a condo for $94 000 in 2012. He made a $14 000 down payment and negotiated a mortgage from the previous owner for the balance. Clarence agreed to pay the previous owner $2000 per month at 12 percent nominal interest, compounded monthly. How long will it take him to pay back the mortgage?

Clarence borrowed only $80 000, since he made a $14 000 down payment. The $2000 payments form an annuity over N months where N is unknown. The interest rate per month is 1 percent. We must find the value of N such that

$$P = A(P/A,i,N) = A\left(\frac{(1+i)^N - 1}{i(1+i)^N}\right) \quad \mathbf{= PV(\mathit{i},\mathit{N},-\mathit{A})}$$

or, alternatively, the value of N such that

$$A = P(A/P,i,N) = P\left(\frac{i(1+i)^N}{(1+i)^N - 1}\right)$$

where $P = \$80\ 000$, $A = \$2000$, and $i = 0.01$.

By substituting the known quantities into either expression, some manipulation is required to find N. For illustration, the capital recovery factor has been used.

$$A = P\left(\frac{i(1+i)^N}{(1+i)^N - 1}\right) \quad \mathbf{= PMT(\mathit{i},\mathit{N},-\mathit{P})}$$

$$2000 = 80\ 000\left(\frac{0.01(1.01)^N}{1.01^N - 1}\right)$$

$$2.5 = \frac{(1.01)^N}{(1.01)^N - 1}$$

$$2.5/1.5 = (1.01)^N$$

$$N[ln(1.01)] = ln(2.5/1.5)$$

$$N = 51.34 \text{ months}$$

It will take Clarence four years and four months to pay off the mortgage. He will make 51 full payments of $2000 and will be left with only a fraction of a full payment for his 52nd and last monthly installment. Problem 4.47 asks what his final payment will be. Note that mortgages can be confusing because of the different terms used. See Close-Up 4.2. ■

In Example 4.4, it was possible to use the formula for the compound interest factor to solve for the unknown quantity directly. It is not always possible to do this when the number of periods or the interest rate is unknown. We can proceed in several ways. One possibility is to determine the unknown value by trial and error with a spreadsheet. Another approach is to find the nearest values using tables, and then to interpolate linearly to determine an approximate value. Some calculators will perform the interpolation automatically. See Close-Up 4.3 and Figure 4.3 for a reminder of how linear interpolation works.

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CLOSE-UP 4.2 Mortgages

Mortgages can be a little confusing because of the terminology used. In particular, the word *term* is used in different ways in different countries. It can mean either the duration over which the original loan is calculated to be repaid (called the **amortization period** in Canada). It can also mean the duration over which the loan agreement is valid (otherwise called the *maturity*). The interest rate is a nominal rate, usually compounded monthly.

For example, Salim has just bought a house for \$135 000. He paid \$25 000 down, and the rest of the cost has been obtained from a mortgage. The mortgage has a nominal interest rate of 9.5 percent compounded monthly with a 20-year amortization period. The term (maturity) of the mortgage is three years. What are Salim's monthly payments? How much does he owe after three years?

Salim's monthly payments can be calculated as

$$\begin{aligned} A &= (135\,000 - 25\,000)(A/P,9.5/12\%,[20 \times 12]) \\ &= 110\,000(A/P,0.7917\%,240) \quad \mathbf{= \mathit{PMT}(0.007917,240,-110\,000)} \\ &= 110\,000(0.00932) \\ &= 1025.20 \end{aligned}$$

A more direct approach would be to compute the present worth (at the end of three years) of the remaining 204 payments:

$$P = \$1025.2(P/A,0.079,204) = 103\,598.$$

Salim's monthly payments would be about \$1025.20. After three years he would have to renegotiate his mortgage at the current interest rate at that time. The amount owed would be

$$\begin{aligned} F &= 110\,000(F/P,9.5/12\%,36) - 1025.20(F/A,9.5/12\%,36) \\ &= 110\,000(1.3283) - 1025.20(41.47) \quad \mathbf{= \mathit{FV}(0.007913,36,-110\,000) - \mathit{FV}(0.007913,36,-1025.20)} \\ &= 103\,598 \end{aligned}$$

After three years, Salim still owes \$103 598.

CLOSE-UP 4.3 Linear Interpolation

Linear interpolation is the process of approximating a complicated function by a straight line in order to estimate a value for the independent variable based on two sample pairs of independent and dependent variables and an instance of the dependent variable. For example, the function f in Figure 4.3 relates the dependent variable y to the independent variable x. Two sample points, (x_1, y_1) and (x_2, y_2), and an instance of y, y^*, are known, but the actual shape of f is not. An estimate of the value for x^* can be made by drawing a straight line between (x_1, y_1) and (x_2, y_2).

Because the line between (x_1, y_1) and (x_2, y_2) is assumed to be straight, the following ratios must be equal:

$$\frac{x^* - x_1}{x_2 - x_1} = \frac{y^* - y_1}{y_2 - y_1}$$

Isolating the x^* gives the linear interpolation formula:

$$x^* = x_1 + (x_2 - x_1)\left[\frac{y^* - y_1}{y_2 - y_1}\right]$$

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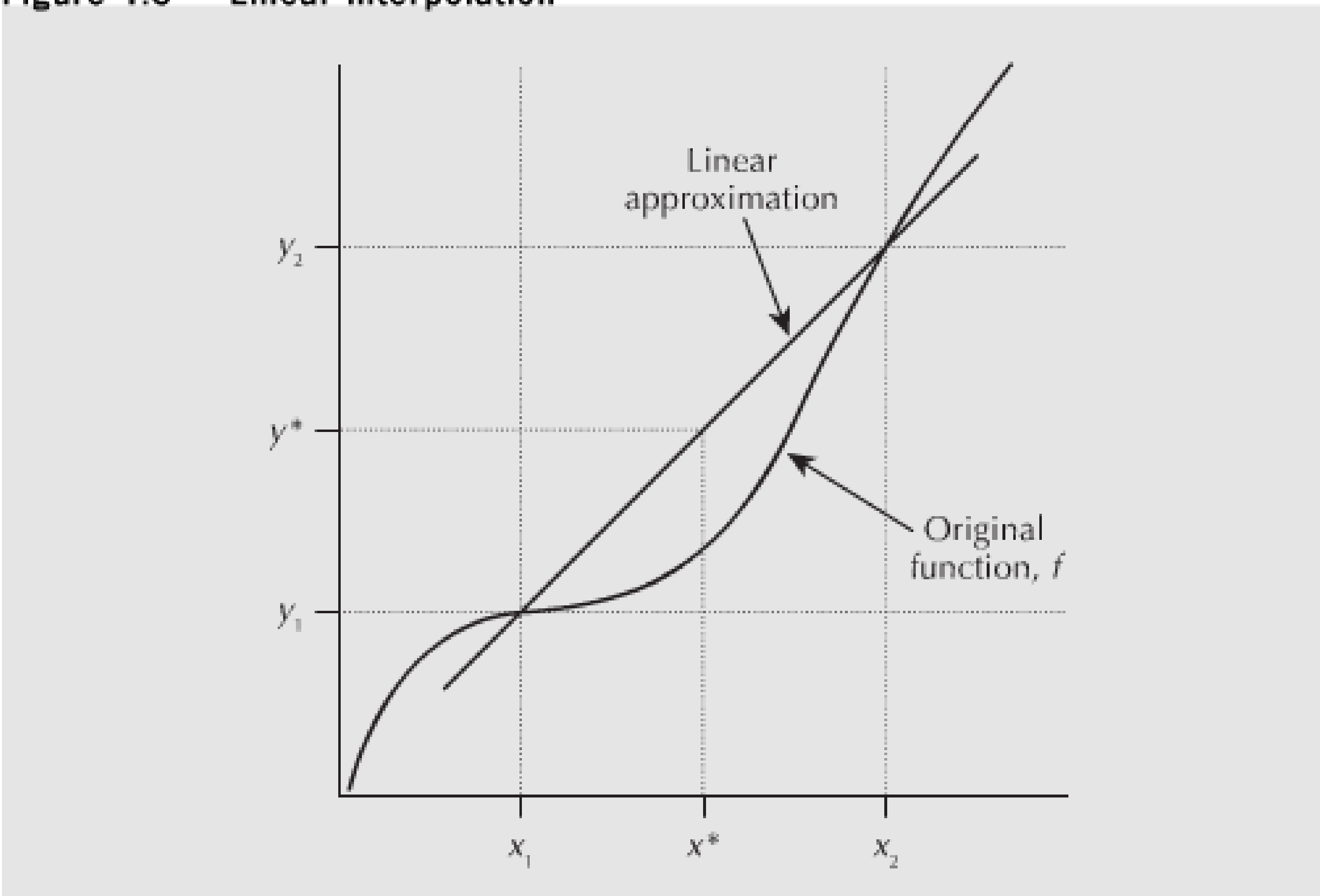
Figure 4.3 Linear Interpolation



EXAMPLE 4.5

Clarence paid off an \$80 000 mortgage completely in 48 months. He paid \$2000 per month, and at the end of the first year made an extra payment of \$7000. What interest rate was he charged on the mortgage?

Using the series present worth factor and the present worth factor, this can be formulated for an unknown interest rate:

$$80\ 000 = 2000(P/A,i,48) + 7000(P/F,i,12)$$

= PV(i,48,−2000) + PV(i,12,−7000)

$$2(P/A,i,48) + 7(P/F,i,12) = 80$$

$$2\left[\frac{(1+i)^{48}-1}{i(1+i)^{48}}\right] + 7\left[\frac{1}{(1+i)^{12}}\right] = 80 \qquad (4.1)$$

Solving such an equation for i directly is generally not possible. However, using a spreadsheet as illustrated in Table 4.1 can establish some close values for the left-hand side of Equation (4.1), and a similar process can be done using either tables or a calculator. Using a spreadsheet program or calculator, trials can establish a value for the unknown interest rate to the desired number of significant digits.

Once the approximate values for the interest rate are found, linear interpolation can be used to find a more precise answer. For instance, by working from the values of the interest rate that give the LHS (left-hand side) value closest to the RHS (right-hand side) value of 80, which are 1.1 percent and 1.2 percent,

$$i = 1.1 + (1.2 - 1.1)\left[\frac{80 - 80.4141}{78.7209 - 80.4141}\right]$$

$$= 1.1 + 0.02 = 1.12 \text{ percent per month}$$

The nominal interest rate was $1.12 \times 12 = 13.44$ percent.

The effective interest rate was $(1.0112)^{12} - 1 = 14.30$ percent. ■

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Table 4.1 Trials to Determine an Unknown Interest Rate

Interest Rate i	$2(P/A,i,48) + 7(P/F,i,12)$
0.5%	91.7540
0.6%	89.7128
0.7%	87.7350
0.8%	85.8185
0.9%	83.9608
1.0%	82.1601
1.1%	80.4141
1.2%	78.7209
1.3%	77.0787
1.4%	75.4855
1.5%	73.9398

Another interesting application of compound interest factors is calculating the value of a bond. See Close-Up 4.4.

CLOSE-UP 4.4 Bonds

Bonds are investments that provide an annuity and a future value in return for a cost today. They have a *par* or *face* value, which is the amount for which they can be redeemed after a certain period of time. They also have a *coupon rate*, meaning that they pay the bearer an annuity, usually semiannually, calculated as a percentage of the face value. For example, a coupon rate of 10 percent on a bond with an \$8000 face value would pay an annuity of \$400 each six months. Bonds can sell at more or less than the face value, depending on how buyers perceive them as investments.

To calculate the worth of a bond today, sum together the present worth of the face value (a future amount) and the coupons (an annuity) at an appropriate interest rate. For example, if money can earn 12 percent compounded semiannually, a bond maturing in 15 years with a face value of \$5000 and a coupon rate of 7 percent is today worth

$$
\begin{aligned}
P &= 5000(P/F,6\%,30) + (5000 \times 0.07/2)\,(P/A,6\%,30) \\
&= 5000(0.17411) + 175(13.765) \\
&= 3279.43
\end{aligned}
$$

The bond is worth about \$3279 today.

4.6 Conversion Factor for Arithmetic Gradient Series

An arithmetic gradient series is a series of receipts or disbursements that starts at zero at the end of the first period and then increases by a constant *amount* from period to period. Figure 4.4 illustrates an arithmetic gradient series of receipts. Figure 4.5 shows

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Figure 4.4 Arithmetic Gradient Series of Receipts

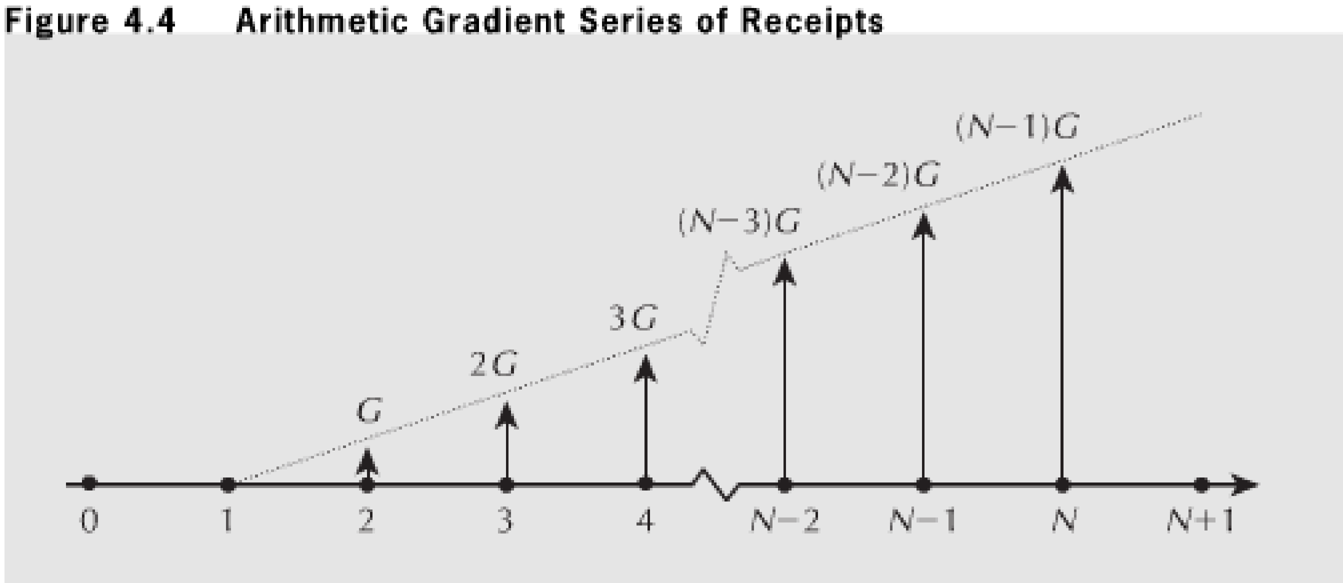
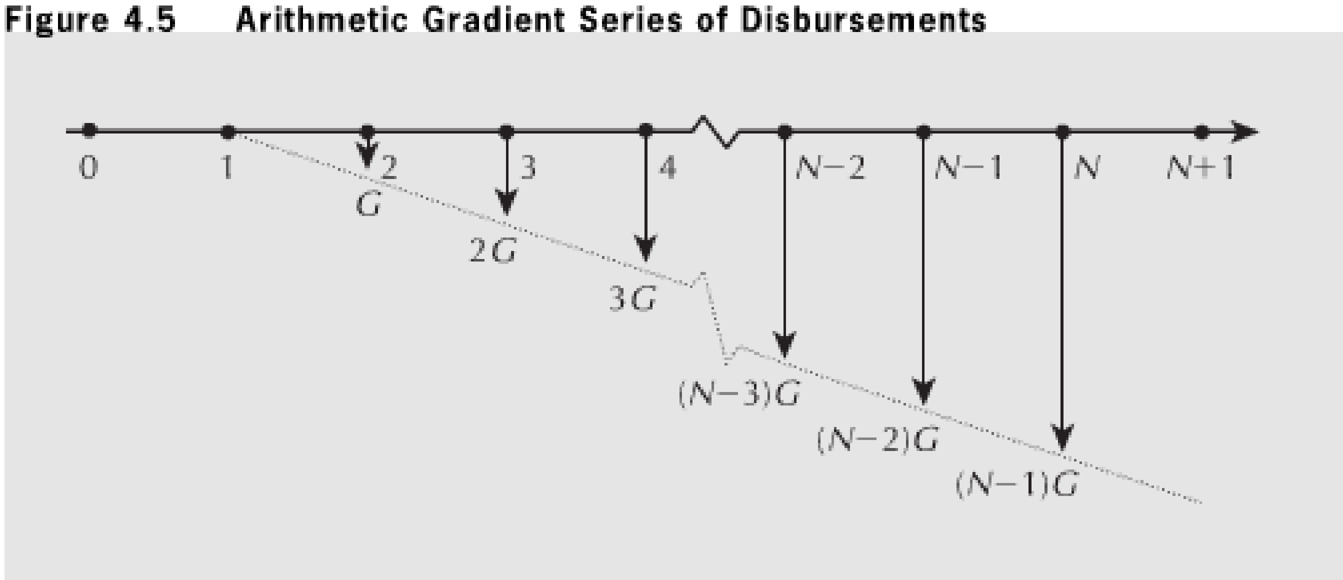


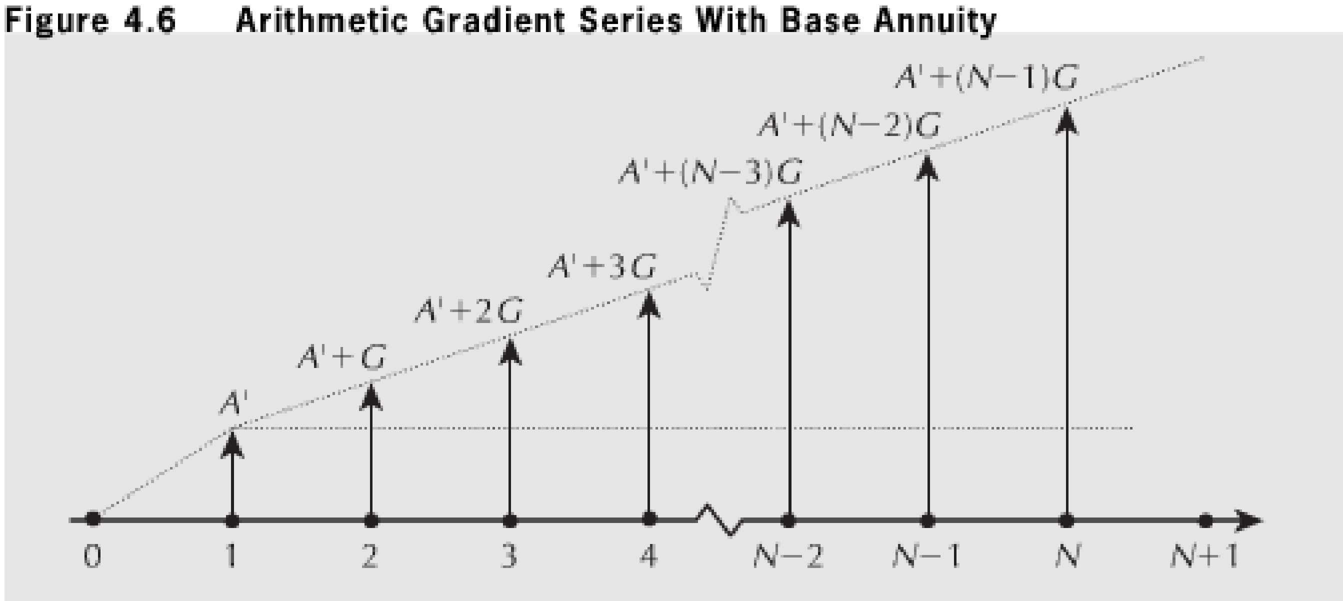
Figure 4.5 Arithmetic Gradient Series of Disbursements



an arithmetic gradient series of disbursements. As an example, we may model a pattern of increasing operating costs for an aging machine as an arithmetic gradient series if the costs are increasing by (approximately) the same amount each period. Note carefully that the first non-zero cash flow of a gradient occurs at the end of the *second* compounding period, not the first.

The sum of an annuity plus an arithmetic gradient series is a common pattern. The annuity is a base to which the arithmetic gradient series is added. This is shown in Figure 4.6. A constant-amount increase to a base level of receipts may occur where the increase in receipts is due to adding capacity and where the ability to add capacity is

Figure 4.6 Arithmetic Gradient Series With Base Annuity



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limited. For example, a company that specializes in outfitting warehouses for grocery chains can expand by adding work crews. But the crews must be trained by managers who have time to train only one crew member every six months. Hence, we would have a base amount and a constant amount of growth in cash flows each period.

The **arithmetic gradient to annuity conversion factor**, denoted by $(A/G,i,N)$, gives the value of an annuity, A, that is equivalent to an arithmetic gradient series where the constant increase in receipts or disbursements is G per period, the interest rate is i, and the number of periods is N. That is, the arithmetic gradient series $0G$, $1G$, $2G$, . . . , $(N - 1)G$ is given and the uniform cash flow, A, over N periods is found. Problem 4.44 asks the reader to show that the equation for the arithmetic gradient to annuity factor is

$$(A/G,i,N) = \frac{1}{i} - \frac{N}{(1+i)^N - 1}$$

There is often a base annuity A' associated with a gradient, as illustrated in Figure 4.6. To determine the uniform series equivalent to the *total* cash flow, the base annuity A' must be included to give the overall annuity:

$$A_{\text{tot}} = A' + G(A/G,i,N)$$

EXAMPLE 4.6

Susan Ng owns an eight-year-old Prius automobile. She wants to find the present worth of repair bills over the four years that she expects to keep the car. Susan has the car in for repairs every six months. Repair costs are expected to increase by \$50 every six months over the next four years, starting with \$500 six months from now, \$550 six months later, and so on. What is the present worth of the repair costs over the next four years if the interest rate is 12 percent compounded monthly?

First, observe that there will be $N = 8$ repair bills over four years and that the base annuity payment, A', is \$500. The arithmetic gradient component of the bills, G, is \$50, and hence the arithmetic gradient series is \$0, \$50, \$100, and so on. The present worth of the repair bills can be obtained in a two-step process:

Step 1. Find the total uniform annuity, A_{tot}, equivalent to the sum of the base annuity, $A' = \$500$, and the arithmetic gradient series with $G = \$50$ over $N = 8$ periods.

Step 2. Find the present worth of A_{tot} using the series present worth factor.

The 12 percent nominal interest rate, compounded monthly, is 1 percent per month. The effective interest rate per six-month period is

$$i_{\text{6month}} = (1 + 0.12/12)^6 - 1 = 0.06152 \text{ or } 6.152\%$$

Step 1

$$\begin{aligned} A_{\text{tot}} &= A' + G(A/G,i,N) \\ &= 500 + 50\left(\frac{1}{i} - \frac{N}{(1+i)^N - 1}\right) \\ &= 500 + 50\left(\frac{1}{0.06152} - \frac{8}{(1.06152)^8 - 1}\right) \\ &= 659.39 \end{aligned}$$

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Step 2

$$P = A_{\text{tot}}(P/A,i,N) = A_{\text{tot}}\left(\frac{(1+i)^N - 1}{i(1+i)^N}\right)$$

$$= 659.39\left(\frac{(1.06152)^8 - 1}{0.06152(1.06152)^8}\right)$$

$$= 4070.09$$

The present worth of the repair costs is about \$4070. ■

4.7 Conversion Factor for Geometric Gradient Series

A geometric gradient series is a series of cash flows that increase or decrease by a constant *percentage* each period. The geometric gradient series may be used to model inflation or deflation, productivity improvement or degradation, and growth or shrinkage of market size, as well as many other phenomena.

In a geometric series, the base value of the series is A and the "growth" rate in the series (the rate of increase or decrease) is referred to as g. The terms in such a series are given by A, $A(1 + g)$, $A(1 + g)^2$, . . . , $A(1 + g)^{N-1}$ at the ends of periods 1, 2, 3, . . . , N, respectively. If the rate of growth, g, is positive, the terms are increasing in value. If the rate of growth, g, is negative, the terms are decreasing. Figure 4.7 shows a series of receipts where g is positive. Figure 4.8 shows a series of receipts where g is negative.

The **geometric gradient to present worth conversion factor**, denoted by $(P/A,g,i,N)$, gives the present worth, P, that is equivalent to a geometric gradient series where the base receipt or disbursement is A, and where the rate of growth is g, the interest rate is i, and the number of periods is N.

Figure 4.7 Geometric Gradient Series for Receipts With Positive Growth

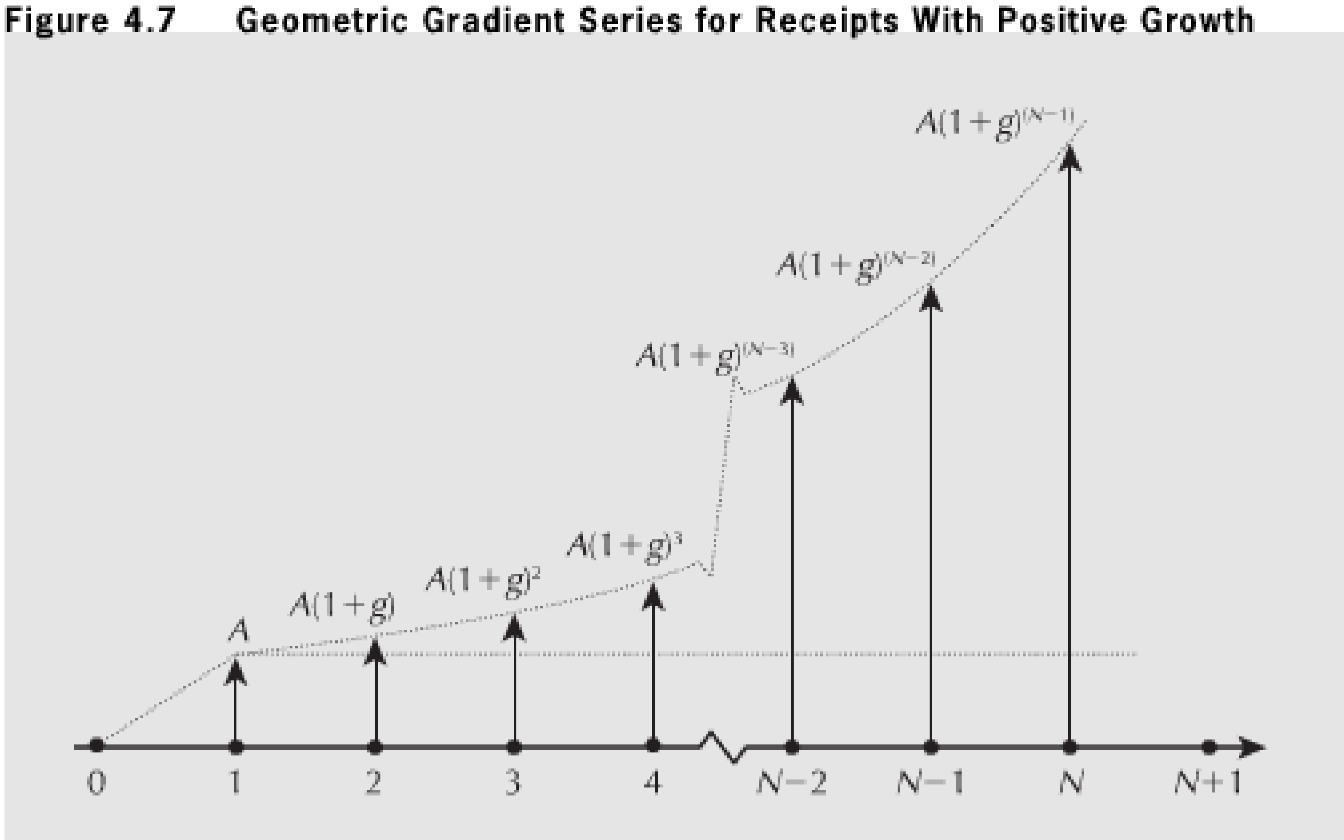

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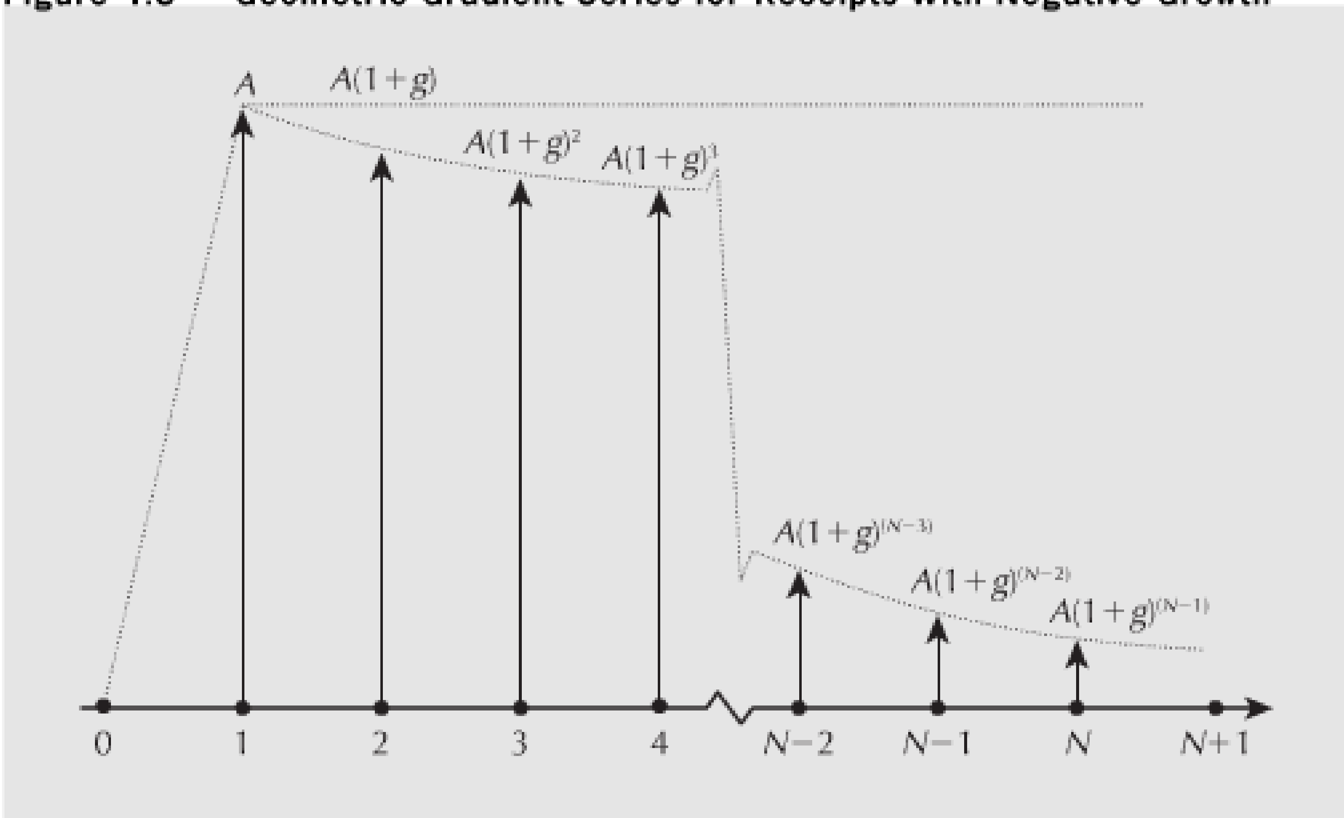
Figure 4.8 Geometric Gradient Series for Receipts With Negative Growth



The present worth of a geometric series is

$$P = \frac{A}{1+i} + \frac{A(1+g)}{(1+i)^2} + \ldots + \frac{A(1+g)^{N-1}}{(1+i)^N}$$

where A = the base amount
g = the rate of growth
i = the interest rate
N = the number of periods
P = the present worth

NET VALUE 4.1

Estimating Growth Rates

Geometric gradient series can be used to model the effects of inflation, deflation, production rate change, and market size change on a future cash flow. When using a geometric gradient series, the relevant growth rate must be estimated. The internet can be a useful research tool for collecting information such as expert opinions and statistics on trends for national and international activities by product type and industry. For example, a sales growth rate may be estimated by considering a number of factors: economic condition indicators (e.g., gross domestic product, employment, consumer spending), population growth, raw material cost, and even online shopping and business-to-business trading. Federal governments are keen to assess what has happened in order to predict what will happen. In Canada, such information is collected by Statistics Canada and is available to the public online at www.statcan.gc.ca.

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We can define a **growth-adjusted interest rate**, $i°$, as

$$i° = \frac{1 + i}{1 + g} - 1$$

so that

$$\frac{1}{1 + i°} = \frac{1 + g}{1 + i}$$

Then the geometric gradient series to present worth conversion factor is given by

$$(P/A,g,i,N) = \frac{(P/A,i°,N)}{1 + g} \text{ or}$$

$$(P/A,g,i,N) = \left(\frac{(1 + i°)^N - 1}{i°(1 + i°)^N}\right)\frac{1}{1 + g} \qquad = \boldsymbol{PV(i,N,-A)/(1 + g)}$$

Care must be taken in using the geometric gradient to present worth conversion factor. Four cases may be distinguished:

1. $i > g > 0$. *Growth is positive, but less than the rate of interest.* The growth-adjusted interest rate, $i°$, is positive. Tables or functions built into software may be used to find the conversion factor.
2. $g > i > 0$. *Growth is positive and greater than the interest rate.* The growth-adjusted interest rate, $i°$, is negative. It is necessary to compute the conversion factor directly from the formula.
3. $g = i > 0$. *Growth is positive and exactly equal to the interest rate.* The growth-adjusted interest rate, $i°$, equals zero. As with any case where the interest rate is zero, the present worth of the series with constant terms, $A/(1 + g)$, is simply the sum of all the N terms:

$$P = N\left(\frac{A}{1 + g}\right)$$

4. $g < 0$. *Growth is negative.* In other words, the series is decreasing. The growth-adjusted interest rate, $i°$, is positive. Tables or functions built into software may be used to find the conversion factor.

EXAMPLE 4.7

Tru-Test is in the business of assembling and packaging automotive and marine testing equipment to be sold through retailers to "do-it-yourselfers" and small repair shops. One of its products is tire pressure gauges. This operation has some excess capacity. Tru-Test is considering using this excess capacity to add engine compression gauges to its line. It can sell engine pressure gauges to retailers for $8 per gauge and expect to be able to produce about 1000 gauges in the first month of production. It also expects that, as the workers learn how to do the work more efficiently, productivity will rise by 0.25 percent per month for the first two years. In other words, each month's output of gauges will be 0.25 percent more than the previous month's. The interest rate is 1.5 percent per month. All gauges are sold in the month in which they are produced, and receipts from sales are at the end of each month. What is the present worth of the sales of the engine pressure gauges in the first two years?

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We first compute the growth-adjusted interest rate, i°:

$$i^\circ = \frac{1+i}{1+g} - 1 = \frac{1.015}{1.0025} - 1 = 0.01247$$

$$i^\circ \approx 1.25\%$$

We then make use of the geometric gradient to present worth conversion factor with the uniform cash flow $A = \$8000$, the growth rate $g = 0.0025$, the growth-adjusted interest rate $i^\circ = 0.0125$, and the number of periods $N = 24$.

$$P = A(P/A,g,i,N) = A\left(\frac{(P/A,i^\circ,N)}{1+g}\right) \quad \mathbf{= PV(\textit{i},N,-\textit{A})/(1 + \textit{g})}$$

$$P = 8000\left(\frac{(P/A,1.25\%,24)}{1.0025}\right)$$

From the interest factor tables we get

$$P = 8000\left(\frac{20.624}{1.0025}\right)$$

$$P = 164\ 580$$

The present worth of sales of engine compression gauges over the two-year period would be about \$165 000. Recall that we worked with an *approximate* growth-adjusted interest rate of 1.25 percent when the correct rate was a bit less than 1.25 percent. This means that \$164 580 is a slight understatement of the present worth. ■

EXAMPLE 4.8

Emery's company, Dry-All, produces control systems for drying grain. Proprietary technology has allowed Dry-All to maintain steady growth in the U.S. market in spite of numerous competitors. Company dividends, all paid to Emery, are expected to rise at a rate of 10 percent per year over the next 10 years. Dividends at the end of this year are expected to total \$110 000. If all dividends are invested at 10 percent interest, how much will Emery accumulate in 10 years?

If we calculate the growth-adjusted interest rate, we get

$$i^\circ = \frac{1.1}{1.1} - 1 = 0$$

and it is natural to think that the present worth is simply the first year's dividends multiplied by 10. However, recall that in the case where $g = i$, the present worth is given by

$$P = N\left(\frac{A}{1+g}\right) = 10\left(\frac{110\ 000}{1.1}\right) = 1\ 000\ 000$$

Intuitively, dividing by $(1 + g)$ compensates for the fact that growth is considered to start after the end of the first period, but the interest rate applies to all periods. We want the future worth of this amount after 10 years:

$$F = 1\ 000\ 000(F/P,10\%,10) = 1\ 000\ 000(2.5937) = 2\ 593\ 700$$

Emery will accumulate \$2 593 700 in dividends and interest. ■

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4.8 Non-Standard Annuities and Gradients

As discussed in Section 4.3, the standard assumption for annuities and gradients is that the payment period and compounding period are the same. If they are not, the formulas given in this chapter cannot be applied directly. There are three methods for dealing with this situation:

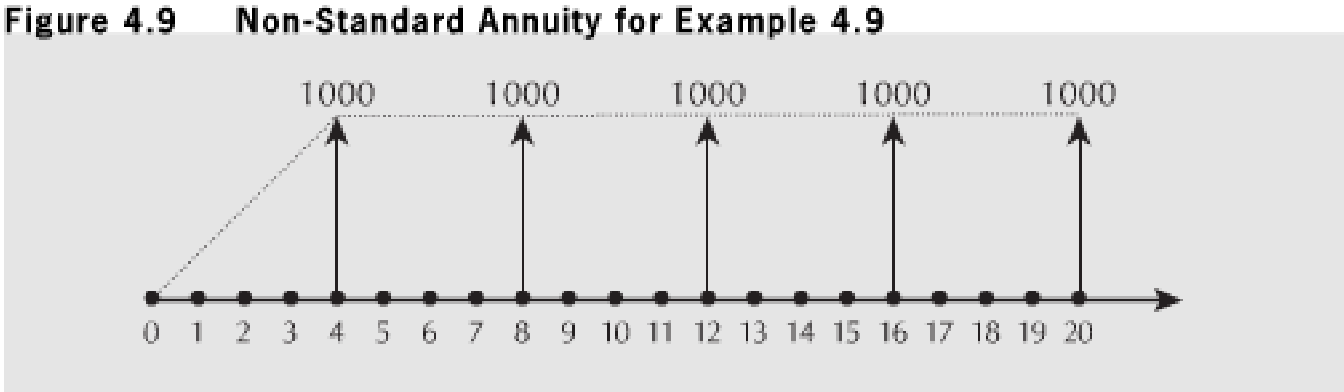
1. Treat each cash flow in the annuity or gradient individually. This is most useful when the annuity or gradient series is not large.
2. Convert the non-standard annuity or gradient to standard form by changing the compounding period.
3. Convert the non-standard annuity to standard form by finding an equivalent standard annuity for the compounding period. This method cannot be used for gradients.

EXAMPLE 4.9

How much is accumulated over 20 years in a fund that pays 4 percent interest, compounded yearly, if $1000 is deposited at the end of every fourth year?

The cash flow diagram for this set of payments is shown in Figure 4.9.

Figure 4.9 Non-Standard Annuity for Example 4.9



Method 1: Consider the annuities as separate future payments.

Formula: $F = P(F/P,i,N)$

Known values: $P = \$1000$, $i = 0.04$, $N = 16, 12, 8, 4$, and 0

Year	Future Value				
4	1000(F/P,4%,16)	=	1000(1.8729)	=	1873
8	1000(F/P,4%,12)	=	1000(1.6010)	=	1601
12	1000(F/P,4%,8)	=	1000(1.3685)	=	1369
16	1000(F/P,4%,4)	=	1000(1.1698)	=	1170
20	1000			=	1000
	Total future value			=	7013

About $7013 is accumulated over the 20 years.

Method 2: Convert the compounding period from yearly to every four years. This can be done with the effective interest rate formula.

$$i_e = (1 + 0.04)^4 - 1$$
$$= 16.99\%$$

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The future value is then

$$F = 1000(F/A,16.99\%,5) = 1000(7.013) \quad = FV(0.1699,5,-1000)$$

$$= 7013$$

Method 3: Convert the annuity to an equivalent yearly annuity. This can be done by considering the first payment as a future value over the first four-year period and finding the equivalent annuity over that period using the sinking fund factor:

$$A = 1000(A/F,4\%,4) \quad = PMT(0.04,4,-1000)$$

$$= 1000(0.23549)$$

$$= 235.49$$

In other words, a \$1000 deposit at the end of the four years is equivalent to four equal deposits of \$235.49 at the end of each of the four years. This yearly annuity is accumulated over the 20 years.

$$F = 235.49(F/A,4\%,20) \quad = FV(0.04,20,-235.49)$$

$$= 235.49(29.777)$$

$$= 7012$$

Note that each method produces the same amount, allowing for rounding. When you have a choice in methods as in this example, your choice will depend on what you find convenient or what is the most efficient computationally. ■

EXAMPLE 4.10

This year's electrical engineering class has decided to save up for a class party. Each of the 90 people in the class is to contribute \$0.25 per day, which will be placed in a daily interest (7 days a week, 365 days a year) savings account that pays a nominal 8 percent interest. Contributions will be made *five* days a week, Monday through Friday, beginning on Monday. The money is put into the account at the beginning of each day, and thus earns interest for the day. The class party is in 14 weeks (a full 14 weeks of payments will be made), and the money will be withdrawn on the Monday morning of the 15th week. How much will be saved, assuming everybody makes payments on time?

There are several good ways to solve this problem. One way is to convert each day's contribution to a weekly amount on Sunday evening/Monday morning, and then accumulate the weekly amounts over the 14 weeks:

Total contribution per day is $0.25 \times 90 = 22.50$

The interest rate per day is $\dfrac{0.08}{365} = 0.000219$

The effective interest rate for a one-week period is

$$i = (1 + 0.08/365)^7 - 1 = 0.001535$$

Value of one week's contribution on Friday evening (*annuity due* formula):

$$22.50 \times (F/P,0.08/365,1) \times (F/A,0.08/365,5)$$

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On Sunday evening, this is worth

$$[22.50(F/P,0.08/365,1)(F/A,0.08/365,5)] \times (F/P,0.08/365,2)$$
$$= 22.50(F/P,0.08/365,3)(F/A,0.08/365,5)$$

Then the total amount accumulated by Monday morning of the 15th week is given by:

$$[22.50(F/P,0.08/365,3)(F/A,0.08/365,5)](F/A,0.1535,14)$$
$$= [22.50(1.000\ 658)(5.002\ 19)](14.1406)$$
$$= 1592.56$$

The total amount saved would be \$1592.56. ■

4.9 Present Worth Computations When $N \rightarrow \infty$

We have until now assumed that the cash flows of a project occur over some fixed, finite number of periods. For long-lived projects, it may be reasonable to model the cash flows as though they will continue indefinitely. The present worth of an infinitely long uniform series of cash flows is called the **capitalized value** of the series. We can get the capitalized value of a series by allowing the number of periods, N, in the series present worth factor to go to infinity:

$$P = \lim_{N\rightarrow\infty} A(P/A,i,N)$$

$$= A \lim_{N\rightarrow\infty} \left[\frac{(1+i)^N - 1}{i(1+i)^N}\right]$$

$$= A \lim_{N\rightarrow\infty} \left[\frac{1 - \frac{1}{(1+i)^N}}{i}\right]$$

$$= \frac{A}{i}$$

EXAMPLE 4.11

The town of South Battleford is considering building a bypass for truck traffic around the downtown commercial area. The bypass will provide merchants and shoppers with benefits that have an estimated value of \$500 000 per year. Maintenance costs will be \$125 000 per year. If the bypass is properly maintained, it will provide benefits for a very long time. The actual life of the bypass will depend on factors such as future economic conditions that cannot be forecast at the time the bypass is being considered. It is therefore reasonable to model the flow of benefits as though they will continue indefinitely. If the interest rate is 10 percent, what is the present worth of benefits minus maintenance costs?

$$P = \frac{A}{i} = \frac{500\ 000 - 125\ 000}{0.1} = 3\ 750\ 000$$

The present worth of benefits net of maintenance costs is \$3 750 000. ■

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REVIEW PROBLEMS

REVIEW PROBLEM 4.1

The benefits of a revised production schedule for a seasonal manufacturer will not be realized until the peak summer months. Net savings will be \$1100, \$1200, \$1300, \$1400, and \$1500 at the ends of months 5, 6, 7, 8, and 9, respectively. It is now the beginning of month 1. Assume 365 days per year, 30 days per month. What is the present worth (PW) of the savings if nominal interest is

(a) 12 percent per year, compounded monthly?

(b) 12 percent per year, compounded daily?

ANSWER

(a) $A = \$1100$

$G = \$100$

$i = 0.12/12 = 0.01$ per month $= 1\%$

$$\begin{aligned}
\text{PW(end of period 4)} &= (P/A,1\%,5)[1100 + 100(A/G,1\%,5)] \\
&= 4.8528[1100 + 100(1.9801)] \\
&= 6298.98 \\
\text{PW(at time 0)} &= \text{PW(end of period 4)}(P/F,1\%,4) \\
&= 6298.98/(1.01)^4 = 6053.20
\end{aligned}$$

The present worth is about \$6053.

(b)
$$\begin{aligned}
\text{Effective interest rate } i &= (1 + 0.12/365)^{30} - 1 = 0.0099102 \\
\text{PW(at time 0)} &= \text{PW(end of period 4)}(P/F,i,4) \\
&= (P/A,i,5)[1100 + 100(A/G,i,5)](P/F,i,4) \\
&= 4.8547[1100 + 100(1.98023)](0.9613) \\
&= 6057.80
\end{aligned}$$

The present worth is about \$6058.■

REVIEW PROBLEM 4.2

It is January 1 of this year. You are starting your new job tomorrow, having just finished your engineering degree at the end of last term. Your take-home pay for this year will be \$66 000. It will be paid to you in equal amounts at the end of each month, starting at the end of January. There is a cost-of-living clause in your contract that says that each subsequent January you will get an increase of 3 percent in your yearly salary (i.e., your take-home pay for next year will be 1.03 × \$66 000). In addition to your salary, a wealthy relative regularly sends you a \$2000 birthday present at the end of each June.

Recognizing that you are not likely to have any government pension, you have decided to start saving 10 percent of your monthly salary and 50 percent of your birthday present for your retirement. Interest is 1 percent per month, compounded monthly. How much will you have saved at the end of five years?

ANSWER

Yearly pay is a geometric gradient; convert your monthly salary into a yearly amount by the use of an effective yearly rate. The birthday present can be dealt with separately.

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Salary:

The future worth (FW) of the salary at the end of the first year is

$$\text{FW(salary, year 1)} = 5500(F/A,1 \text{ percent},12) = 69\,756.00$$

This forms the base of the geometric gradient; all subsequent years increase by 3 percent per year. Savings are 10 percent of salary, which implies that $A = \$6976.00$.

$A = \$6976.00 \qquad g = 0.03$

Effective yearly interest rate $i_e = (1 + 0.01)^{12} - 1 = 0.1268$ per year

$$i° = \frac{1 + i_e}{1 + g} - 1 = \frac{1 + 0.1268}{1 + 0.03} - 1 = 0.093981$$

$$\begin{aligned} \text{PW(gradient)} &= A\,(P/A,i°,5)/(1 + g) = 6976(3.8498)/1.03 \\ &= 26\,074 \end{aligned}$$

$$\begin{aligned} \text{FW(gradient, end of five years)} &= \text{PW(gradient)}(F/P,i_e,5) \\ &= 26\,074(1.1268)^5 = 43\,363 \end{aligned}$$

Birthday Present:

The present arrives in the middle of each year. To get the total value of the five gifts, we can find the present worth of an annuity of five payments of \$2000(0.5) as of six months prior to employment:

$$\text{PW}(-6 \text{ months}) = 2000(0.5)(P/A,i_e,5) = 3544.6$$

The future worth at $5 \times 12 + 6 = 66$ months later is

$$\text{FW(end of five years)} = 35544.6(1.01)^{66} = 6836$$

$$\text{Total amount saved} = \$6836 + \$43\,363 = \$54\,199 \blacksquare$$

REVIEW PROBLEM 4.3

The Easy Loan Company advertises a "10 percent" loan. You need to borrow \$1000, and the deal you are offered is the following: You pay \$1100 (\$1000 plus \$100 interest) in 11 equal \$100 amounts, starting one month from today. In addition, there is a \$25 administration fee for the loan, payable immediately, and a processing fee of \$10 per payment. Furthermore, there is a \$20 non-optional closing fee to be included in the last payment. Recognizing fees as a form of interest payment, what is the actual effective interest rate?

ANSWER

Since the \$25 administration fee is paid immediately, you are only getting \$975. The remaining payments amount to an annuity of \$110 per month, plus a \$20 future payment 11 months from now.

Formulas: $P = A(P/A,i,N)$, $P = F(P/F,i,N)$

Known values: $P = \$975$, $A = \$110$, $F = \$20$, $N = 11$

$975 = 110(P/A,i,11) + 20(P/F,i,11)$ $\quad$ $\mathbf{= \mathit{PV}(\mathit{i},11,-110) + \mathit{PV}(\mathit{i},11,-20)}$

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At $i = 4$ percent

$$110(P/A,4\%,11) + 20(P/F,4\%,11) \quad = \boldsymbol{PV(0.04,11,-110) + PV(0.04,11,-20)}$$
$$= 110(8.7603) + 20(0.64958)$$
$$= 976.62$$

At $i = 5$ percent

$$110(P/A,5\%,11) + 20(P/F,5\%,11) \quad = \boldsymbol{PV(0.05,11,-110) + PV(0.05,11,-20)}$$
$$= 110(8.3062) + 20(0.58469)$$
$$= 925.37$$

Linearly interpolating gives

$$i = 4 + (5 - 4)\,(975 - 976.62)/(925.37 - 976.62)$$
$$= 4.03$$

The effective interest rate is then

$$i = (1 + 0.0403)^{12} - 1$$
$$= 60.69\% \text{ per annum (!)}$$

Although the loan is advertised as a "10 percent" loan, the actual effective rate is over 60 percent.■

REVIEW PROBLEM 4.4

Ming wants to retire as soon as she has enough money invested in a special bank account (paying 14 percent interest, compounded annually) to provide her with an annual income of \$25 000. She is able to save \$10 000 per year, and the account now holds \$5000. If she just turned 20, and expects to die in 50 years, how old will she be when she retires? There should be no money left when she turns 70.

ANSWER

Let Ming's retirement age be $20 + x$ so that

$$5000(F/P,14\%,x) + 10\,000(F/A,14\%,x) = 25\,000(P/A,14\%,50 - x)$$

Dividing both sides by 5000,

$$(F/P,14\%,x) + 2(F/A,14\%,x) - 5(P/A,14\%,50 - x) = 0$$

At $x = 5$

$$(F/P,14\%,5) + 2(F/A,14\%,5) - 5(P/A,14\%,45)$$
$$= 1.9254 + 2(6.6101) - 5(7.1232) = -20.4704$$

At $x = 10$

$$(F/P,14\%,10) + 2(F/A,14\%,10) - 5(P/A,14\%,40)$$
$$= 3.7072 + 2(19.337) - 5(7.1050) = 6.8562$$

Linearly interpolating,

$$x = 5 + 5 \times (20.4704)/(6.8562 + 20.4704)$$
$$= 8.7$$

Ming can retire at age $20 + 8.7 = 28.7$ years old.■

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SUMMARY

In Chapter 4 we considered ways of modelling patterns of cash flows that enable easy comparisons of the worths of projects. The emphasis was on discrete models. Four basic patterns of discrete cash flows were considered:

1. Flows at a single point
2. Flows that are constant over time
3. Flows that grow or decrease at a constant arithmetic rate
4. Flows that grow or decrease at a constant geometric rate

Compound interest factors were presented that defined mathematical equivalence among the basic patterns of cash flows. A list of these factors with their names, symbols, and formulas appears in Table 4.2. Table 4.3 summarizes the Excel equivalents to the compound interest factors. The chapter also addressed the issue of how to analyze non-standard annuities and gradients as well as the ideas of capital recovery and capitalized value.

Table 4.2 Summary of Useful Formulas for Discrete Models

Name	Symbol and Formula
Compound amount factor	$(F/P,i,N) = (1+i)^N$
Present worth factor	$(P/F,i,N) = \dfrac{1}{(1+i)^N}$
Sinking fund factor	$(A/F,i,N) = \dfrac{i}{(1+i)^N - 1}$
Uniform series compound amount factor	$(F/A,i,N) = \dfrac{(1+i)^N - 1}{i}$
Capital recovery factor	$(A/P,i,N) = \dfrac{i(1+i)^N}{(1+i)^N - 1}$
Series present worth factor	$(P/A,i,N) = \dfrac{(1+i)^N - 1}{i(1+i)^N}$
Arithmetic gradient to annuity conversion factor	$(A/G,i,N) = \dfrac{1}{i} - \dfrac{N}{(1+i)^N - 1}$
Geometric gradient to present worth conversion factor	$(P/A,g,i,N) = \dfrac{(P/A,i^{\circ},N)}{1+g}$
	$(P/A,g,i,N) = \left(\dfrac{(1+i^{\circ})^N - 1}{i^{\circ}(1+i^{\circ})^N}\right)\dfrac{1}{1+g}$
	$i^{\circ} = \dfrac{1+i}{1+g} - 1$
Capitalized value formula	$P = \dfrac{A}{i}$
Capital recovery formula	$A = (P - S)(A/P,i,N) + Si$

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Table 4.3 Compound Interest Factors and Equivalent Excel Computations

Name	Use of Compound Interest Factor	Equivalent Excel Computation
Compound amount factor	$F = P(F/P,i,N)$	$F = FV(i,N,,-P)$
Present worth factor	$P = F(P/F,i,N)$	$P = PV(i,N,,-F)$
Sinking fund factor	$A = F(A/F,i,N)$	$A = PMT(i,N,,-F)$
Uniform series compound amount factor	$F = A(F/A,i,N)$	$F = FV(i,N,-A)$
Capital recovery factor	$A = P(A/P,i,N)$	$A = PMT(i,N,-P)$
Series present worth factor	$P = A(P/A,i,N)$	$P = PV(i,N,-A)$
Arithmetic gradient to annuity conversion factor	$A_{tot} = A' + G(A/G,I,N)$	No equivalent Excel function
Geometric gradient to present worth conversion factor	$P = A(P/A,g,i,N)$	$P = PV(i^{\circ},N,-A)/(1 + g)$
Capital recovery formula	$A = (P - S)(A/P,i,N) + Si$	$A = PMT(i,N,-(P - S)) + Si$

ENGINEERING ECONOMICS IN ACTION, PART 4B

No Free Lunch

This time it was Naomi who stuck her head in Clem's doorway. "Here's the recommendation on the shipping palletizer. Oh, and thanks for the hint on the leasing figures. It cleared up my confusion right away."

"No problem. What did you figure out?" Clem had his "mentor" expression on his face, so Naomi knew he was expecting a clear explanation of the trick used by the leasing company.

"Well, as you hinted, they were adding apples and oranges. They listed the various costs for each choice over time, including interest charges, taxes, and so on. But then, for the final comparison, they added up these costs. When they were added, leasing was cheaper."

"So what's wrong with that?" Clem prompted.

"They're adding apples and oranges. We're used to thinking of money as being just money, without remembering that money always has a 'when' associated with it. If you add money at different points in time, you might as well be adding apples and oranges: you have a number but it doesn't mean anything. In order to compare leasing with buying, you first have to change the cash flows into the same money—that is, at the same point in time. That's a little harder to do, especially when there's a complicated set of cash flows."

"So were you able to do it?"

"Yes. I identified various components of the cash flows as annuities, gradients, and present and future worths. Then I converted all of these to a present worth for each alternative and summed them. This is the correct way to compare them. If you do that, buying is cheaper, even when borrowing money to do so. And of course it has to be—that leasing company has to pay for those slick brochures somehow. There's no free lunch."

Clem nodded. "I think you've covered it. Mind you, there are some circumstances where leasing is worthwhile. For example, we lease our company cars to save us the time and trouble of reselling them when we're finished with them. Leasing can be good when it's hard to raise the capital for very large purchases, too. But almost always, buying is better. And you know, it amazes me how easy it is to fall for simplistic cash flow calculations that fail to take into account the time value of money. I've even seen articles in the newspaper quoting accountants who make the same mistake, and you'd think they would know better."

"Engineers can make that mistake, too, Clem. I almost did."

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PROBLEMS

A. Key Concepts

4.1 St. Agatha Kennels provides dog breeding and boarding services for a nearby city. Most of the income is derived from boarding, with typical boarding stays being one or two weeks. Customers pay at the end of the dog's stay. Boarding is offered only during the months of May to September. Other income is received from breeding golden retrievers, with two litters of about eight dogs each being produced per year in the spring and fall. Expenses include heating, water, and sewage, which are paid monthly, and food, bought in bulk every spring. The business has been neither growing nor shrinking over the past few years.

Joan, the owner of the kennels, wants to model the cash flows for the business over the next 10 years. What cash flow elements (e.g., single payments, annuities, gradients) would she likely consider, and how would she estimate their value? Consider the present to be the first of May. For example, one cash flow element is food. It would be modelled as an *annuity due* over 10 years, and estimated by the amount paid for food over the past few years.

4.2 It is September, the beginning of his school year, and Marco has to watch his expenses while he is going to school. Over the next eight months, he wants to estimate his cash flows. He pays rent once a month. He takes the bus to and from school. A couple of times a week he goes to the grocery store for food, and he eats lunch in the cafeteria at school every school day. At the end of every four-month term, he will have printing and copying expenses because of reports that will be due. Over the Christmas holidays after the first term, he will have extra expenses for buying presents, but will also get some extra cash from his parents. What cash flow elements (e.g., single payments, annuities, gradients) should Marco likely consider in his estimates? How should he estimate them?

4.3 How much money will be in a bank account at the end of 15 years if \$100 is deposited today and the interest rate is 8 percent compounded annually?

4.4 How much should you invest today at 12 percent interest to accumulate \$1 000 000 in 30 years?

4.5 You have \$1725 to invest. You know that a particular investment will double your money in five years. How much will you have in 10 years if you invest in this investment, assuming that the annual rate of return is guaranteed for the time period?

4.6 Morris paid £500 a month for 20 years to pay off the mortgage on his Glasgow house. If his down payment was £5000 and the interest rate was 6 percent compounded monthly, what was the purchase price of the house?

4.7 An industrial juicer costs \$45 000. It will be used for five years and then sold to a remarketer for \$25 000. If interest is 15 percent, what net yearly savings are needed to justify its purchase?

4.8 Fred wants to save up for an automobile. What amount must he put in his bank account each month to save \$10 000 in two years if the bank pays 6 percent interest compounded monthly?

4.9 How much is accumulated over two years in each of the following savings plans?

(a) \$40 at the end of each month for 24 months at 12 percent compounded monthly

(b) \$30 at the end of the first month, \$31 at the end of the second month, and so forth, increasing by \$1 per month, at 12 percent compounded monthly

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4.10 A UK lottery prize pays £1000 at the end of the first year, £2000 the second, £3000 the third, and so on for 20 years. If there is only one prize in the lottery, 10 000 tickets are sold, and you could invest your money elsewhere at 15 percent interest, how much is each ticket worth, on average?

4.11 Reginald is expecting steady growth of 10 percent per year in profits from his new company. All profits are going to be invested at 20 percent interest. If profits for this year (at the end of the year) total $10 000, how much will be saved at the end of 10 years?

4.12 Reginald is expecting steady growth in profits of 20 percent per year from his new company. All profits are going to be invested at 10 percent interest. If profits for this year (at the end of the year) total $10 000, how much will be saved at the end of 10 years?

4.13 An investment pays $10 000 every five years, starting in seven years, for a total of four payments. If interest is 9 percent, how much is this investment worth today?

4.14 It is May 1. You have just bought $2000 worth of furniture. You will pay for it in 24 equal monthly payments, starting at the end of May next year. Interest is 6 percent nominal per year, compounded monthly. How much will your payments be?

4.15 What is the present worth of the total of 20 payments, occurring at the end of every four months (the first payment is in four months), which are $400, $500, $600, increasing arithmetically? Interest is 12 percent nominal per year, compounded monthly.

4.16 City engineers are considering several plans for building municipal aqueduct tunnels. They use an interest rate of 8 percent. One plan calls for a full-capacity tunnel that will meet the needs of the city forever. The cost is $3 000 000 now and $100 000 every 10 years thereafter for repairs. What is the total present worth of the costs of building and maintaining the aqueduct?

4.17 Goderich Automotive (GA) wants to donate a vacant lot next door to its plant to the city for use as a public park and ball field. The city will accept only if GA will also donate enough cash to maintain the park indefinitely. The estimated maintenance costs are $18 000 per year and interest is 7 percent. How much cash must GA donate?

4.18 A 7 percent, 20-year municipal bond has a $10 000 face value. I want to receive at least 10 percent compounded semiannually on this investment. How much should I pay for the bond?

4.19 If money is worth 8 percent compounded semiannually, how much is a bond maturing in nine years, with a face value of $10 000 and a coupon rate of 9 percent, worth today?

4.20 Trenny has asked her assistant to prepare estimates of cost of two different-sized power plants. The assistant reports that the cost of the 100 MW plant is $200 000 000, while the cost of the 200 MW plant is $360 000 000. If Trenny has a budget of only $300 000 000, estimate how large a power plant she could afford using linear interpolation.

4.21 What interest rate will result in $5000 seven years from now, starting with $2300 today?

4.22 Gwen just bought solar panels to power ventilation at her chicken farm. The panels cost $2000 and will reduce her electricity bills by $40 per month. How long will it take her to recoup her investment in the panels if she can earn 12 percent interest, compounded monthly, on her money?

B. Applications

4.23 Martin and Marcy McCormack have just become proud parents of septuplets. They have savings of $5000. They want to invest their savings so that they can partially support the children's university education. Martin and Marcy hope to provide $20 000

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for each child by the time the children turn 18. What must the annual rate of return on the investment be for Martin and Marcy to meet their goal?

4.24 Refer back to the Kelowna Go-Kart Klub problem of Example 4.2 on page 127. The members determined that it is possible to set aside only $7000 each year, and that they will have to put off building the clubhouse until they have saved the $50 000 necessary. How long will it take to save a total of $50 000, assuming that the interest rate is 10 percent? (*Hint:* Use logarithms to simplify the sinking fund factor.)

4.25 Yoko has just bought a new computer ($2000), a printer ($350), and a scanner ($210). She wants to take the monthly payment option. There is a monthly interest of 3 percent on her purchase.

(a) If Yoko pays $100 per month, how long does it take to complete her payments?

(b) If Yoko wants to finish paying in 24 months, how much will her monthly payment be?

4.26 Rinku has just finished her first year of university. She wants to tour Europe when she graduates in three years. By having a part-time job through the school year and a summer job during the summer, she plans to make regular weekly deposits into a savings account, which bears 18 percent interest, compounded monthly.

(a) If Rinku deposits $15 per week, how much will she save in three years? How about $20 per week?

(b) Find out exactly how much Rinku needs to deposit every week if she wants to save $5000 in three years.

4.27 Seema is looking at an investment in upgrading an inspection line at her plant. The initial cost would be $140 000 with a salvage value of $37 000 after five years. Use the capital recovery formula to determine how much money must be saved every year to justify the investment at an interest rate of 14 percent.

4.28 Enrique has determined that investing $500 per month will enable him to accumulate $11 350 in 12 years, and that investing $800 per month will enable him to accumulate $18 950 over the same period. Estimate, using linear interpolation, how much he would have to invest each month to accumulate exactly $15 000.

4.29 Joseph and three other friends bought a $260 000 house close to the university at the end of August last year. At that time they put down a deposit of $10 000 and took out a mortgage for the balance. Their mortgage payments are due at the end of each month (September 30, last year, was the date of the first payment) and are based on the assumption that Joseph and friends will take 20 years to pay off the debt. Annual nominal interest is 12 percent, compounded monthly. It is now February. Joseph and friends have made all their fall-term payments and have just made the January 31 payment for this year. How much do they still owe?

4.30 A new software package is expected to improve productivity at Grand Insurance. However, because of training and implementation costs, savings are not expected to occur until the third year of operation. At that time, savings of $10 000 are expected, increasing by $1000 per year for the following five years. After this time (eight years from implementation), the software will be abandoned with no scrap value. How much is the software worth today, at 15 percent interest?

4.31 Clem is saving for a car in a bank account that pays 12 percent interest, compounded monthly. The balance is now $2400. Clem will be saving $120 per month from his

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salary, and once every four months (starting in four months) he adds $200 in dividends from an investment. Bank fees, currently $10 per month, are expected to increase by $1 per month henceforth. How much will Clem have saved in two years?

4.32 Yogajothi is thinking of investing in a rental house. The total cost to purchase the house, including legal fees and taxes, is $230 000. All but $30 000 of this amount will be mortgaged. He will pay $1600 per month in mortgage payments. At the end of two years, he will sell the house and at that time expects to clear $40 000 after paying off the remaining mortgage principal (in other words, he will pay off all his debts for the house and still have $40 000 left). Rents will earn him $2000 per month for the first year and $2400 per month for the second year. The house is in fairly good condition now, so he doesn't expect to have any maintenance costs for the first six months. For the seventh month, Yogajothi has budgeted $400. This figure will be increased by $40 per month thereafter (e.g., the expected month 7 expense will be $400, month 8, $440, month 9, $480, etc.). If interest is 6 percent compounded monthly, what is the present worth of this investment? Given that Yogajothi's estimates of revenue and expenses are correct, should he buy the house?

4.33 A new wave-soldering machine is expected to save Burnaby Circuit Boards $15 000 per year through reduced labour costs and increased quality. The device will have a life of eight years and will have no salvage value after this time. If the company can generally expect to get 12 percent return on its capital, how much could it afford to pay for the wave-soldering machine?

4.34 Gail has won a lottery that pays her $100 000 at the end of this year, $110 000 at the end of next year, $120 000 the following year, and so on, for 30 years. Leon has offered Gail $2 500 000 today in exchange for all the money she will receive. If Gail can get 8 percent interest on her savings, is this a good deal?

4.35 Gail has won a lottery that pays her $100 000 at the end of this year and increases by 10 percent per year thereafter for 30 years. Leon has offered Gail $2 500 000 today in exchange for all the money she will receive. If Gail can get 8 percent interest on her savings, is this a good deal?

4.36 Tina has saved $20 000 from her summer jobs. Rather than work for a living, she plans to buy an annuity from a trust company and become a beachcomber in Fiji. An annuity will pay her a certain amount each month for the rest of her life and is calculated at 7 percent interest, compounded monthly, over Tina's 55 remaining years. Tina calculates that she needs at least $5 per day to live in Fiji, and she needs $1200 for air fare. Can she retire now? How much would she have available to spend each day?

4.37 A regional municipality is studying a water supply plan for its tri-city and surrounding area to the end of year 2060. To satisfy the water demand, one suggestion is to construct a pipeline from a major lake some distance away. Construction would start in 2020 and take five years at a cost of $20 million per year. The cost of maintenance and repairs starts after completion of construction and for the first year is $2 million, increasing by 1 percent per year thereafter. At an interest rate of 6 percent, what is the present worth of this project?

Assume that all cash flows take place at year-end. Consider the present to be the end of 2015/beginning of 2016. Assume that there is no salvage value at the end of year 2060.

4.38 A French software genius has been offered €10 000 per year for the next five years and then €20 000 per year for the following 10 years for the rights to his new smart phone app. At 9 percent interest, how much is this worth today?

4.39 A bank offers a personal loan called "The Eight Percent Plan." The bank adds 8 percent to the amount borrowed; the borrower pays back 1/12 of this total at the end of each month for

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a year. On a loan of \$500, the monthly payment is 540/12 = \$45. There is also an administrative fee of \$45, payable now. What is the actual effective interest rate on a \$500 loan?

4.40 Shamsir's small business has been growing slowly. He has noticed that his monthly profit increases by 1 percent every two months. Suppose that the profit at the end of this month is \$10 000. What is the present value of all his profit over the next two years? Annual nominal interest is 18 percent, compounded monthly.

4.41 A Paradorian bond pays \$500 (Paradorian dollars) twice each year and \$5000 five years from now. I want to earn at least 300 percent *annual* (effective) interest on this investment (to compensate for the very high inflation in Parador). How much should I pay for this bond now?

4.42 A bond with a face value of \$5000 pays quarterly interest of 1.5 percent each period. Twenty-six interest payments remain before the bond matures. How much would you be willing to pay for this bond today if the next interest payment is due now and you want to earn 8 percent compounded quarterly on your money?

C. More Challenging Problems

4.43 You have been paying off a mortgage in quarterly payments at a 24 percent nominal annual rate, compounded quarterly. Your bank is now offering an alternative payment plan, so you have a choice of two methods—continuing to pay as before or switching to the new plan. Under the new plan, you would make monthly payments 30 percent of the size of your current payments. The interest rate would be 24 percent nominal, compounded monthly. The time until the end of the mortgage would not change, regardless of the method chosen.

(a) Which plan would you choose, given that you naturally wish to minimize the level of your payment costs? (*Hint:* Look at the costs over a three-month period.)

(b) Under which plan would you be paying a higher effective yearly interest rate?

4.44 Derive the arithmetic gradient conversion to a uniform series formula. (*Hint:* Convert each period's gradient amount to its future value, and then look for a substitution from the other compound amount factors.)

4.45 Derive the geometric gradient to present worth conversion factor. (*Hint:* Divide and multiply the present worth of a geometric series by $[1 + g]$ and then substitute in the growth-adjusted interest rate.)

4.46 Ruby's business has been growing quickly over the past few years, with sales increasing at about 50 percent per year. She has been approached by a buyer for the business. She has decided she will sell it for half of the value of the estimated sales for the next five years. This year she will sell products worth \$1 456 988. Use the geometric gradient factor to calculate her selling price for an interest rate of 5 percent.

4.47 In Example 4.4 on page 129, Clarence bought a \$94 000 condo with a \$14 000 down payment and took out a mortgage for the remaining \$80 000 at 12 percent nominal interest, compounded monthly. We determined that he would make 51 \$2000 payments and then a final payment. What is his final payment?

4.48 Clem has a \$50 000 loan. The interest rate offered is 8 percent compounded annually and the repayment period is 15 years. Payments are to be received in equal installments at the end of each year. Construct a spreadsheet (you must use a spreadsheet program) similar to the following table that shows the amount received each year, the portion that is interest, the portion that is unrecovered capital, and the amount that is outstanding

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(i.e., unrecovered). Also, compute the total recovered capital, which must equal the original capital amount; this can serve as a check on your solution. Design the spreadsheet so that the capital amount and the interest rate can be changed by updating only one cell for each. Construct:

(a) The completed spreadsheet for the amount, interest rate, and repayment period indicated

(b) The same spreadsheet, but for \$75 000 at 10 percent interest (same repayment period)

(c) A listing showing the formulas used

Sample Capital Recovery Calculations				
Capital amount			\$50 000.00	
Annual interest rate			8.00%	
Number of years to repay			15	
Payment Periods	**Annual Payment**	**Interest Received**	**Recovered Capital**	**Unrecovered Capital**
0				\$50 000.00
1	\$5841.48	\$4000.00	\$1841.48	48 158.52
2				
.				
.				
.				
15				0.00
Total			\$50 000.00	

4.49 Coastal Shipping is setting aside capital to fund an expansion project. Funds earmarked for the project will accumulate at the rate of \$50 000 per month until the project is completed in two years. Once the project starts, costs will be incurred at the rate of \$150 000 per month over 24 months. Coastal currently has \$250 000 saved. What is the minimum number of months it will have to wait before it can start if money is worth 18 percent nominal, compounded monthly? Assume that

1. Cash flows are all at the ends of months.
2. The first \$50 000 savings occurs one month from today.
3. The first \$150 000 payment occurs one month after the start of the project.
4. The project must start at the beginning of a month.

4.50 A company is about to invest in a joint venture research and development project with another company. The project is expected to last eight years, but the company will begin its yearly payments immediately (i.e., a payment is made today, and the last payment will be made eight years from today). Salaries will account for \$40 000 of each payment. The remainder will cover equipment costs and facility overhead. The initial (immediate) equipment and facility cost is \$26 000. Each subsequent year, this figure will drop by

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\$3000 until a cost of \$14 000 is reached, after which the costs will remain constant until the end of the project.

(a) Draw a cash flow diagram to illustrate the cash flows for this situation.

(b) At an interest rate of 7 percent, what is the total future worth of all project payments at the end of the eight years?

4.51 Xiaohang is conducting a biochemical experiment for the next 12 months. In the first month, the expenses are estimated to be \$15 000. As the experiment progresses, the expenses are expected to increase by 5 percent each month. Xiaohang plans to pay for the experiment with a government grant, which is received in six monthly installments, starting a month after the experiment completion date. Determine the amount of the monthly installment so that the total of the six installments pays for all expenses incurred during the experiment. Annual nominal interest is 12 percent, compounded monthly.

4.52 The city of Sault Ste. Marie is installing a new swimming pool in the municipal recreation centre. One design being considered is a reinforced concrete pool, which will cost \$1 500 000 to install. Thereafter, the inner surface of the pool will need to be refinished and painted every 10 years at a cost of \$200 000 per refinishing. Assuming that the pool will have essentially an infinite life, what is the present worth of the costs associated with this pool design? The city uses a 5 percent interest rate.

4.53 What happens to the present worth of an arithmetic gradient series as the number of periods approaches infinity? Consider all four cases:

(a) $i > g > 0$

(b) $g > i > 0$

(c) $g = i = 0$

(d) $g < 0$

MINI-CASE 4.1

The Canadian Oil Sands

The Canadian Oil Sands are a group of bitumen deposits located in northeastern Alberta. Bitumen is a form of crude oil, and in oil sands (formerly called tar sands) the bitumen is mixed with sand, clay, and water, making it difficult to process into gasoline and other products. The Canadian deposits are huge—comparable in size to all other sources of conventional crude oil in the world combined.

Commercial development of the oil sands began in the 1960s led by familiar Canadian companies such as Suncor and Syncrude. In recent years, international oil companies including Royal Dutch Shell, Chevron, and ExxonMobil have been investing in various projects, as have the national oil companies of China, Japan, and Korea.

Extracting synthetic crude oil from oil sands bitumen for use in refineries is difficult and expensive. If the bitumen can be mined from the surface, the process essentially involves mixing it with hot water so that the oil rises to the top. If the bitumen is too deep underground to extract, steam is pumped down into the bitumen to separate the oil so that it can be more easily pumped out. Both methods require enormous amounts of energy to heat large quantities of water. Oil sands processing currently consumes about 4 percent of Canada's entire natural gas supply.

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There are a large number of uncertainties with conventional oil production. Exploration is risky because many wells may need to be drilled before one is found that produces oil. Even when production starts, it is unknown how much oil the well will produce. Oil fields may be in politically or economically unstable countries in which an investment could be expropriated or damaged by war or terrorism. But Canada's oil sands are different. The existence and quantity of the oil is certain; it merely needs to be dug or pumped out. Canada is unlikely to expropriate investments or be involved in a war that might affect them. Even though the cost of production is higher than for conventional oil, the physical and political certainty arguably offsets that extra cost.

Consequently, one might expect that developing oil production projects in the Canadian oil sands would be a relatively reliable and easy process. However, projects in northern Alberta have been anything but straightforward. Some that were announced with great fanfare at their inception were cancelled a few years later—over $90 billion in projects were cancelled in 2009. In other cases, costs for projects escalated to multiples of the initial estimates. Contrary to expectations, a resource that should provide very predictable profits has turned out to be remarkably unpredictable.

Discussion

Oil industry projects tend to require anywhere from hundreds of millions to tens of billions of dollars in investments. As one might expect, very capable people think through all aspects of a project—technical, financial, environmental, political—very carefully. Oil companies take planning seriously, and their engineers are very experienced. The $90 billion of cancelled projects in 2009 does not represent incompetence, but rather something more fundamental—no matter how careful the planning process is, one can never fully predict how the future will turn out.

Three key issues have strongly affected development of the Canadian oil sands. The first is that crude oil is a commodity, meaning that there are so many sources that no one can easily predict or control its price. Even if the cost of production is absolutely certain, the profitability and project viability depends very much on the world price, which itself is subject to many random forces. No one predicted that the price of oil would rise to a peak of US$145 per barrel in 2008, or drop the same year to below US$50. Both are extremes outside of the planning window imagined earlier in the same decade. For conventional oil production, costs can be controlled—to a degree. The cost of exploration efforts can be reduced, for example, when prices are low. But oil sands project costs are much more difficult to cut back on once they are started. There are very large capital costs to recover and high direct costs per barrel of oil produced. As such, investment decisions are more vulnerable to low oil prices.

The second confounding issue concerns social, environmental, and political forces. Mining oil sands is very dirty work that damages the physical sites and produces vast quantities of carbon dioxide. Engineers involved in early oil sands projects sometimes completely failed to manage their environmental impact and ended up with unexpected costs for administration, legal bills, remediation, and regulation adherence. Even in recent years, when such costs are taken into account in the planning process, they are somewhat unpredictable because of the inherent nature of social and political intervention. Otherwise benign activities can suddenly become difficult and expensive if they somehow gain media attention. This has happened on several occasions in the oil sands. For example, in 2011, the "Rethink Alberta" movement, formed by several environmental groups, gained international media attention for its efforts to dissuade tourists from visiting Alberta unless new oil sands developments were stopped.

A third problem is a confluence of global trends, which has been compounded by the oil sands' remote location. Between 2003 and 2008, for example, a key global force was the industrialization of China. China's industrialization led to an increase in demand for oil and gas worldwide, causing oil companies to increase supply. This in turn caused a global proliferation

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of oil and gas developments, creating a tremendous demand for manufacturing capacity, technical expertise, and specialized equipment that significantly increased the costs of acquiring the resources necessary to develop the oil sands. In particular, due to the isolated location of the sands and a shortage of workers, the cost of labour in Alberta skyrocketed to nearly double the previously estimated amount, far beyond even the most pessimistic expectations.

Even with the best planning and the most reliable process and product, the future remains unpredictable. Economic analyses still need to be done, however. There are sophisticated ways to deal with uncertainty about future cash flows, some of which are discussed in Chapter 10. In most cases, it makes sense to carry out economic analyses with a range of possible values for future cash flows. But, as the oil sands example shows, there are situations when even this approach is unable to account for what the future actually holds.

Questions

1. For each of the following, comment on how sensible it is to estimate the precise value of future cash flows:
   - **(a)** Your rent for the next six months
   - **(b)** Your food bill for the next six months
   - **(c)** Your medical bills for the next six months
   - **(d)** A company's payroll for the next six months
   - **(e)** A company's raw material costs for the next six months
   - **(f)** A company's legal costs for liability lawsuits for the next six months
   - **(g)** Canada's costs for funding university research for the next six months
   - **(h)** Canada's costs for employment insurance for the next six months
   - **(i)** Canada's costs for emergency management for the next six months
2. Your company is looking at the possibility of buying a new widget grinder for the widget line. The future cash flows associated with the purchase of the grinder are fairly predictable, except for one factor. A significant benefit is achieved with the higher production volume of widgets, which depends on a contract to be signed with a particular important customer. This won't happen for several months, but you must make the decision about the widget grinder now. Discuss some sensible ways of dealing with this issue.

Appendix 4A Derivation of Discrete Compound Interest Factors

This appendix derives six discrete compound interest factors presented in this chapter. All of them can be derived from the compound interest equation

$$F = P(1 + i)^N$$

4A.1 Compound Amount Factor

In the symbolic convention used for compound interest factors, the compound interest equation can be written

$$F = P(1 + i)^N = P(F/P,i,N)$$

so that the compound amount factor is

$$(F/P,i,N) = (1 + i)^N \tag{4A.1}$$

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4A.2 Present Worth Factor

The present worth factor, $(P/F,i,N)$, converts a future amount F to a present amount P:

$$P = F(P/F,i,N)$$
$$\Rightarrow F = P\left(\frac{1}{(P/F,i,N)}\right)$$

Thus the present worth factor is the reciprocal of the compound amount factor. From Equation (4A.1),

$$(P/F,i,N) = \frac{1}{(1+i)^N}$$

4A.3 Sinking Fund Factor

If a series of payments A follows the pattern of a standard annuity of N payments in length, then the future value of the payment in the j^{th} period, from Equation (4A.1), is:

$$F = A(1+i)^{N-j}$$

The future value of all of the annuity payments is then

$$F = A(1+i)^{N-1} + A(1+i)^{N-2} + \ldots + A(1+i)^1 + A$$

Factoring out the annuity amount gives

$$F = A[(1+i)^{N-1} + (1+i)^{N-2} + \ldots + (1+i)^1 + 1] \tag{4A.2}$$

Multiplying Equation (4A.2) by $(1 + i)$ gives

$$F(1+i) = A[(1+i)^{N-1} + (1+i)^{N-2} + \ldots + (1+i)^1 + 1](1+i)$$
$$F(1+i) = A[(1+i)^{N} + (1+i)^{N-1} + \ldots + (1+i)^2 + (1+i)] \tag{4A.3}$$

Subtracting Equation (4A.2) from Equation (4A.3) gives

$$F(1+i) - F = A[(1+i)^N - 1]$$
$$Fi = A[(1+i)^N - 1]$$
$$A = F\left[\frac{i}{(1+i)^N - 1}\right]$$

Thus the sinking fund factor is given by

$$(A/F,i,N) = \frac{i}{(1+i)^N - 1} \tag{4A.4}$$

4A.4 Uniform Series Compound Amount Factor

The uniform series compound amount factor, $(F/A,i,N)$, converts an annuity A into a future amount F:

$$F = A(F/A,i,N)$$
$$\Rightarrow A = F\left(\frac{1}{(F/A,i,N)}\right)$$

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Thus the uniform series compound amount factor is the reciprocal of the sinking fund factor. From Equation (4A.4),

$$(F/A,i,N) = \frac{(1+i)^N - 1}{i}$$

4A.5 Capital Recovery Factor

If a series of payments A follows the pattern of a standard annuity of N payments in length, then the present value of the payment in the jth period is

$$P = A\frac{1}{(1+i)^j}$$

The present value of the total of all the annuity payments is

$$P = A\left(\frac{1}{(1+i)}\right) + A\left(\frac{1}{(1+i)^2}\right) + \ldots + A\left(\frac{1}{(1+i)^{N-1}}\right) + A\left(\frac{1}{(1+i)^N}\right)$$

Factoring out the annuity amount gives

$$P = A\left[\left(\frac{1}{(1+i)}\right) + \left(\frac{1}{(1+i)^2}\right) + \ldots + \left(\frac{1}{(1+i)^{N-1}}\right) + \left(\frac{1}{(1+i)^N}\right)\right] \tag{4A.5}$$

Multiplying both sides of Equation (4A.5) by $(1 + i)$ gives

$$P(1+i) = A\left[1 + \left(\frac{1}{(1+i)}\right) + \ldots + \left(\frac{1}{(1+i)^{N-2}}\right) + \left(\frac{1}{(1+i)^{N-1}}\right)\right] \tag{4A.6}$$

Subtracting Equation (4A.5) from Equation (4A.6) gives

$$Pi = A\left[1 - \left(\frac{1}{(1+i)^N}\right)\right]$$

$$P = A\left[\frac{(1+i)^N - 1}{i(1+i)^N}\right]$$

$$A = P\left[\frac{i(1+i)^N}{(1+i)^N - 1}\right]$$

Thus the capital recovery factor is given by

$$(A/P,i,N) = \frac{i(1+i)^N}{(1+i)^N - 1} \tag{4A.7}$$

4A.6 Series Present Worth Factor

The series present worth factor, $(P/A,i,N)$, converts an annuity A into a present amount P:

$$P = A(P/A,i,N)$$

$$\Rightarrow A = P\left(\frac{1}{(P/A,i,N)}\right)$$

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Thus the uniform series compound amount factor is the reciprocal of the sinking fund factor. From Equation (4A.7),

$$(P/A,i,N) = \frac{(1 + i)^N - 1}{i(1 + i)^N}$$

4A.7 Arithmetic and Geometric Gradients

The derivation of the arithmetic gradient to annuity conversion factor and the geometric gradient to present worth conversion factor are left as problems for the student. See Problems 4.44 and 4.45.

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CHAPTER 5

Comparison Methods Part 1

Taken from *Engineering Economics: Financial Decision Making for Engineers*, Fifth Edition by Niall M. Fraser and Elizabeth M. Jewkes.

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ENGINEERING ECONOMICS IN ACTION, PART 5A

What's Best?

Naomi waved hello as she breezed by Carole Brown, the receptionist, on her way in from the parking lot one Monday morning. She stopped as Carole caught her eye. "Clem wants to see you right away. Good morning."

After a moment of socializing, Clem got right to the point. "I have a job for you. Put aside the vehicle-life project for a couple of days."

"Okay, but you wanted a report by Friday."

"This is more important. You know that drop forging hammer in the South Shop? The beast is about 50 years old. I don't remember the exact age. We got it used four years ago. We were having quality control problems with the parts we were buying on contract and decided to bring production in-house. Stinson Brothers sold it to us cheap when it upgraded its forging operation. Fundamentally the machine is still sound, but the guides are worn out. The production people are spending too much time fiddling with it instead of turning out parts. Something has to be done. I have to make a recommendation to Ed Burns and Anna Kulkowski, who are going to be making decisions on investments for the next quarter. I'd like you to handle it." Ed Burns was the manager of manufacturing, and Anna Kulkowski was, among other things, the president of Canadian Widgets.

"What's the time frame?" Naomi asked. She was shifting job priorities in her mind and deciding what she would need to postpone.

"I want a report by tomorrow morning. I'd like to have a chance to review what you've done and submit a recommendation to Burns and Kulkowski for their Wednesday meeting." Clem sat back and gave Naomi his best big smile.

Naomi's return smile was a bit weak, as she was preoccupied with trying to sort out where to begin.

Clem laughed and continued with, "It's really not so bad. Dave Sullivan has done most of the work. But he's away and can't finish. His father-in-law had a heart attack on Friday, and he and Helena have gone to Florida to see him."

"What's involved?" asked Naomi.

"Not much, really. Dave has estimated all the cash flows. He's put everything on a spreadsheet. Essentially, there are three major possibilities. We can refurbish and upgrade the existing machine. We can get a manually operated mechanical press that will use less energy and be a lot quieter. Or we can go for an automated mechanical press.

"Since there is going to be down time while we are changing the unit, we might also want to replace the materials-handling equipment at the same time. If we get the automated press, there is the possibility of going the whole hog and integrating materials handling with the press. But even if we automate, we could stay with a separate materials-handling setup.

"Basically, you're looking at a fairly small first cost to upgrade the current beast versus a large first cost for the automated equipment. But if you take the high-first-cost route, you will get big savings down the road. All you have to do is decide what's best."

5.1 Introduction

The essential idea of investing is to give up something valuable now for the expectation of receiving something of greater value later. An investment may be thought of as an exchange of resources now for an expected flow of benefits in the future. Business firms, other organizations, and individuals all have opportunities to make such exchanges. A company may be able to use funds to install equipment that will reduce labour costs in the future. These funds might otherwise have been used on another project or returned to the shareholders or owners. An individual may be able to study to become an engineer. Studying requires that time be given up that could have been used to earn money or to travel. The benefit of study, though, is the expectation of a good income from an interesting job in the future.

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Not all investment opportunities *should* be taken. The company considering a labour-saving investment may find that the value of the savings is less than the cost of installing the equipment. Not all investment opportunities *can* be taken. The person spending the next four years studying engineering cannot also spend that time getting degrees in law and science.

Engineers play a major role in making decisions about investment opportunities. In many cases, they are the ones who estimate the expected costs of and returns from an investment. They then must decide whether the expected returns outweigh the costs to see if the opportunity is potentially acceptable. They may also have to examine competing investment opportunities to see which is best. Engineers frequently refer to investment opportunities as **projects**. Throughout most of this text, the term *project* will be used to mean *investment opportunity*.

In this chapter and in Chapter 6, we deal with methods of evaluating and comparing projects, sometimes called **comparison methods**. We start in this chapter with a scheme for classifying groups of projects. This classification system permits the appropriate use of any of the comparison methods. We then turn to a consideration of several widely used methods for evaluating opportunities. The **present worth method** compares projects by looking at the present worth of all cash flows associated with the projects. The **annual worth method** is similar, but converts all cash flows to a uniform series—that is, an annuity. The **payback period method** estimates how long it takes to "pay back" investments. The study of comparison methods is continued in Chapter 6, which deals with the internal rate of return.

We have made six assumptions about all the situations presented in this chapter and in Chapter 6:

1. We have assumed that costs and benefits are always measurable in terms of money. In reality, costs and benefits need not be measurable in terms of money. For example, providing safe working conditions has many benefits, including improvement of worker morale. However, it would be difficult to express the value of improved worker morale objectively in dollars and cents. Such other benefits as the pleasure gained from appreciating beautiful design may not be measurable quantitatively.
2. We have assumed that future cash flows are known with certainty. In reality, future cash flows can only be estimated. Usually the further into the future we try to forecast, the less certain our estimates become. We look at methods of assessing the impact of uncertainty and risks in Chapter 10.
3. We have assumed that cash flows are unaffected by inflation or deflation. In reality, the purchasing power of money typically declines over time. We shall consider how inflation affects decision making in Chapter 9.
4. Unless otherwise stated, we have assumed that sufficient funds are available to implement all projects. In reality, cash constraints on investments may be very important, especially for new enterprises with limited ability to raise capital. We look at methods of raising capital in Appendix 5A.
5. We have assumed that taxes are not applicable. In reality, taxes are pervasive. We shall show how to include taxes in the decision-making process in Chapter 7.
6. Unless otherwise stated, we shall assume that all investments have a cash outflow at the start. These outflows are called *first costs*. We also assume that projects with first costs have cash inflows after the first costs that are at least as great in total as the first costs. In reality, some projects have cash inflows at the start, but involve a commitment of cash outflows at a later period. For example, a consulting engineer may receive an advance payment from a client—a cash inflow—to cover

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some of the costs of a project, but to complete the project the engineer will have to make disbursements over the project's life. We shall consider evaluation of such projects in Chapter 6.

5.2 Relations Among Projects

Companies and individuals are often faced with a large number of investment opportunities at the same time. Relations among these opportunities can range from the simple to the complex. We can distinguish three types of connections among projects that cover all the possibilities. Projects may be

1. Independent,
2. Mutually exclusive, or
3. Related but not mutually exclusive.

The simplest relation between projects occurs when they are **independent**. Two projects are independent if the expected costs and the expected benefits of each project do not depend on whether the other one is chosen. A student considering the purchase of a vacuum cleaner and the purchase of a personal computer would probably find that the expected costs and benefits of the computer did not depend on whether he or she bought the vacuum cleaner. Similarly, the benefits and costs of the vacuum cleaner would be the same whether or not the computer was purchased. If there are more than two projects under consideration, they are said to be independent if all possible pairs of projects in the set are independent. When two or more projects are independent, evaluation is simple. Consider each opportunity one at a time, and accept or reject it on its own merits.

Projects are **mutually exclusive** if, in the process of choosing one, all other alternatives are excluded. In other words, two projects are mutually exclusive if it is impossible to do both or it clearly would not make sense to do both. For example, suppose Bismuth Realty Company wants to develop downtown office space on a specific piece of land. It is considering two potential projects. The first is a low-rise poured-concrete building. The second is a high-rise steel-frame structure with the same capacity as the low-rise building, but it has a small park at the entrance. It is impossible for Bismuth to have both buildings on the same site.

As another example, consider a student about to invest in a computer printer. She can get an inkjet printer or a laser printer, but it would not make sense to get both. She would consider the options to be mutually exclusive.

The third class of projects consists of those that are **related but not mutually exclusive**. For pairs of projects in this category, the expected costs and benefits of one project depend on whether the other one is chosen. For example, Klamath Petroleum may be considering a service station at Fourth Avenue and Main Street as well as one at Twelfth and Main. The costs and benefits from either station will clearly depend on whether the other is built, but it may be possible, and may make sense, to have both stations.

Evaluation of related but not mutually exclusive projects can be simplified by combining them into exhaustive, mutually exclusive sets. For example, the two projects being considered by Klamath can be put into four mutually exclusive sets:

1. Neither station—the "do nothing" option
2. Just the station at Fourth and Main
3. Just the station at Twelfth and Main
4. Both stations

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In general, n related projects can be put into 2^n sets, including the "do nothing" option. Once the related projects are put into mutually exclusive sets, the analyst treats these sets as the alternatives. We can make 2^n mutually exclusive sets with n related projects by noting that for any single set, there are exactly two possibilities for each project. The project may be *in* or *out* of that set. To get the total number of sets, we multiply the n twos to get 2^n. In the Klamath example, there were two possibilities for the station at Fourth and Main—accept or reject. These are combined with the two possibilities for the station at Twelfth and Main to give the four sets that we listed.

A special case of related projects is where one project is *contingent* on another. Consider the case where project A could be done alone or A and B could be done together, but B could not be done by itself. Project B is then contingent on project A because it cannot be taken unless A is taken first. For example, the Athens and Manchester Development Company is considering building a shopping mall on the outskirts of town. It is also considering building a parking garage to avoid long outdoor walks by patrons. Clearly, it would not build the parking garage unless it were also building the mall.

Another special case of related projects is due to resource constraints. Usually the constraints are financial. For example, Bismuth may be considering two office buildings at different sites, where the expected costs and benefits of the two are unrelated, but Bismuth may be able to finance only one building. The two office-building projects would then be mutually exclusive because of financial constraints. If there are more than two projects, then all of the sets of projects that meet the budget form a mutually exclusive set of alternatives.

When there are several related projects, the number of logically possible combinations becomes quite large. If there are four related projects, there are $2^4 = 16$ mutually exclusive sets, including the "do nothing" alternative. If there are five related projects, the number of alternatives doubles to 32. A good way to keep track of these alternatives is to construct a table with all possible combinations of projects. Example 5.1 demonstrates the use of a table.

EXAMPLE 5.1

The Small Street Residential Association wants to improve the district. Four ideas for renovation projects have been proposed: (1) converting part of the roadway to gardens, (2) adding old-fashioned light standards, (3) replacing the pavement with cobblestones, and (4) making the street one way. However, there are a number of restrictions. The association can afford to do only two of the first three projects together. Also, gardens are possible only if the street is one way. Finally, old-fashioned light standards would look out of place unless the pavement was replaced with cobblestones. The residential association feels it must do something. It does not want simply to leave things the way they are. What mutually exclusive alternatives are possible?

Since the association does not want to "do nothing," only $15 = 2^4 - 1$ alternatives will be considered. These are shown in Table 5.1. The potential projects are listed in rows. The alternatives, which are sets of projects, are in columns. An "x" in a cell indicates that a project is in the alternative represented by that column. Not all logical combinations of projects represent feasible alternatives, as seen in the special cases of contingent alternatives or budget constraints. A last row, below the potential-project rows, indicates whether the sets are feasible alternatives.

The result is that there are seven feasible mutually exclusive alternatives:

1. Cobblestones (alternative 3)
2. One-way street (alternative 4)
3. One-way street with gardens (alternative 7)

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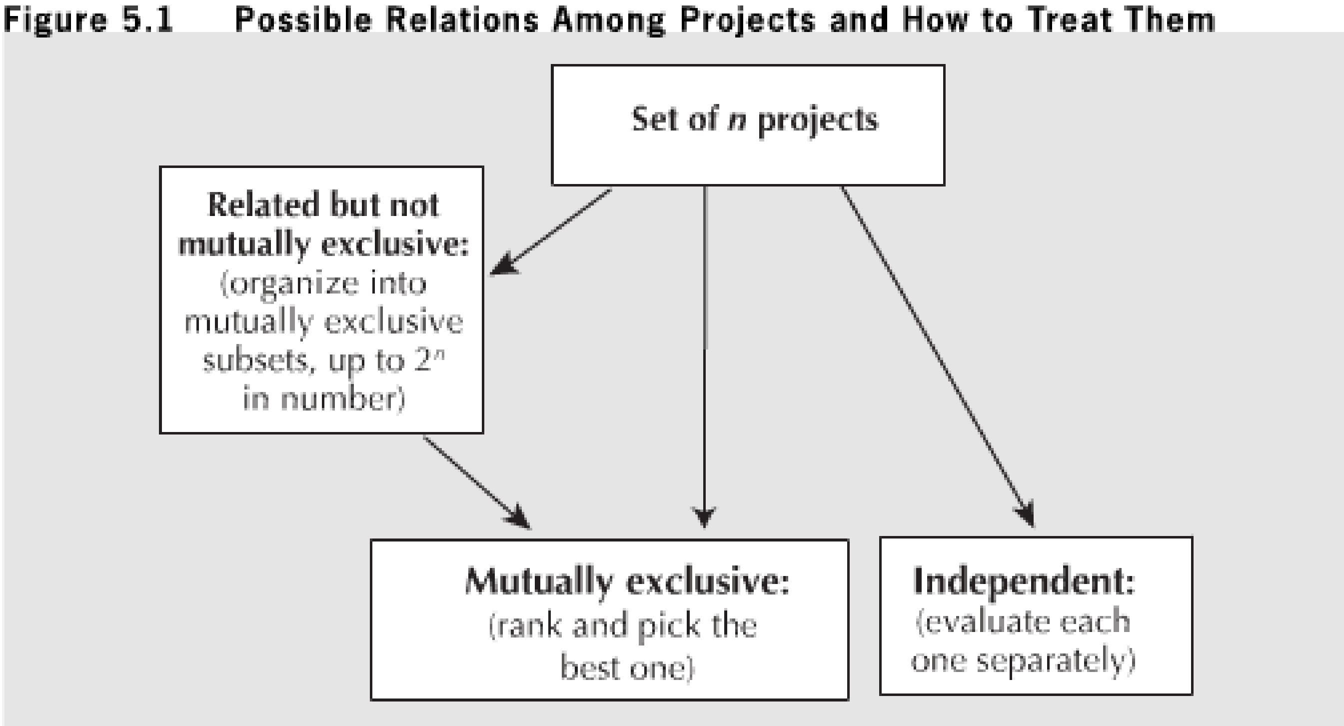
4. Cobblestones with lights (alternative 8)
5. One-way street with cobblestones (alternative 10)
6. One-way street with cobblestones and gardens (alternative 13)
7. One-way street with cobblestones and lights (alternative 14) ■

Table 5.1 Potential Alternatives for the Small Street Renovation

Potential Alternative	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Gardens	x				x	x	x				x	x	x		x
Lights		x			x			x	x		x	x		x	x
Cobblestones			x			x		x		x	x		x	x	x
One-way				x			x		x	x		x	x	x	x
Feasible?	No	No	Yes	Yes	No	No	Yes	Yes	No	Yes	No	No	Yes	Yes	No

To summarize our investigation of possible relations among projects, we have a threefold classification system: (1) independent projects, (2) mutually exclusive projects, and (3) related but not mutually exclusive projects. We can, however, arrange related projects into mutually exclusive sets and treat the sets as mutually exclusive alternatives. This reduces the system to two categories, independent and mutually exclusive. (See Figure 5.1.) Therefore, in the remainder of this chapter we consider only independent and mutually exclusive projects.

Figure 5.1 Possible Relations Among Projects and How to Treat Them



5.3 Minimum Acceptable Rate of Return (MARR)

A company evaluating projects will set for itself a lower limit for investment acceptability known as the **minimum acceptable rate of return (MARR)**. The MARR is an interest rate that must be earned for any project to be accepted. Projects that earn at least the MARR are desirable, since this means that the money is earning at least as much as can be

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earned elsewhere. Projects that earn less than the MARR are not desirable, since investing money in these projects denies the opportunity to use the money more profitably elsewhere.

The MARR can also be viewed as the rate of return required to get investors to invest in a business. If a company accepts projects that earn less than the MARR, investors will not be willing to put money into the company. This minimum return required to induce investors to invest in the company is the company's **cost of capital**. Methods for determining the cost of capital are presented in Appendix 5A.

The MARR is thus an opportunity cost in two senses. First, investors have investment opportunities outside any given company. Investing in a given company implies forgoing the opportunity of investing elsewhere. Second, once a company sets a MARR, investing in a given project implies giving up the opportunity of using company funds to invest in other projects that pay at least the MARR.

We shall show in this chapter and in Chapter 6 how the MARR is used in calculations involving the present worth, annual worth, or internal rate of return to evaluate projects. Henceforth, it is assumed that a value for the MARR has been supplied.

5.4 Present Worth (PW) and Annual Worth (AW) Comparisons

The present worth (PW) comparison method and the annual worth (AW) comparison method are based on finding a comparable basis to evaluate projects in monetary units. With the present worth method, the analyst compares project A and project B by computing the present worths of the two projects at the MARR. The preferred project is the one with the greater present worth. The value of any company can be considered to be the present worth of all of its projects. Therefore, choosing projects with the greatest present worth maximizes the value of the company. With the annual worth method, the analyst compares projects A and B by transforming all disbursements and receipts of the two projects to a uniform series at the MARR. The preferred project is the one with the greater annual worth. One can also speak of *present cost* and *annual cost*. See Close-Up 5.1.

5.4.1 Present Worth Comparisons for Independent Projects

The alternative to investing money in an independent project is to "do nothing." Doing nothing doesn't mean that the money is not used productively. In fact, it would be used for some other project, earning interest at a rate at least equal to the MARR.

CLOSE-UP 5.1 Present Cost and Annual Cost

Sometimes mutually exclusive projects are compared in terms of present cost or annual cost. That is, the best project is the one with the minimum present worth of cost as opposed to the maximum present worth. Two conditions should hold for this to be valid: (1) All projects have the same major benefit, and (2) the estimated value of the major benefit clearly outweighs the projects' costs, even if that estimate is imprecise. Therefore, the "do nothing" option is rejected. The value of the major benefit is ignored in further calculations since it is the same for all projects. We choose the project with the lowest cost, considering secondary benefits as offsets to costs.

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However, the present worth of any money invested at the MARR is zero, since the present worth of future receipts would exactly offset the current disbursement. Consequently, if an independent project has a present worth greater than zero, it is acceptable. If an independent project has a present worth less than zero, it is unacceptable. If an independent project has a present worth of exactly zero, it is considered *marginally* acceptable.

EXAMPLE 5.2

Steve Chen, a third-year electrical engineering student, is really into gaming. He and all of his friends like online multi-player games, but are annoyed by delays caused by slow internet connections. Sometimes they link their own computers into local networks and play, but it's hard to find a place to play and their laptops are not the best machines for gaming. On his work term in Abu Dhabi, Steve noticed that gaming halls are popular. High-level networked game machines are located in malls, and people rent the machines by the hour for playing games either with each other or over a very fast internet connection. Steve expects to be on campus for the next five years and sees an opportunity in setting up a similar business at the mall next to his university. The first cost for equipment, furniture, and software is expected to be \$70 000. Students will be able to rent time on the computers by the hour, and Steve will be able to augment this income with some auxiliary services. Net annual cash flow, after paying for labour, supplies, and other costs, is expected to be \$30 000 a year for five years. When Steve finishes his graduate program in five years, he plans to close the business. The five-year-old equipment and furniture are expected to have zero value. If investors in this type of service enterprise demand a return of 20 percent per year, is this a good investment?

The present worth of the project is

$$\begin{aligned} \text{PW} &= -70\,000 + 30\,000(P/A,20\%,5) \quad \mathbf{= -70\,000 + \mathit{PV}(0.20,5,-30\,000)} \\ &= -70\,000 + 30\,000(2.9906) \\ &= 19\,718 \\ &\cong 20\,000 \end{aligned}$$

The project is acceptable, since the present worth of about \$20 000 is greater than zero.

Another way to look at the project is to suppose that, once Steve has set up the business off campus, he tries to sell it. If he can convince potential investors, who demand a return of 20 percent a year, that the expectation of a \$30 000 per year cash flow for five years is accurate, how much would they be willing to pay for the network? Investors would calculate the present worth of a 20 percent annuity paying \$30 000 for five years. This is given by

$$\begin{aligned} \text{PW} &= 30\,000(P/A,20\%,5) \quad \mathbf{= \mathit{PV}(0.20,5,-30\,000)} \\ &= 30\,000(2.9906) \\ &= 89\,718 \\ &\cong 90\,000 \end{aligned}$$

Investors would be willing to pay approximately \$90 000. Steve will have taken \$70 000, the first cost, and used it to create an asset worth almost \$90 000. As illustrated in Figure 5.2, the \$20 000 difference may be viewed as profit. ■

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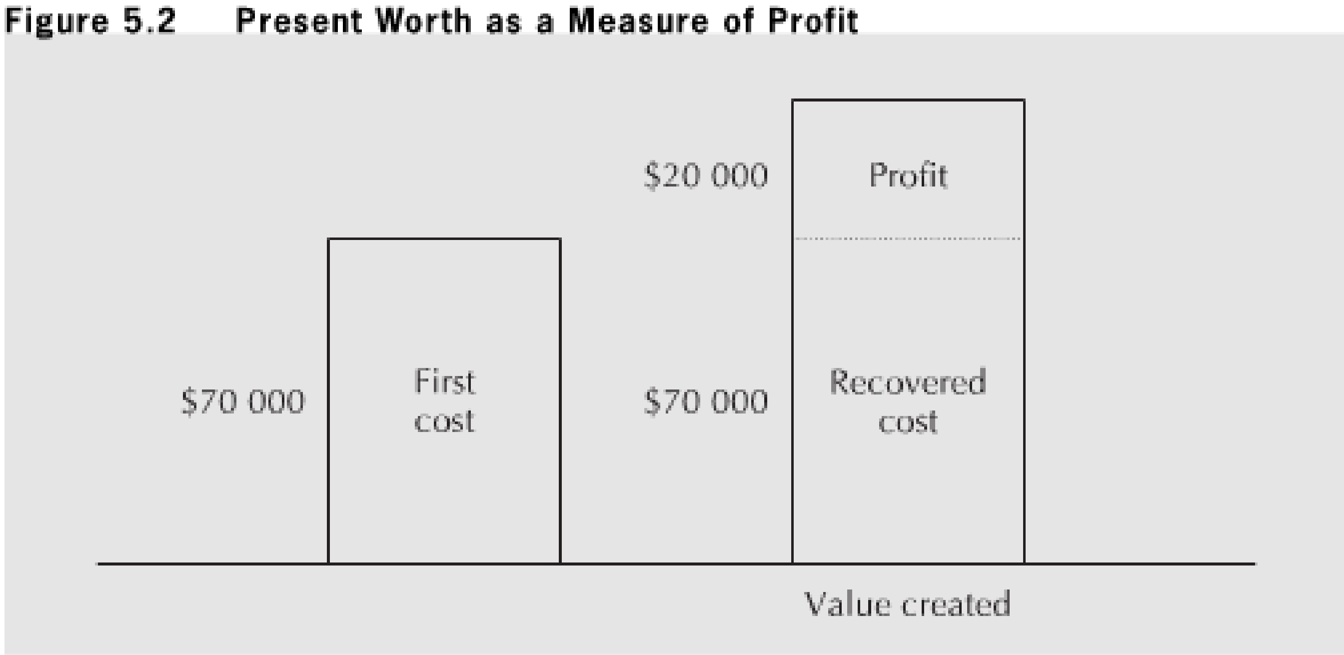
Figure 5.2 Present Worth as a Measure of Profit



Let us now consider an example in which the benefit of an investment is a reduction in cost.

EXAMPLE 5.3

A mechanical engineer is considering building automated materials-handling equipment for a production line. On the one hand, the equipment would substantially reduce the manual labour currently required to move items from one part of the production process to the next. On the other hand, the equipment would consume energy, require insurance, and need periodic maintenance.

Alternative 1: Continue to use the current method. Yearly labour costs are $9200.

Alternative 2: Build automated materials-handling equipment with an expected service life of 10 years.

First cost	$15 000	
Labour	$3300	per year
Power	$400	per year
Maintenance	$2400	per year
Taxes and insurance	$300	per year

If the MARR is 9 percent, which alternative is better? Use a present worth comparison.

The investment of $15 000 can be viewed as yielding a positive cash flow of 2800 = 9200 − (3300 + 400 + 2400 + 300) per year in the form of a reduction in cost.

$$\begin{aligned} \text{PW} &= -15\,000 + [9200 - (3300 + 400 + 2400 + 300)](P/A,9\%,10) \\ &= -15\,000 + 2800(P/A,9\%,10) \quad \mathbf{= -15\,000 + \mathit{PV}(0.09,10,-2800)} \\ &= -15\,000 + 2800(6.4176) \\ &= 2969.44 \end{aligned}$$

The present worth of the cost savings is approximately $3000 greater than the $15 000 first cost. Therefore, alternative 2 is worth implementing. ■

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5.4.2 Present Worth Comparisons for Mutually Exclusive Projects

It is very easy to use the present worth method to choose the best project among a set of mutually exclusive projects *when the service lives are the same*. One just computes the present worth of each project using the MARR. The project with the greatest present worth is the preferred project because it is the one with the greatest profit.

EXAMPLE 5.4

Fly-by-Night Aircraft must purchase a new lathe. It is considering four lathes, each of which has a life of 10 years with no scrap value.

Lathe	1	2	3	4
First cost	\$100 000	\$150 000	\$200 000	\$255 000
Annual savings	25 000	34 000	46 000	55 000

Given a MARR of 15 percent, which alternative should be taken?

The present worths are:

$$\mathrm{PW}_1 = -100\,000 + 25\,000(P/A,15\%,10) \quad \mathbf{= -10\,000 + \mathit{PV}(0.15,10,-25\,000)}$$
$$= -100\,000 + 25\,000(5.0187) \cong 25\,468$$
$$\mathrm{PW}_2 = -150\,000 + 34\,000(P/A,15\%,10)$$
$$= -150\,000 + 34\,000(5.0187) \cong 20\,636$$
$$\mathrm{PW}_3 = -200\,000 + 46\,000(P/A,15\%,10)$$
$$= -200\,000 + 46\,000(5.0187) \cong 30\,860$$
$$\mathrm{PW}_4 = -255\,000 + 55\,000(P/A,15\%,10)$$
$$= -155\,000 + 55\,000(5.0187) \cong 21\,029$$

Lathe 3 has the greatest present worth, and is therefore the preferred alternative. ■

5.4.3 Annual Worth Comparisons

Annual worth comparisons are essentially the same as present worth comparisons, except that all disbursements and receipts are transformed to a uniform series at the MARR, rather than to the present worth. Any present worth P can be converted to an annuity A by the capital recovery factor $(A/P,i,N)$. Therefore, a comparison of two projects *that have the same life* by the present worth and annual worth methods will always indicate the same preferred alternative. Note that, although the method is called annual worth, the uniform series is not necessarily on a yearly basis.

Present worth comparisons make sense because they compare the worth today of each alternative, but annual worth comparisons can sometimes be more easily grasped mentally. For example, to say that operating an automobile over five years has a present cost of \$20 000 is less meaningful than saying that it will cost about \$5300 per year for each of the following five years.

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NET VALUE 5.1

Car Payment Calculators

The internet offers websites that are useful when you are thinking of buying a car—you can learn more about different makes and models, optional features, prices, what's available (used or new) at which dealer, and financing information if a car is to be purchased and not leased. Major car manufacturers, financial services companies, and car information websites make it easy for customers to figure out their financing plans by offering web-based car payment calculators.

A typical monthly payment calculator determines how much a customer pays every month on the basis of the purchase price, down payment, interest rate, and loan term. This is essentially an annuity calculation. An affordability calculator, on the other hand, gives a present worth (what price of a car you could afford to buy now) or a future worth (total amount of money that would be spent on a car after all payments are made including interest) based on down payment, monthly payment, interest rate, and loan term. The calculators are useful in making instant comparisons among different cars or car companies, studying what-if scenarios with various payment amounts or lengths of the loan, and determining budget limitations. Similar calculators are available for house mortgage payments.

Sometimes there is no clear justification for preferring either the present worth method or the annual worth method. Then it is reasonable to use the one that requires less conversion. For example, if most receipts or costs are given as annuities or gradients, one can more easily perform an annual worth comparison. Sometimes it can be useful to compare projects on the basis of future worths. See Close-Up 5.2.

CLOSE-UP 5.2 Future Worth

Sometimes it may be desirable to compare projects with the **future worth method** on the basis of the future worth of each project. This is most likely to be true for cases where money is being saved for some future expense.

For example, two investment plans are being compared to see which accumulates more money for retirement. Plan A consists of a payment of $10 000 today and then $2000 per year over 20 years. Plan B is $3000 per year over 20 years. Interest for both plans is 10 percent. Rather than convert these cash flows to either present worth or annual worth, it is sensible to compare the future worths of the plans, since the actual dollar value in 20 years has particular meaning.

$$\begin{aligned} FW_A &= 10\,000(F/P,10\%,20) + 2000(F/A,10\%,20) \quad \boldsymbol{= FV(0.10,20,-10\,000) + FV(0.10,20,-2000)} \\ &= 10\,000(6.7275) + 2000(57.275) \\ &= 181\,825 \end{aligned}$$

$$\begin{aligned} FW_B &= 3000(F/A,10\%,20) \quad \boldsymbol{= FV(0.10,20,-3\,000)} \\ &= 3000(57.275) \\ &= 171\,825 \end{aligned}$$

Plan A is the better choice. It will accumulate to $181 825 over the next 20 years.

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EXAMPLE 5.5

Sweat University is considering two alternative types of bleachers for a new athletic stadium.

Alternative 1: Concrete bleachers. The first cost is \$350 000. The expected life of the concrete bleachers is 90 years and the annual upkeep costs are \$2500.

Alternative 2: Wooden bleachers on earth fill. The first cost of \$200 000 consists of \$100 000 for earth fill and \$100 000 for the wooden bleachers. The annual painting costs are \$5000. The wooden bleachers must be replaced every 30 years at a cost of \$100 000. The earth fill will last the entire 90 years.

One of the two alternatives will be chosen. It is assumed that the receipts and other benefits of the stadium are the same for both construction methods. Therefore, the greatest net benefit is obtained by choosing the alternative with the lower cost. The university uses a MARR of 7 percent. Which of the two alternatives is better?

For this example, let us base the analysis on annual worth. Since both alternatives have a life of 90 years, we shall get the equivalent annual costs over 90 years for both at an interest rate of 7 percent.

Alternative 1: Concrete bleachers

The equivalent annual cost over the 90-year life span of the concrete bleachers is

$$\begin{aligned} AW &= 350\,000(A/P,7\%,90) + 2500 \quad \boldsymbol{= PMT(0.07,90,-350\,000) + 2500} \\ &= 350\,000(0.07016) + 2500 \\ &= 27\,056 \text{ per year} \end{aligned}$$

Alternative 2: Wooden bleachers on earth fill

The total annual costs can be broken into three components: AW_1 (for the earth fill), AW_2 (for the bleachers), and AW_3 (for the painting). The equivalent annual cost of the earth fill is

$$AW_1 = 100\,000(A/P,7\%,90) \quad \boldsymbol{= PMT(0.07,90,-100\,000)}$$

The equivalent annual cost of the bleachers is easy to determine. The first set of bleachers is put in at the start of the project, the second set at the end of 30 years, and the third set at the end of 60 years, but the cost of the bleachers is the same at each installation. Therefore, we need to get only the cost of the first installation.

$$AW_2 = 100\,000(A/P,7\%,30) \quad \boldsymbol{= PMT(0.07,30,-100\,000)}$$

The last expense is for annual painting:

$$AW_3 = 5000$$

The total equivalent annual cost for alternative 2, wooden bleachers on earth fill, is the sum of AW_1, AW_2, and AW_3:

$$\begin{aligned} AW &= AW_1 + AW_2 + AW_3 \\ &= 100\,000[(A/P,7\%,90) + (A/P,7\%,30)] + 5000 \\ &= 100\,000(0.07016 + 0.08059) + 5000 \\ &= 20\,075 \end{aligned}$$

The concrete bleachers have an equivalent annual cost of about \$7000 more than the wooden ones. Therefore, the wooden bleachers are the better choice. ■

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5.4.4 Comparison of Alternatives With Unequal Lives

When making present worth comparisons, we must always use the same time period in order to take into account the full benefits and costs of each alternative. If the lives of the alternatives are not the same, we can transform them to equal lives with one of the following two methods:

1. Repeat the *service life* of each alternative to arrive at a common time period for all alternatives. Here we assume that each alternative can be repeated with the same costs and benefits in the future—an assumption known as **repeated lives**. Usually we use the *least common multiple* of the lives of the various alternatives. Sometimes it is convenient to assume that the lives of the various alternatives are repeated indefinitely. Note that the assumption of repeated lives may not be valid where it is reasonable to expect technological improvements.
2. Adopt a specified **study period**—a time period that is given for the analysis. To set an appropriate study period, a company will usually take into account the time of required service or the length of time it can be relatively certain of its forecasts. The study period method necessitates an additional assumption about *salvage value* whenever the life of one of the alternatives exceeds that of the given study period. Arriving at a reliable estimate of salvage value may be difficult sometimes.

Because they rest on different assumptions, the repeated lives and the study period methods can lead to different conclusions when applied to a particular project choice.

EXAMPLE 5.6 (MODIFICATION OF EXAMPLE 5.3)

A mechanical engineer has decided to introduce automated materials-handling equipment for a production line. She must choose between two alternatives: building the equipment or buying the equipment off the shelf. Each alternative has a different service life and a different set of costs.

Alternative 1: Build custom automated materials-handling equipment.

First cost	$15 000	
Labour	$3300	per year
Power	$400	per year
Maintenance	$2400	per year
Taxes and insurance	$300	per year
Service life	10	years

Alternative 2: Buy off-the-shelf standard automated materials-handling equipment.

First cost	$25 000	
Labour	$1450	per year
Power	$600	per year
Maintenance	$3075	per year
Taxes and insurance	$500	per year
Service life	15	years

If the MARR is 9 percent, which alternative is better?

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The present worth of the custom system over its 10-year life is

$$\begin{aligned}PW(1) &= -15\,000 - (3300 + 400 + 2400 + 300)(P/A,9\%,10)\\ &= -15\,000 - 6400(6.4176) \quad \mathbf{= -15\,000 - \mathit{PV}(0.09,10,-6400)}\\ &\cong -56\,073\end{aligned}$$

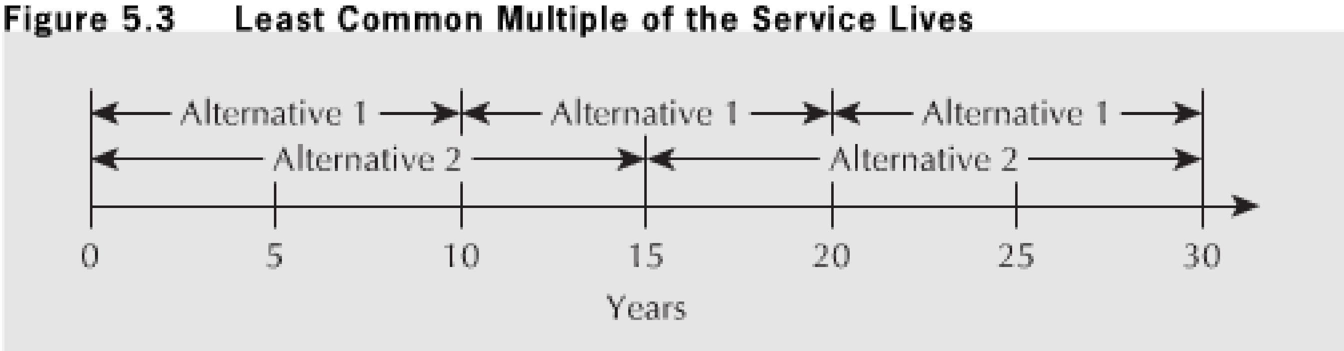
The present worth of the off-the-shelf system over its 15-year life is

$$\begin{aligned}PW(2) &= -25\,000 - (1450 + 600 + 3075 + 500)(P/A,9\%,15)\\ &= -25\,000 - 5625(8.0606) \quad \mathbf{= -25\,000 - \mathit{PV}(0.09,15,-5625)}\\ &\cong -70\,341\end{aligned}$$

The custom system has a lower cost for its 10-year life than the off-the-shelf system for its 15-year life, but it would be *wrong* to conclude from these calculations that the custom system should be preferred. The custom system yields benefits for only 10 years, whereas the off-the-shelf system lasts 15 years. It would be surprising if the cost of 15 years of benefits were not higher than the cost of 10 years of benefits. A fair comparison of the costs can be made only if equal lives are compared.

Let us apply the repeated lives method. If each alternative is repeated enough times, there will be a point in time where their service lives are simultaneously completed. This will happen first at the time equal to the least common multiple of the service lives. The least common multiple of 10 years and 15 years is 30 years. Alternative 1 will be repeated twice (after 10 years and after 20 years), while alternative 2 will be repeated once (after 15 years) during the 30-year period. At the end of 30 years, both alternatives will be completed simultaneously. See Figure 5.3.

Figure 5.3 Least Common Multiple of the Service Lives



With the same time period of 30 years for both alternatives, we can now compare present worths.

Alternative 1: Build custom automated materials-handling equipment and repeat twice.

$$\begin{aligned}PW(1) &= -15\,000 - 15\,000(P/F,9\%,10) - 15\,000(P/F,9\%,20)\\ &\quad - (3300 + 400 + 2400 + 300)(P/A,9\%,30)\end{aligned}$$

$$\mathbf{= -15\,000 - \mathit{PV}(0.09,10,-15\,000) - \mathit{PV}(0.09,20,-15\,000) - \mathit{PV}(0.09,30,-6400)}$$

$$\begin{aligned}&= -15\,000 - 15\,000(0.42241) - 15\,000(0.17843) - 6400\,(10.273)\\ &\cong -89\,760\end{aligned}$$

Alternative 2: Buy off-the-shelf standard automated materials-handling equipment and repeat once.

$$\begin{aligned}PW(2) &= -25\,000 - 25\,000(P/F,9\%,15) \quad \mathbf{= -25\,000 - \mathit{PV}(0.09,15,-25\,000) - \mathit{PV}(0.09,30,-5625)}\\ &\quad - (1450 + 600 + 3075 + 500)(P/A,9\%,30)\\ &= -25\,000 - 25\,000(0.27454) - 5625(10.273)\\ &\cong -89\,649\end{aligned}$$

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Using the repeated lives method, we find little difference between the alternatives. An annual worth comparison can also be done over a period of time equal to the least common multiple of the service lives by multiplying each of these present worths by the capital recovery factor for 30 years.

$$\begin{aligned} AW(1) &= -89\,760(A/P,9\%,30) \quad \mathbf{= -\mathit{PMT}(0.09,30,-89\,760)} \\ &= -89\,760(0.09734) \\ &\cong -8737 \end{aligned}$$

$$\begin{aligned} AW(2) &= -89\,649(A/P,9\%,30) \\ &= -89\,649(0.09734) \\ &\cong -8726 \end{aligned}$$

As we would expect, there is again little difference in the annual cost between the alternatives. However, there is a more convenient approach for an annual worth comparison if it can be assumed that the alternatives are repeated indefinitely. Since the annual costs of an alternative remain the same no matter how many times it is repeated, it is not necessary to determine the least common multiple of the service lives. The annual worth of each alternative can be assessed for whatever time period is most convenient for each alternative.

Alternative 1: Build custom automated materials-handling equipment.

$$\begin{aligned} AW(1) &= -15\,000(A/P,9\%,10) - 6400 \quad \mathbf{= -\mathit{PMT}(0.09,10,-15\,000) - 6400} \\ &= -15\,000(0.15582) - 6400 \\ &\cong -8737 \end{aligned}$$

Alternative 2: Buy off-the-shelf standard automated materials-handling equipment.

$$\begin{aligned} AW(2) &= -25\,000(A/P,9\%,15) - 5625 \quad \mathbf{= -\mathit{PMT}(0.09,15,-25\,000) - 5625} \\ &= -25\,000(0.12406) - 5625 \\ &\cong -8726 \end{aligned}$$

If it cannot be assumed that the alternatives can be repeated to permit a calculation over the least common multiple of their service lives, then it is necessary to use the study period method.

Suppose that the given study period is 10 years because the engineer is uncertain about costs past that time. The service life of the off-the-shelf system (15 years) is greater than the study period (10 years). Therefore, we have to make an assumption about the salvage value of the off-the-shelf system after 10 years. Suppose the engineer judges that its salvage value will be \$5000. We can now proceed with the comparison.

Alternative 1: Build custom automated materials-handling equipment (10-year study period).

$$\begin{aligned} PW(1) &= -15\,000 - (3300 + 400 + 2400 + 300)(P/A,9\%,10) \\ &= -15\,000 - 6400(6.4176) \quad \mathbf{= -15\,000 - \mathit{PV}(0.09,10,-6400)} \\ &\cong -56\,073 \end{aligned}$$

Alternative 2: Buy off-the-shelf standard automated materials-handling equipment (10-year study period).

$$\begin{aligned} PW(2) = &-25\,000 - (1450 + 600 + 3075 + 500)(P/A,9\%,10) \\ &+ 5000(P/F,9\%,10) \end{aligned}$$

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$$= -25\ 000 - 5625(6.4176) + 5000(0.42241)$$
$$\cong -58\ 987$$

Using the study period method of comparison, alternative 1 has the smaller present worth of costs at $56 073 and is, therefore, preferred.

Note that here the study period method gives a different answer than the repeated lives method gives. The study period method is often sensitive to the chosen salvage value. A larger salvage value tends to make an alternative with a life longer than the study period more attractive, and a smaller value tends to make it less attractive.

In some instances, it may be difficult to arrive at a reliable estimate of salvage value. Given the sensitivity of the study period method to the salvage value estimate, the analyst may be uncertain about the validity of the results. One way of circumventing this problem is to avoid estimating the salvage value at the outset. Instead we calculate what salvage value would make the alternatives equal in value. Then we decide whether the actual salvage value will be above or below the break-even value found. Applying this approach to our example, we set PW(1) = PW(2) so that

$$\text{PW}(1) = \text{PW}(2)$$
$$56\ 073 = -25\ 000 - 5625(6.4176) + S(0.42241)$$

where S is the salvage value.

Solving for S, we find $S = 11\ 834$. Is a reasonable estimate of the salvage value above or below $11 834? If it is above $11 834, then we conclude that the off-the-shelf system is the preferred choice. If it is below $11 834, then we conclude that the custom system is preferable. ■

The study period can also be used for the annual worth method if the assumption of being able to indefinitely repeat the choice of alternatives is not justified.

EXAMPLE 5.7

Joan is renting a flat while on a one-year assignment in England. The flat does not have a refrigerator. She can rent one for a £100 deposit (returned in a year) and £15 per month (paid at the end of each month). Alternatively, she can buy a refrigerator for £300, which she would sell in a year when she leaves. For how much would Joan have to be able to sell the refrigerator in one year when she leaves in order to be better off buying the refrigerator than renting one? Interest is at 6 percent nominal, compounded monthly.

Let S stand for the unknown salvage value (i.e., the amount Joan will be able to sell the refrigerator for in a year). We then equate the present worth of the rental alternative with the present worth of the purchase alternative for the one-year study period:

$$\text{PW(rental)} = \text{PW(purchase)}$$
$$-100 - 15(P/A,0.5\%,12) + 100(P/F,0.5\%,12) = -300 + S(P/F,0.5\%,12)$$
$$-100 - 15(11.616) + 100(0.94192) = -300 + S(0.94192)$$
$$S = 127.35$$

If Joan can sell the used refrigerator for more than about £127 after one year's use, she is better off buying it rather than renting one. ■

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SPREADSHEET SAVVY

Spreadsheets can be indispensable when it comes to making present worth or annual worth comparisons among projects. It is useful to spend a bit of time thinking about how to set up spreadsheet rows and columns before starting a comparison so you can do the analysis easily and can document your work. A careful setup will also allow you to check the individual components of your work as you go along.

The tables below demonstrate the use of the NPV and PMT Excel functions. The NPV function takes the present worth of a series of cash flows. It assumes that the cash flows start at the end of period 1 and that the interest rate is i. In contrast to other Excel functions, NPV assumes that the cash flows are receipts, so the sign of cash flows does not need to be reversed. The PMT Excel function computes the annual worth of a single cash flow that occurs at time 0 (assumed to be a disbursement) over N periods at an interest rate of i.

The tables show how to compute the present worth of cash flows in cells B5 through to B10 (B5:B10). The two methods shown are used to first compute the present worth of the individual cash flows and then to sum (cell C11), and then to use the NPV function (cell C14). The equivalent annual worth, in cells C12 and C15, is found by using either a compound interest factor (cell C12) or the PMT Excel function (cell C15).

In the top part of the table on the right, cell B2 contains the interest rate. It is good practice to put the interest rate in a cell that is referred to by other formulas rather than to enter it directly into the compound interest formula. The reason for this is twofold: First, the reader can see what the interest rate is for documentation purposes. Second, should you need to do a different computation with another interest rate, it is easier to change one cell than it is to re-enter the formulas.

	A	B	C
1	Use of Basic Computations:		
2	*i* =	10.00%	
3			Present Worth
4	Period	Cash Flow	*P(P/F,i,N)*
5	0	- 100 000	- 100 000
6	1	55 000	50 000
7	2	63 000	52 066
8	3	37 000	27 799
9	4	32 000	21 856
10	5	76 000	47 190
11	PW		98 911
12	AW		26 093
13	Use of Excel Functions: (NPV and PMT)		
14	PW		98 911
15	AW		26 093

	A	B	C
1	Use of Basic Computations:		
2	*i* =	0.1	
3			Present Worth
4	Period	Cash Flow	*P(P/F,i,N)*
5	0	-100000	=B5/(1+$B$2)^A5
6	1	55000	=B6/(1+$B$2)^A6
7	2	63000	=B7/(1+$B$2)^A7
8	3	37000	=B8/(1+$B$2)^A8
9	4	32000	=B9/(1+$B$2)^A9
10	5	76000	=B10/(1+$B$2)^A10
11	PW		=SUM(C5:C10)
12	AW		=C11*B2*(1+B2)^5/((1+B2)^5-1)
13	Use of Excel Functions: (NPV and PMT):		
14	PW		=B5+NPV(B2,B6:B10)
15	AW		=PMT(B2,5,-C14)

5.5 Payback Period

The simplest method for judging the economic viability of projects is the payback period method. It is a rough measure of the time it takes for an investment to pay for itself. More precisely, the **payback period** is the number of years it takes for an investment to be recouped when the interest rate is assumed to be zero. When annual savings are constant, the payback period is usually calculated as follows:

$$\text{Payback period} = \frac{\text{First cost}}{\text{Annual savings}}$$

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For example, if a first cost of \$20 000 yielded a return of \$8000 per year, then the payback period would be 20 000/8000 = 2.5 years.

If the annual savings are not constant, we can calculate the payback period by deducting each year of savings from the first cost until the first cost is recovered. The number of years required to pay back the initial investment is the payback period. For example, suppose the saving from a \$20 000 first cost is \$5000 the first year, increasing by \$1000 each year thereafter. By adding the annual savings one year at a time, we see that it would take just over three years to pay back the first cost (5000 + 6000 + 7000 + 8000 = 26 000). The payback period would then be stated as either four years (if we assume that the \$8000 is received at the end of the fourth year) or 3.25 years (if we assume that the \$8000 is received uniformly over the fourth year).

According to the payback period method of comparison, the project with the shorter payback period is the preferred investment. A company may have a policy of rejecting projects for which the payback period exceeds some preset number of years. The length of the maximum payback period depends on the type of project and the company's financial situation. If the company expects a cash constraint in the near future, or if a project's returns are highly uncertain after more than a few periods, the company will set a maximum payback period that is relatively short. As a common rule, a payback period of two years is often considered acceptable, while one of more than four years is unacceptable. Accordingly, government grant programs often target projects with payback periods of between two and four years with the rationale that in this range the grant can justify economically feasible projects that a company with limited cash flow would otherwise be unwilling to undertake.

The payback period need not, and perhaps should not, be used as the sole criterion for evaluating projects. It is a rough method of comparison and possesses some glaring weaknesses (as we shall discuss after Examples 5.8 and 5.9). Nevertheless, the payback period method can be used effectively as a preliminary filter. All projects with paybacks within the minimum would then be evaluated, using either rate of return methods (Chapter 6) or present/annual worth methods.

EXAMPLE 5.8

Elyse runs a second-hand book business out of her home where she advertises and sells the books over the internet. Her small business is becoming quite successful and she is considering purchasing an upgrade to her computer system that will give her more reliable uptime. The cost is \$5000. She expects that the investment will bring about an annual savings of \$2000, due to the fact that her system will no longer suffer long failures and thus she will be able to sell more books. What is the payback period on her investment, assuming that the savings accrue over the whole year?

$$\text{Payback period} = \frac{\text{First cost}}{\text{Annual savings}} = \frac{5000}{2000} = 2.5 \text{ years}$$ ■

EXAMPLE 5.9

Pizza-in-a-Hurry operates a pizza delivery service to its customers with two eight-year-old vehicles, both of which are large, consume a great deal of gas, and are starting to cost a lot to repair. The owner, Ray, is thinking of replacing one of the cars with a smaller, three-year-old car that his sister-in-law is selling for \$8000. Ray figures he can save \$3000, \$2000, and \$1500 per year for the next three years and \$1000 per year for the following two years by purchasing the smaller car. What is the payback period for this decision?

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The payback period is the number of years of savings required to pay back the initial cost. After three years, \$3000 + \$2000 + \$1500 = \$6500 has been paid back, and this amount is \$7500 after four years and \$8500 after five years. The payback period would be stated as five years if the savings are assumed to occur at the end of each year, or 4.5 years if the savings accrue continuously throughout the year. ■

The payback period method has four main advantages:

1. It is very easy to understand. One of the goals of engineering decision making is to communicate the reasons for a decision to managers or clients with a variety of backgrounds. The reasons behind the payback period and its conclusions are very easy to explain.
2. The payback period is very easy to calculate. It can usually be done without even using a calculator, so projects can be very quickly assessed.
3. It accounts for the need to recover capital quickly. Cash flow is almost always a problem for small to medium-sized companies. Even large companies sometimes can't tie up their money in long-term projects.
4. The future is unknown. The future benefits from an investment may be estimated imprecisely. It may not make much sense to use precise methods like present worth on numbers that are imprecise to start with. A simple method like the payback period may be good enough for most purposes.

But the payback period method has three important disadvantages:

1. It discriminates against long-term projects. No houses or highways would ever be built if they had to pay themselves off in two years.
2. It ignores the effect of the timing of cash flows within the payback period. It disregards interest rates and takes no account of the time value of money. (Occasionally, a discounted payback period is used to overcome this disadvantage. See Close-Up 5.3.)
3. It ignores the expected service life. It disregards the benefits that accrue after the end of the payback period.

CLOSE-UP 5.3 Discounted Payback Period

In a discounted payback period calculation, the present worth of each year's savings is subtracted from the first cost until the first cost is diminished to zero. The number of years of savings required to do this is the discounted payback period. The main disadvantages of using a discounted payback period include the more complicated calculations and the need for an interest rate.

For instance, in Example 5.8, Elyse had an investment of \$5000 recouped by annual savings of \$2000. If interest were at 10 percent, the present worth of savings would be:

Year	Present Worth	Cumulative
Year 1	$2000(P/F,10\%,1) = 2000(0.90909) = 1818$	1818
Year 2	$2000(P/F,10\%,2) = 2000(0.82645) = 1653$	3471
Year 3	$2000(P/F,10\%,3) = 2000(0.75131) = 1503$	4974
Year 4	$2000(P/F,10\%,4) = 2000(0.68301) = 1366$	6340

Thus the discounted payback period is over 3 years, compared with 2.5 years calculated for the standard payback period.

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Example 5.10 illustrates how the payback period method can ignore future cash flows.

EXAMPLE 5.10

Self Defence Systems of Cape Town is going to upgrade its paper-shredding facility. The company has a choice between two models. Model 007, with a first cost of R500 000 and a service life of seven years, would save R100 000 per year. Model MX, with a first cost of R100 000 and an expected service life of 20 years, would save R15 000 per year. If the company's MARR is 8 percent, which model is the better buy?

Using payback period as the sole criterion:

Model 007: Payback period = 500 000/100 000 = 5 years

Model MX: Payback period = 100 000/15 000 = 6.6 years

It appears that the 007 model is better.

Using annual worth:

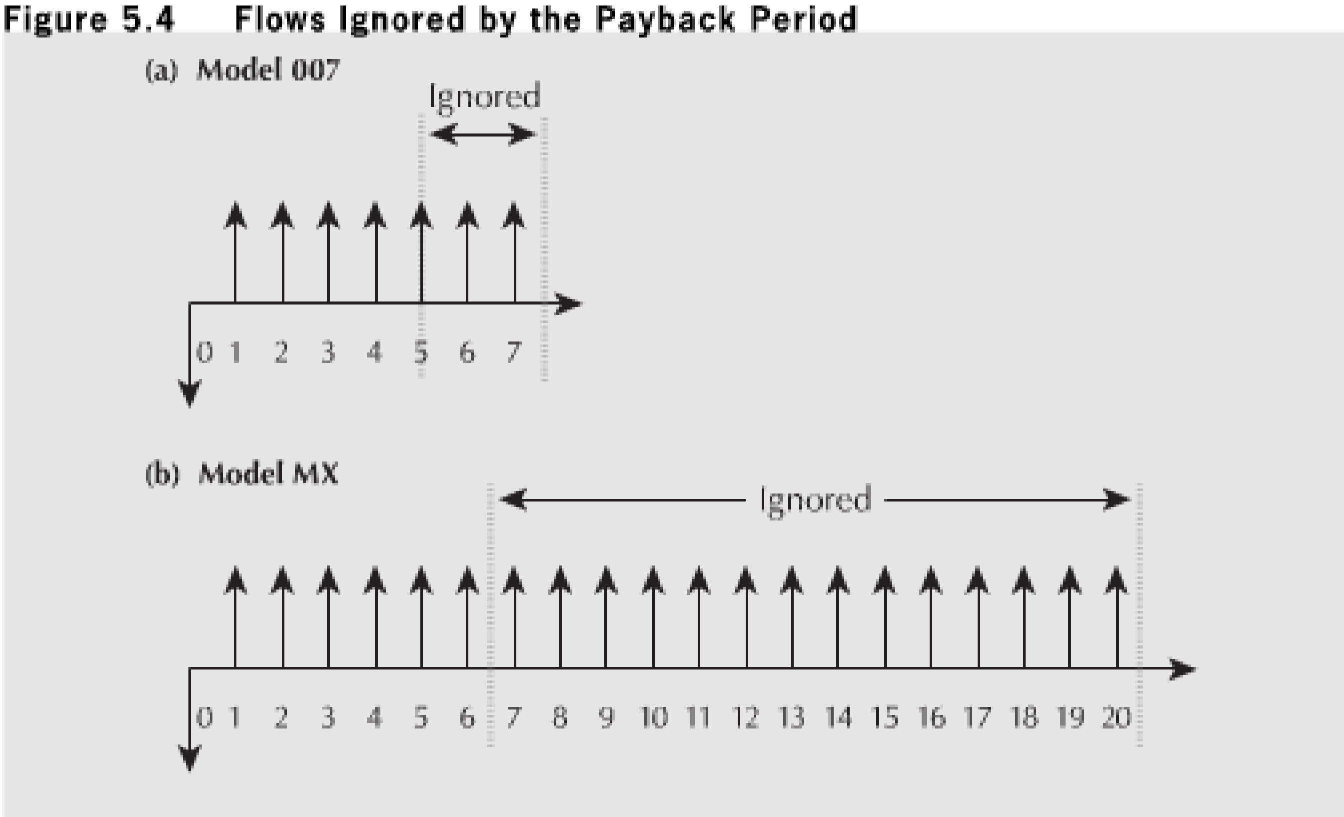
Model 007: AW = $-500\,000(A/P,8\%,7) + 100\,000 = 3965$

Model MX: AW = $-100\,000(A/P,8\%,20) + 15\,000 = 4815$

Here, Model MX is substantially better.

The difference in the results from the two comparison methods is that the payback period method has ignored the benefits of the models that occur after the models have paid themselves off. This is illustrated in Figure 5.4. For Model MX, about 14 years of benefits have been omitted, whereas for model 007, only two years of benefits have been left out. ■

Figure 5.4 Flows Ignored by the Payback Period



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REVIEW PROBLEMS

REVIEW PROBLEM 5.1

Tilson Dairies operates several cheese plants. The plants are all old and in need of renovation. Tilson's engineers have developed plans to renovate all of them. Each project would have a positive present worth at the company's MARR. Tilson has $3.5 million available to invest in these projects. The following facts about the potential renovation projects are available:

Project	First Cost	Present Worth
A: Renovate plant 1	$0.8 million	$1.1 million
B: Renovate plant 2	$1.2 million	$1.7 million
C: Renovate plant 3	$1.4 million	$1.8 million
D: Renovate plant 4	$2.0 million	$2.7 million

Which projects should Tilson accept?

ANSWER

Table 5.2 shows the possible mutually exclusive projects that Tilson can consider.

Table 5.2 Mutually Exclusive Projects for Tilson Dairies

Project	Total First Cost	Total Present Worth	Feasibility
Do nothing	$0.0 million	$0.0 million	Feasible
A	$0.8 million	$1.1 million	Feasible
B	$1.2 million	$1.7 million	Feasible
C	$1.4 million	$1.8 million	Feasible
D	$2.0 million	$2.7 million	Feasible
A and B	$2.0 million	$2.8 million	Feasible
A and C	$2.2 million	$2.9 million	Feasible
A and D	$2.8 million	$3.8 million	Feasible
B and C	$2.6 million	$3.5 million	Feasible
B and D	$3.2 million	$4.4 million	Feasible
C and D	$3.4 million	$4.5 million	Feasible
A, B, and C	$3.4 million	$4.6 million	Feasible
A, B, and D	$4.0 million	$5.5 million	Not feasible
A, C, and D	$4.2 million	$5.6 million	Not feasible
B, C, and D	$4.6 million	$6.2 million	Not feasible
A, B, C, and D	$5.4 million	$7.3 million	Not feasible

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Tilson should accept projects A, B, and C. They have a combined present worth of \$4.6 million. Other feasible combinations that come close to using all available funds are B and D with a total present worth of \$4.4 million, and C and D with a total present worth of \$4.5 million.

Note that it is not necessary to consider explicitly the "leftovers" of the \$3.5 million budget when comparing the present worths. The assumption is that any leftover part of the budget will be invested and provide interest at the MARR, resulting in a zero present worth for that part. Therefore, it is best to choose the combination of projects that has the largest total present worth and stays within the budget constraint.■

REVIEW PROBLEM 5.2

City engineers are considering two plans for municipal aqueduct tunnels. They are to decide between the two using an interest rate of 8 percent.

Plan A is a full-capacity tunnel that will meet the needs of the city forever. Its cost is \$3 000 000 now and \$100 000 every 10 years for lining repairs.

Plan B involves building a half-capacity tunnel now and a second half-capacity tunnel in 20 years, when the extra capacity will be needed. Each of the half-capacity tunnels costs \$2 000 000. Maintenance costs for each tunnel are \$80 000 every 10 years. There is also an additional \$15 000 per tunnel per year required to pay for extra pumping costs caused by greater friction in the smaller tunnels.

(a) Which alternative is preferred? Use a present worth comparison.

(b) Which alternative is preferred? Use an annual worth comparison.

ANSWER

(a) *Plan A: Full-Capacity Tunnel*

First, the \$100 000 paid at the end of 10 years can be thought of as a future amount that has an equivalent annuity.

$$AW = 100\,000(A/F,8\%,10) \quad \mathbf{= -\mathit{PMT}(0.8,10,-100\,000)}$$
$$= 100\,000(0.06903) = 6903$$

Thus, at 8 percent interest, \$100 000 every 10 years is equivalent to \$6903 every year.

Since the tunnel will have (approximately) an infinite life, the present cost of the lining repairs can be found using the capitalized cost formula, giving a total cost of

$$PW(\text{Plan A}) = 3\,000\,000 + 6903/0.08 = 3\,086\,288$$

Plan B: Half-Capacity Tunnels

For the first tunnel, the equivalent annuity for the maintenance and pumping costs is

$$AW = 15\,000 + 80\,000(0.06903) = 20\,522$$

The present cost is then found with the capitalized cost formula, giving a total cost of

$$PW_1 = 2\,000\,000 + 20\,522/0.08 = 2\,256\,525$$

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Now, for the second tunnel, basically the same calculation is used, except that the present worth calculated must be discounted by 20 years at 8 percent, since the second tunnel will be built 20 years in the future.

$$\begin{aligned}PW_2 &= \{2\,000\,000 + [15\,000 + 80\,000(0.06903)]/0.08\}(P/F,8\%,20)\\ &= 2\,256\,525(0.21455) \cong 484\,137\end{aligned}$$

$$PW(\text{Plan B}) = PW_1 + PW_2 = 2\,740\,662$$

Consequently, the two half-capacity aqueducts with a present worth of costs of \$2 740 662 are economically preferable.

(b) *Plan A: Full-Capacity Tunnel*

First, the \$100 000 paid at the end of 10 years can be thought of as a future amount that has an equivalent annuity of

$$AW = 100\,000(A/F,8\%,10) = 100\,000(0.06903) = 6903$$

Thus, at 8 percent interest, \$100 000 every 10 years is equivalent to \$6903 every year.

Since the tunnel will have (approximately) an infinite life, an annuity equivalent to the initial cost can be found using the capitalized cost formula, giving a total annual cost of

$$AW(\text{Plan A}) = 3\,000\,000(0.08) + 6903 = 246\,903$$

Plan B: Half-Capacity Tunnels

For the first tunnel, the equivalent annuity for the maintenance and pumping costs is

$$AW = 15\,000 + 80\,000(0.06903) \cong 20\,522$$

The annual equivalent of the initial cost is then found with the capitalized cost formula, giving a total cost of

$$AW_1 = 2\,000\,000(0.08) + 20\,522 = 180\,522$$

Now, for the second tunnel, basically the same calculation is used, except that the annuity must be discounted by 20 years at 8 percent, since the second tunnel will be built 20 years in the future.

$$\begin{aligned}AW_2 &= AW_1(P/F,8\%,20)\\ &= 180\,522(0.21455) \cong 38\,731\end{aligned}$$

$$\begin{aligned}AW(\text{Plan B}) &= AW_1 + AW_2\\ &= 180\,522 + 38\,731 = 219\,253\end{aligned}$$

Consequently, the two half-capacity aqueducts with an annual worth of costs of \$219 253 are economically preferable.■

REVIEW PROBLEM 5.3

Fernando Constantia, an engineer at Brandy River Vineyards, has a \$100 000 budget for winery improvements. He has identified four mutually exclusive investments, all of five years' duration, which have the cash flows shown in Table 5.3. For each alternative, he wants to determine the payback period and the present worth. For his recommendation report, he will order the alternatives from most preferred to least preferred in each case. Brandy River uses an 8 percent MARR for such decisions.

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Table 5.3 Cash Flows for Review Problem 5.3

Alternative	Cash Flow at the End of Each Year 0	1	2	3	4	5
A	−$100 000	$25 000	$25 000	$25 000	$25 000	$ 25 000
B	−100 000	5000	10 000	20 000	40 000	80 000
C	−100 000	50 000	50 000	10 000	0	0
D	−100 000	0	0	0	0	1 000 000

ANSWER

The payback period can be found by decrementing yearly. The payback periods for the alternatives are then

A: 4 years
B: 4.3125 or 5 years
C: 2 years
D: 4.1 or 5 years

The order of the alternatives from most preferred to least preferred using the payback period method with yearly decrementing is: C, A, D, B. The present worth computations for each alternative are:

$$\begin{aligned} \text{A:}\quad \text{PW} &= -100\,000 + 25\,000(P/A,8\%,5) \\ &= -100\,000 + 25\,000(3.9926) \\ &= -185 \end{aligned}$$

$$\begin{aligned} \text{B:}\quad \text{PW} &= -100\,000 + 5000(P/F,8\%,1) + 10\,000(P/F,8\%,2) \\ &\quad + 20\,000(P/F,8\%,3) + 40\,000(P/F,8\%,4) + 80\,000(P/F,8\%,5) \\ &= -100\,000 + 5000(0.92593) + 10\,000(0.85734) \\ &\quad + 20\,000(0.79383) + 40\,000(0.73503) + 80\,000(0.68059) \\ &= 12\,928 \end{aligned}$$

$$\begin{aligned} \text{C:}\quad \text{PW} &= -100\,000 + 50\,000(P/F,8\%,1) + 50\,000(P/F,8\%,2) \\ &\quad + 10\,000(P/F,8\%,3) \\ &= -100\,000 + 50\,000(0.92593) + 50\,000(0.85734) \\ &\quad + 10\,000(0.79283) \\ &= -2908 \end{aligned}$$

$$\begin{aligned} \text{D:}\quad \text{PW} &= -100\,000 + 1\,000\,000(P/F,8\%,5) \\ &= -100\,000 + 1\,000\,000(0.68059) \\ &= 580\,590 \end{aligned}$$

The order of the alternatives from most preferred to least preferred using the present worth method is: D, B, A, C.■

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SUMMARY

This chapter discussed relations among projects, and the present worth, annual worth, and payback period methods for evaluating projects. There are three classes of relations among projects: (1) independent, (2) mutually exclusive, and (3) related but not mutually exclusive. We then showed how the third class of projects, those that are related but not mutually exclusive, could be combined into sets of mutually exclusive projects. This enabled us to limit the discussion to the first two classes—independent and mutually exclusive. Independent projects are considered one at a time and are either accepted or rejected. Only the best of a set of mutually exclusive projects is chosen.

The present worth method compares projects on the basis of converting all cash flows for the project to a present worth. An independent project is acceptable if its present worth is greater than zero. The mutually exclusive project with the highest present worth should be taken. Projects with unequal lives must be compared by assuming that the projects are repeated or by specifying a study period. Annual worth is similar to present worth, except that the cash flows are converted to a uniform series. The annual worth method may be more meaningful and does not require more complicated calculations when the projects have different service lives.

The payback period is a simple method that calculates the length of time it takes to pay back an initial investment. It is inaccurate but very easy to calculate.

ENGINEERING ECONOMICS IN ACTION, PART 5B

Doing It Right

Naomi stopped for coffee on her way back from Clem's office. She needed time to think about how to decide which potential forge shop investments were best. She wasn't sure that she knew what "best" meant. She got down her engineering economics text and looked at the table of contents. There were a couple of chapters on comparison methods that seemed to be what she wanted. She sat down with the coffee in her right hand and the text on her lap and hoped for an uninterrupted hour.

One read through the chapters was enough to remind Naomi of the main relevant ideas that she had learned in school. The first thing she had to do was decide whether the investments were independent or not. They clearly were not independent. It would not make sense to refurbish the current forging hammer and replace it with a mechanical press. Where potential investments were not independent, it was easiest to form mutually exclusive combinations as investment options. Naomi came up with seven options. She ranked the options by first cost, starting with the one with the lowest cost:

1. Refurbish the current machine.
2. Refurbish the current machine plus replace the materials-handling equipment.
3. Buy a manually operated mechanical press.
4. Buy a manual mechanical press plus replace the materials-handling equipment.
5. Buy an automated mechanical press.
6. Buy an automated mechanical press plus replace the materials-handling equipment.
7. Buy an automated mechanical press plus integrate it with the materials-handling equipment.

At this point, Naomi wasn't sure what to do next. There were different ways of comparing the options.

Naomi wanted a break from thinking about theory. She decided to take a look at Dave Sullivan's work. She started up her computer and opened up Dave's email. In it Dave apologized for dumping the work on her and invited Naomi to call him in Florida if she needed help. Naomi decided to call him. The phone was answered by

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Dave's wife, Helena. After telling Naomi that her father was out of intensive care and was in good spirits, Helena turned the phone over to Dave.

"Hi, Naomi. How's it going?"

"Well, I'm trying to finish off the forge project you started. And I'm taking you up on your offer to consult."

"You have my attention. What's the problem?"

"Well, I've gotten started. I have formed seven mutually exclusive combinations of potential investments." Naomi went on to explain her selection of alternatives.

"That sounds right, Naomi. I like the way you've organized that. Now, how are you going to make the choice?"

"I've just reread the present worth, annual worth, and payback period stuff, and of those three, present worth makes the most sense to me. I can just compare the present worths of the cash flows for each alternative, and the one whose present worth is highest is the best one. Annual worth is the same, but I don't see any good reason in this case to look at the costs on an annual basis."

"What about internal rate of return?"

"Well, actually, Dave, I haven't reviewed IRR yet. I'll need it, will I?"

"You will. Have a look at it, and also remember that your recommendation is for Burns and Kulkowski. Think about how they will be looking at your information."

"Thanks, Dave. I appreciate your help."

"No problem. This first one is important for you; let's make sure we do it right."

PROBLEMS

A. Key Concepts

5.1 The Alabaster Marble Company (AM) is considering opening three new quarries. One, designated T, is in Tusksarelooser County; a second, L, is in Lefant County; the third, M, is in Marxbro County. Marble is shipped mainly within a 500-kilometre range of its quarry because of its weight. The market within this range is limited. The returns that AM can expect from any of the quarries depend on how many quarries AM opens. Therefore, these potential projects are related.

(a) Construct a set of mutually exclusive alternatives from these three potential projects.

(b) The Lefant County quarry has very rich deposits of marble. This makes the purchase of mechanized cutter-loaders a reasonable investment at this quarry. Such loaders would not be considered at the other quarries. Construct a set of mutually exclusive alternatives from the set of quarry projects augmented by the potential mechanized cutter-loader project.

(c) AM has decided to invest no more than $2.5 million in the potential quarries. The first costs are as follows:

Project	First Cost
T quarry	$0.9 million
L quarry	1.4 million
M quarry	1.0 million
Cutter-loader	0.4 million

Construct a set of mutually exclusive alternatives that are feasible, given the investment limitation.

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5.2 The intersection of King and Main streets needs widening and improvement. The possibilities include:

1. Widen King
2. Widen Main
3. Add a left-turn lane on King
4. Add a left-turn lane on Main
5. Add traffic lights at the intersection
6. Add traffic lights at the intersection with advanced green for Main
7. Add traffic lights at the intersection with advanced green for King

A left-turn lane can be installed only if the street in question is widened. A left-turn lane is necessary if the street has traffic lights with an advanced green. The city cannot afford to widen both streets. How many mutually exclusive projects are there?

5.3 Yun is deciding among a number of business opportunities. She can

(a) Sell the X division of her company, Yunco

(b) Buy Barzoo's company, Barco

(c) Get new financing

(d) Expand into Quebec

There is no sense in getting new financing unless she is either buying Barco or expanding into Quebec. She can only buy Barco if she gets financing or sells the X division. She can only expand into Quebec if she has purchased Barco. The X division is necessary to compete in Quebec. What are the feasible projects she should consider?

5.4 Margaret has a project with a \$28 000 first cost that returns \$5000 per year over its 10-year life. It has a salvage value of \$3000 at the end of 10 years. If the MARR is 15 percent, what is the present worth of this project?

5.5 Nabil is considering buying a house while he is at university. The house costs \$200 000 today. Renting out part of the house and living in the rest over his five years at school will net, after expenses, \$2000 per month. He estimates that he will sell the house after five years for \$210 000. If Nabil's MARR is 6 percent compounded monthly, should he buy the house? Use present worth.

5.6 Appledale Dairy is considering upgrading an old ice-cream maker. Upgrading is available at two levels: moderate and extensive. Moderate upgrading costs \$6500 now and yields annual savings of \$3300 in the first year, \$3000 in the second year, \$2700 in the third year, and so on. Extensive upgrading costs \$10 550 and saves \$7600 in the first year. The savings then decrease by 20 percent each year thereafter. If the upgraded ice-cream maker will last for seven years, which upgrading option is better? Use a present worth comparison. Appledale's MARR is 8 percent.

5.7 A young software genius is selling the rights to a new video game he has developed. Two companies have offered him contracts. The first contract offers \$10 000 at the end of each year for the next five years, and then \$20 000 per year for the following 10 years. The second offers 10 payments, starting with \$10 000 at the end of the first year, \$13 000 at the end of the second, and so forth, increasing by \$3000 each year (i.e., the tenth payment will be $\$10\,000 + 9 \times \$3000$). Assume the genius uses a MARR of 9 percent. Which contract should he choose? Use a present worth comparison.

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5.8 Water supply for an irrigation system can be obtained from a stream in some nearby mountains. Two alternatives are being considered, both of which have essentially infinite lives, provided proper maintenance is performed. The first is a concrete reservoir with a steel pipe system and the second is an earthen dam with a wooden aqueduct. Below are the costs associated with each.

Compare the present worths of the two alternatives using an interest rate of 8 percent. Which alternative should be chosen?

	Concrete Reservoir	Earthen Dam
First cost	\$500 000	\$200 000
Annual maintenance costs	\$2000	\$12 000
Replacing the wood portion of the aqueduct each 15 years	N/A	\$100 000

5.9 Margaret has a project with a \$28 000 first cost that returns \$5000 per year over its 10-year life. It has a salvage value of \$3000 at the end of 10 years. If the MARR is 15 percent, what is the annual worth of this project?

5.10 Nabil is considering buying a house while he is at university. The house costs \$200 000 today. Renting out part of the house and living in the rest over his five years at school will net, after expenses, \$2000 per month. He estimates that he will sell the house after five years for \$210 000. If Nabil's MARR is 6 percent compounded monthly, should he buy the house? Use annual worth.

5.11 Midland Metalworking is examining a 750-tonne hydraulic press and a 600-tonne moulding press for purchase. Midland has only enough budget for one of them. If Midland's MARR is 12 percent and the relevant information is as given below, which press should it purchase? Use an annual worth comparison.

	Hydraulic Press	Moulding Press
Initial cost	\$275 000	\$185 000
Annual savings	\$33 000	\$24 500
Annual maintenance cost	\$2000, increasing by 15% each year thereafter	\$1000, increasing by \$350 each year thereafter
Life	15 years	10 years
Salvage value	\$19 250	\$14 800

5.12 Tom is considering purchasing a \$24 000 car. After five years, he will be able to sell the vehicle for \$8000. Petrol costs will be \$2000 per year, insurance \$600 per year, and parking \$600 per year. Maintenance costs for the first year will be \$1000, rising by \$400 per year thereafter.

The alternative is for Tom to take taxis everywhere. This will cost an estimated \$6000 per year. Tom will rent a vehicle each year at a total cost (to year-end) of \$600 for the family vacation, if he has no car. If Tom values money at 11 percent annual interest, should he buy the car? Use an annual worth comparison method.

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5.13 A chemical recovery system costs \$300 000 and saves \$52 800 each year of its seven-year life. The salvage value is estimated at \$75 000. The MARR is 9 percent. What is the net annual benefit or cost of purchasing the chemical recovery system? Use the capital recovery formula.

5.14 Savings of \$5600 per year can be achieved through either a \$14 000 machine (A) with a seven-year service life and a \$2000 salvage value, or a \$25 000 machine (B) with a ten-year service life and a \$10 000 salvage value. If the MARR is 9 percent, which machine is a better choice, and for what annual benefit or cost? Use annual worth and the capital recovery formula.

5.15 Sam is considering buying a new lawnmower. He has a choice between a Lawn Guy mower and a Bargain Joe's Clip Job mower. Sam has a MARR of 5 percent. The salvage value of each mower at the end of its service life is zero.

	Lawn Guy	Clip Job
First cost	\$350	\$120
Life	10 years	4 years
Annual gas	\$60	\$40
Annual maintenance	\$30	\$60

(a) Using the information above, determine which alternative is preferable. Use a present worth comparison and the least common multiple of the service lives.

(b) For a four-year study period, what salvage value for the Lawn Guy mower would result in its being the preferred choice? What salvage value for the Lawn Guy would result in the Clip Job being the preferred choice?

5.16 Sam is buying a refrigerator. He has two choices. A used one, at \$475, should last him about three years. A new one, at \$1250, would likely last eight years. Both have a scrap value of zero. The interest rate is 8 percent.

(a) Which refrigerator has a lower cost? (Use a present worth analysis with repeated lives. Assume operating costs are the same.)

(b) If Sam knew that he could resell the new refrigerator after three years for \$1000, would this change the answer in part (a)? (Use a present worth analysis with a three-year study period. Assume operating costs are the same.)

5.17 Margaret has a project with a \$28 000 first cost that returns \$5000 per year over its 10-year life. It has a salvage value of \$3000 at the end of 10 years. If the MARR is 5 percent, what is the payback period of this project?

5.18 A new gizmo costs \$10 000. Maintenance costs \$2000 per year and labour savings are \$6567 per year. What is the gizmo's payback period?

5.19 Building a bridge will cost \$65 million. A round-trip toll of \$12 will be charged to all vehicles. Traffic projections are estimated to be 5000 per day. The operating and maintenance costs will be 20 percent of the toll revenue. Find the payback period (in years) for this project.

5.20 A new packaging machine will save Greene Cheese Ltd. \$3000 per year in reduced spoilage, \$2500 per year in labour, and \$1000 per year in packaging material. The new machine will have additional expenses of \$700 per year in maintenance and \$200 per year in energy. If it costs \$20 000 to purchase, what is its payback period? Assume that the savings are earned throughout the year, not just at year-end.

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B. Applications

5.21 IQ Computer assembles UNIX workstations at its plant. The current product line is nearing the end of its marketing life, and it is time to start production of one or more new products. The data for several candidates are shown below.

The maximum budget for research and development is \$300 000. A minimum of \$200 000 should be spent on these projects. It is desirable to spread out the introduction of new products, so if two products are to be developed together, they should have different lead times. Resource draw refers to the labour and space that are available to the new products; it cannot exceed 100 percent.

On the basis of the above information, determine the set of feasible mutually exclusive alternative projects that IQ Computers should consider.

	Potential Product			
	A	B	C	D
Research and development costs	\$120 000	\$60 000	\$150 000	\$75 000
Lead time	1 year	2 years	1 year	2 years
Resource draw	60%	50%	40%	30%

5.22 Angus Automotive has \$100 000 to invest in internal projects. The choices are:

Project	Cost
1. Line improvements	\$20 000
2. New manual tester	30 000
3. New automatic tester	60 000
4. Overhauling press	50 000

Only one tester may be bought and the press will not need overhauling if the line improvements are not made. What mutually exclusive project combinations are available if Angus Auto will invest in at least one project?

5.23 Nottawasaga Printing has four printing lines, each of which consists of three printing stations, A, B, and C. The company has allocated \$20 000 for upgrading the printing stations. Station A costs \$7000 and takes 10 days to upgrade. Station B costs \$5000 and takes 5 days, and station C costs \$3000 and takes 3 days. Due to the limited number of technicians, Nottawasaga can only upgrade one printing station at a time. That is, if it decides to upgrade two Bs, the total downtime will be 10 days. During the upgrading period, the downtime should not exceed 14 days in total. Also, at least two printing lines must be available at all times to satisfy the current customer demand. The entire line will not be available if any of the printing stations is turned off for upgrading. Nottawasaga Printing wants to know which line and which printing station to upgrade. Determine the feasible mutually exclusive combinations of lines and stations for Nottawasaga Printing.

5.24 Kiwidale Dairy is considering purchasing a new ice-cream maker. Two models, Smoothie and Creamy, are available and their information is given below.

(a) What is Kiwidale's MARR that makes the two alternatives equivalent? Use a present worth comparison.

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	Smoothie	Creamy
First cost	\$15 000	\$36 000
Service life	12 years	12 years
Annual profit	\$4200	\$10 800
Annual operating cost	\$1200	\$3520
Salvage value	\$2250	\$5000

(b) It turned out that the service life of Smoothie was 14 years. Which alternative is better on the basis of the MARR computed in part (a)? Assume that each alternative can be repeated indefinitely.

5.25 Margaret has a project with a \$28 000 first cost that returns \$5000 per year over its 10-year life. It has a salvage value of \$3000 at the end of 10 years. If the MARR is 15 percent, what is the future worth of this project after 10 years? What is the discounted payback period for this project?

5.26 Westmount Waxworks is considering buying a new wax melter for its line of replicas of statues of government leaders. There are two choices of supplier, Finedetail and Simplicity. Their proposals are as follows:

	Finedetail	Simplicity
Expected life	7 years	10 years
First cost	\$200 000	\$350 000
Maintenance	\$10 000/year + \$0.05/unit	\$20 000/year + \$0.01/unit
Labour	\$1.25/unit	\$0.50/unit
Other costs	\$6500/year + \$0.95/unit	\$15 500/year + \$0.55/unit
Salvage value	\$5000	\$20 000

Management thinks the company will sell about 30 000 replicas per year if there is stability in world governments. If the world becomes very unsettled so that there are frequent overturns of governments, sales may be as high as 200 000 units a year. Westmount Waxworks uses a MARR of 15 percent for equipment projects.

(a) Who is the preferred supplier if sales are 30 000 units per year? Use an annual worth comparison.

(b) Who is the preferred supplier if sales are 200 000 units per year? Use an annual worth comparison.

(c) How sensitive is the choice of supplier to sales level? Experiment with sales levels between 30 000 and 200 000 units per year. At what sales level will the costs of the two melters be equal?

5.27 The City of Brandon is installing a new swimming pool in the municipal recreation centre. Two designs are under consideration, both of which are to be permanent (i.e., lasting forever). The first design is for a reinforced concrete pool that has a first cost of \$1 500 000. Every 10 years, the inner surface of the pool would have to be refinished and painted at a cost of \$200 000.

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The second design consists of a metal frame and a plastic liner, which would have an initial cost of \$500 000. For this alternative, the plastic liner must be replaced every 5 years at a cost of \$100 000, and every 15 years the metal frame would need replacement at a cost of \$150 000. Extra insurance of \$5000 per year is required for the plastic liner (to cover repair costs if the liner leaks). The city's cost of long-term funds is 5 percent.

Determine which swimming pool design has the lower present cost.

5.28 Val is considering purchasing a new video plasma display panel to use with her notebook computer. One model, the XJ3, costs \$4500 new, while another, the Y19, sells for \$3200. Val figures that the XJ3 will last about three years, at which point it could be sold for \$1000, while the Y19 will last for only two years and will also sell for \$1000. Both panels give similar service, except that the Y19 is not suitable for client presentations. If she buys the Y19, about four times a year she will have to rent one similar to the XJ3, at a total year-end cost of about \$300. Using present worth and the least common multiple of the service lives, determine which display panel Val should buy. Val's MARR is 10 percent.

5.29 For Problem 5.28, Val has determined that the salvage value of the XJ3 after two years of service is \$1900. Which display panel is the better choice, on the basis of present worth with a two-year study period?

5.30 Diana usually uses a three-year payback period to determine if a project is acceptable. A recent project with uniform yearly savings over a five-year life had a payback period of almost exactly three years, so Diana decided to find the project's present worth to help determine if the project was truly justifiable. However, that calculation didn't help either since the present worth was exactly zero. What interest rate was Diana using to calculate the present worth? The project has no salvage value at the end of its five-year life.

5.31 The Biltmore Garage has lights in places that are difficult to reach. Management estimates that it costs about \$2 to change a bulb. Standard 100-watt bulbs with an expected life of 1000 hours are now used. Standard bulbs cost \$1. A long-life bulb that requires 90 watts for the same effective level of light is available. Long-life bulbs cost \$3. The bulbs that are difficult to reach are in use for about 500 hours a month. Electricity costs \$0.08/kilowatt-hour payable at the end of each month. Biltmore uses a 12 percent MARR (1 percent per month) for projects involving supplies.

(a) What minimum life for the long-life bulb would make its cost lower?

(b) If the cost of changing bulbs is ignored, what is the minimum life for the long-life bulb for them to have a lower cost?

(c) If the solutions are obtained by linear interpolation of the capital recovery factor, will the approximations understate or overstate the required life?

5.32 Ridgley Custom Metal Products (RCMP) must purchase a new tube bender. RCMP's MARR is 11 percent. The company is considering two models:

Model	First Cost	Economic Life	Yearly Net Savings	Salvage Value
T	\$100 000	5 years	\$50 000	\$20 000
A	150 000	5 years	60 000	30 000

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(a) Using the *present worth* method, which tube bender should it buy?

(b) RCMP has discovered a third alternative, which has been added to the table below. Now which tube bender should it buy?

Model	First Cost	Economic Life	Yearly Net Savings	Salvage Value
T	$100 000	5 years	$50 000	$ 20 000
A	150 000	5 years	60 000	30 000
X	200 000	3 years	75 000	100 000

5.33 RCMP (see Problem 5.32, part (b)) can forecast demand for its products for only three years in advance. The salvage value after three years is $40 000 for model T and $80 000 for model A. Using the study period method, which of the three alternatives is best?

5.34 Using the annual worth method, which of the three tube benders should RCMP buy? The MARR is 11 percent. Use the data from Problem 5.32, part (b).

5.35 What is the payback period for each of the three alternatives from the RCMP problem? Use the data from Problem 5.32, part (b).

5.36 Data for two independent investment opportunities are shown below.

	Machine A	Machine B
Initial cost	$1 500 000	$2 000 000
Revenues (annual)	$ 900 000	$1 100 000
Costs (annual)	$ 600 000	$ 800 000
Scrap value	$ 100 000	$ 200 000
Service life	5 years	10 years

(a) For a MARR of 8 percent, should either, both, or neither machine be purchased? Use the annual worth method.

(b) For a MARR of 8 percent, should either, both, or neither machine be purchased? Use the present worth method.

(c) What are the payback periods for these machines? Should either, both, or neither machine be purchased, based on the payback periods? The required payback period for investments of this type is three years.

5.37 Two plans have been proposed for accumulating money for capital projects at Bobbin Bay Lighting. One idea is to put aside $100 000 per year, independent of growth. The second is to start with a smaller amount, $80 000 per year, but to increase this in proportion to the expected company growth. The money will accumulate interest at 10 percent, and the company is expected to grow about 5 percent per year. Which plan will accumulate more money in 10 years?

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5.38 Derek has two choices for a heat-loss prevention system for the shipping doors at Kirkland Manufacturing. He can isolate the shipping department from the rest of the plant, or he can curtain off each shipping door separately. Isolation consists of building a permanent wall around the shipping area. It will cost \$60 000 and will save \$10 000 in heating costs per year. Plastic curtains around each shipping door will have a total cost of about \$5000, but will have to be replaced about once every two years. Savings in heating costs for installing the curtains will be about \$3000 per year. Use the payback period method to determine which alternative is better. Comment on the use of the payback period for making this decision.

5.39 Assuming that the wall built to isolate the shipping department in Problem 5.38 will last forever, and that the curtains have zero salvage value, compare the annual worths of the two alternatives. The MARR for Kirkland Manufacturing is 11 percent. Which alternative is better?

C. More Challenging Problems

5.40 CB Electronix needs to expand its capacity. It has two feasible alternatives under consideration. Both alternatives will have essentially infinite lives.

Alternative 1: Construct a new building of 20 000 square metres now. The first cost will be \$2 000 000. Annual maintenance costs will be \$10 000. In addition, the building will need to be painted every 15 years (starting in 15 years) at a cost of \$15 000.

Alternative 2: Construct a new building of 12 500 square metres now and an additional 7500 square metres in 10 years. The first cost of the 12 500-square-metre building will be \$1 250 000. The annual maintenance costs will be \$5000 for the first 10 years (i.e., until the addition is built). The 7500-square-metre addition will have a first cost of \$1 000 000. Annual maintenance costs of the renovated building (the original building and the addition) will be \$11 000. The renovated building will cost \$15 000 to repaint every 15 years (starting 15 years after the addition is done).

Carry out an annual worth comparison of the two alternatives. Which is preferred if the MARR is 15 percent?

5.41 Katie's project has a five-year term, a first cost, no salvage value, and annual savings of \$20 000 per year. After doing present worth and annual worth calculations with a 15 percent interest rate, Katie notices that the calculated annual worth for the project is exactly three times the present worth. What is the project's present worth and annual worth? Should Katie undertake the project?

5.42 Nighhigh Newsagent wants to replace its cash register and is currently evaluating two models that seem reasonable. The information on the two alternatives, CR1000 and CRX, is shown in the table.

	CR1000	CRX
First cost	\$680	\$1100
Annual savings	\$245	\$440
Annual maintenance cost	\$35 in year 1, increasing by \$10 each year thereafter	\$60
Service life	4 years	6 years
Scrap value	\$100	\$250

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(a) If Nighhigh Newsagent's MARR is 10 percent, which type of cash register should it choose? Use the present worth method.

(b) For the less preferred type of cash register found in part (a), what scrap value would make it the preferred choice?

5.43 Xaviera is comparing two mutually exclusive projects, A and B, that have the same initial investment and the same present worth over their service lives. Wolfgang points out that, using the annual worth method, A is clearly better than B. What can be said about the service lives for the two projects?

5.44 Xaviera noticed that two mutually exclusive projects, A and B, have the same payback period and the same economic life, but A has a larger present worth than B does. What can be said about the size of the annual savings for the two projects?

5.45 Cleanville Environmental Services is evaluating two alternative methods for the disposing of municipal waste. The first involves developing a landfill site near the city. Costs of the site include \$1 000 000 start-up costs, \$100 000 closedown costs 30 years from now, and operating costs of \$20 000 per year. Starting in 10 years, it is expected that there will be revenues from user fees of \$30 000 per year. The alternative is to ship the waste out of the region. An area firm will agree to a long-term contract to dispose of the waste for \$130 000 per year. Using the *annual worth* method, which alternative is economically preferred for a MARR of 11 percent? Would this likely be the actual preferred choice?

5.46 Alfredo Auto Parts is considering investing in a new forming line for grille assemblies. For a five-year study period, the cash flows for two separate designs are shown below. Create a spreadsheet that will calculate the present worths for each project for a variable MARR. Through trial and error, establish the MARR at which the present worths of the two projects are exactly the same.

Cash Flows for Grille Assembly Project						
	Automated Line			Manual Line		
Year	Disbursements	Receipts	Net Cash Flow	Disbursements	Receipts	Net Cash Flow
0	\$1 500 000	\$ 0	– \$1 500 000	\$1 000 000	\$ 0	– \$1 000 000
1	50 000	300 000	250 000	20 000	200 000	180 000
2	60 000	300 000	240 000	25 000	200 000	175 000
3	70 000	300 000	230 000	30 000	200 000	170 000
4	80 000	300 000	220 000	35 000	200 000	165 000
5	90 000	800 000	710 000	40 000	200 000	160 000

5.47 Stayner Catering is considering setting up a temporary division to handle demand created by its city's special tourist promotion during the coming year. The company will invest in tables, serving equipment, and trucks for a one-year period. Labour is employed on a monthly basis. Warehouse space is rented monthly and revenue is generated monthly. The items purchased will be sold at the end of the year, but the salvage values are somewhat uncertain. Given below are the known or expected cash flows for the project.

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Month	Purchase	Labour Expenses	Warehouse Expenses	Revenue
January (beginning)	$200 000			
January (end)		$ 2000	$3000	$ 2000
February		2000	3000	2000
March		2000	3000	2000
April		2000	3000	2000
May		4000	3000	10 000
June		10 000	6000	40 000
July		10 000	6000	110 000
August		10 000	6000	60 000
September		4000	3000	30 000
October		2000	3000	10 000
November		2000	3000	5000
December	Salvage?	2000	3000	2000

For an interest rate of 12 percent compounded monthly, create a spreadsheet that calculates and graphs the present worth of the project for a range of salvage values of the purchased items from 0 percent to 100 percent of the purchase price. Should Stayner Catering go ahead with this project?

5.48 Alfredo Auto Parts has two options for increasing efficiency. It can expand the current building or keep the same building but remodel the inside layout. For a five-year study period, the cash flows for the two options are shown below. Construct a spreadsheet that will calculate the present worth for each option with a variable MARR. By trial and error, determine the MARR at which the present worths of the two options are equivalent.

	Expansion Option			Remodelling Option		
Year	Disburse-ments	Receipts	Net Cash Flow	Disburse-ments	Receipts	Net Cash Flow
0	$850 000	$ 0	– $850 000	$230 000	$ 0	– $230 000
1	25 000	200 000	175 000	9000	80 000	71 000
2	30 000	225 000	195 000	11 700	80 000	68 300
3	35 000	250 000	215 000	15 210	80 000	64 790
4	40 000	275 000	235 000	19 773	80 000	60 227
5	45 000	300 000	255 000	25 705	80 000	54 295

5.49 Cleanville Environmental Services is considering investing in a new water treatment system. On the basis of the information given below for two alternatives, a fully automated and a partially automated system, construct a spreadsheet for computing the annual worths for each alternative with a variable MARR. Through trial and error, determine the MARR at which the annual worths of the two alternatives are equivalent.

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	Fully Automated System			Partially Automated System		
Year	Disburse-ments	Receipts	Net Cash Flow	Disburse-ments	Receipts	Net Cash Flow
0	$1 000 000	$ 0	– $1 000 000	$650 000	$ 0	– $650 000
1	30 000	300 000	270 000	30 000	220 000	190 000
2	30 000	300 000	270 000	30 000	220 000	190 000
3	80 000	300 000	220 000	35 000	220 000	185 000
4	30 000	300 000	270 000	35 000	220 000	185 000
5	30 000	300 000	270 000	40 000	220 000	180 000
6	80 000	300 000	220 000	40 000	220 000	180 000
7	30 000	300 000	270 000	45 000	220 000	175 000
8	30 000	300 000	270 000	45 000	220 000	175 000
9	80 000	300 000	220 000	50 000	220 000	170 000
10	30 000	300 000	270 000	50 000	220 000	170 000

5.50 Fred has projects to consider for economic feasibility. All of his projects consist of a first cost P and annual savings A. His rule of thumb is to accept all projects for which the series present worth factor (for the appropriate MARR and service life) is equal to or greater than the payback period. Is this a sensible rule?

MINI-CASE 5.1

Rockwell International

The Light Vehicle Division of Rockwell International makes seat-slide assemblies for the automotive industry. It has two major classifications for investment opportunities: developing new products to be manufactured and sold, and developing new machines to improve production. The overall approach to assessing whether an investment should be made depends on the nature of the project.

In evaluating a new product, it considers the following:

1. *Marketing strategy:* Does it fit the business plan for the company?
2. *Workforce:* How will it affect human resources?
3. *Margins:* The product should generate appropriate profits.
4. *Cash flow:* Positive cash flow is expected within two years.

In evaluating a new machine, it considers the following:

1. *Cash flow:* Positive cash flow is expected within a limited time period.
2. *Quality issues:* For issues of quality, justification is based on cost avoidance rather than positive cash flow.
3. *Cost avoidance:* Savings should pay back an investment within one year.

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Discussion

All companies consider more than just the economics of a decision. Most take into account the other issues—often called *intangibles*—by using managerial judgment in an informal process. Others, like Rockwell International, explicitly consider a selection of intangible issues.

The trend today is to carefully consider several intangible issues, either implicitly or explicitly. Human resource issues are particularly important since employee enthusiasm and commitment have significant repercussions. Environmental impacts of a decision can affect the image of the company. Health and safety is another intangible with significant effects.

However, the economics of the decision is usually (but not always) the single most important factor in a decision. Also, economics is the factor that is usually the easiest to measure.

Questions

1. Why do you think Rockwell International has different issues to consider depending on whether an investment is a new product or a new machine?
2. For each of the issues mentioned, describe how it would be measured. How would you determine if it is worth investing in a new product or new machine with respect to that issue?
3. There are two kinds of errors that can be made. The first is that an investment is made when it should not be, and the second is that an investment is not made when it should be. Describe examples of both kinds of errors for both products and machines (four examples in total) if the issues listed for Rockwell International are strictly followed. What are some sensible ways to prevent such errors?

Appendix 5A The MARR and the Cost of Capital

For a business to survive, it must be able to earn a high enough return to induce investors to put money into the company. The minimum rate of return required to get investors to invest in a business is that business's **cost of capital**. A company's cost of capital is also its minimum acceptable rate of return for projects—its MARR. This appendix reviews how the cost of capital is determined. We first look at the relation between risk and the cost of capital. Then we discuss sources of capital for large businesses and small businesses.

5A.1 Risk and the Cost of Capital

There are two main forms of investment in a company, *debt* and *equity*. Investors in a company's debt are lending money to the company. The loans are contracts that give lenders rights to repayment of their loans and to interest at predetermined interest rates. Investors in a company's equity are the owners of the company. They hold rights to the residual after all contractual payments, including those to lenders, are made.

Investing in equity is more risky than investing in debt. Equity owners are paid only if the company first meets its contractual obligations to lenders. This higher risk means that equity owners require an expectation of a greater return on average than the interest rate paid to debt holders. Consider a simple case in which a company has three possible

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performance levels—weak results, normal results, and strong results. Investors do not know which level will actually occur. Each level is equally probable. To keep the example simple, we assume that all after-tax income is paid to equity holders as dividends so that there is no growth. The data are shown in Table 5A.1.

We see that, no matter what happens, lenders will get a return of 10 percent:

$$0.1 = \frac{10\ 000}{100\ 000}$$

Table 5A.1 Cost of Capital Example

	Possible Performance Levels		
	Weak Results	Normal Results	Strong Results
Net operating income ($/year)[1]	40 000	100 000	160 000
Interest payment ($/year)	10 000	10 000	10 000
Net income before tax ($/year)	30 000	90 000	150 000
Tax at 40% ($/year)	12 000	36 000	60 000
After-tax income = Dividends ($/year)	18 000	54 000	90 000
Debt ($)	100 000	100 000	100 000
Value of shares ($)	327 273	327 273	327 273

[1]Net operating income per year is revenue per year minus cost per year.

Owners get one of three possible returns:

$$5.5\% \left(0.055 = \frac{18\ 000}{327\ 273}\right),$$

$$16.5\% \left(0.165 = \frac{54\ 000}{327\ 273}\right), \text{ or}$$

$$27.5\% \left(0.275 = \frac{90\ 000}{327\ 273}\right)$$

These three possibilities average out to 16.5 percent. If things are good, owners do better than lenders. If things are bad, owners do worse. But their average return is greater than returns to lenders.

The lower rate of return to lenders means that companies would like to get their capital with debt. However, reliance on debt is limited for two reasons.

1. If a company increases the share of capital from debt, it increases the chance that it will not be able to meet the contractual obligations to lenders. This means the company will be bankrupt. Bankruptcy may lead to reorganizing the company or possibly closing the company. In either case, bankruptcy costs may be high.
2. Lenders are aware of the dangers of high reliance on debt and will therefore limit the amount they lend to the company.

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5A.2 Company Size and Sources of Capital

Large, well-known companies can secure capital both by borrowing and by selling ownership shares with relative ease because there will be ready markets for their shares as well as any debt instruments, like bonds, they may issue. These companies will seek ratios of debt to equity that balance the marginal advantages and disadvantages of debt financing. Hence, the cost of capital for large, well-known companies is a weighted average of the costs of borrowing and of selling shares, which is referred to as the **weighted average cost of capital**. The weights are the fractions of total capital that come from the different sources. If market conditions do not change, a large company that seeks to raise a moderate amount of additional capital can do so at a stable cost of capital. This cost of capital is the company's MARR.

We can compute the after-tax cost of capital for the example shown in Table 5A.1 as follows.

Weighted average cost of capital

$$= 0.1\left(\frac{100\ 000}{427\ 273}\right) + 0.165\left(\frac{327\ 273}{427\ 273}\right) = 0.150$$

This company has a cost of capital of about 15 percent.

For smaller, less well-known companies, raising capital may be more difficult. Most investors in large companies are not willing to invest in unknown small companies. At start-up, a small company may rely entirely on the capital of the owners and their friends and relatives. Here the cost of capital is the opportunity cost for the investors.

If a new company seeks to grow more rapidly than the owners' investment plus cash flow permits, the next source of capital with the lowest cost is usually a bank loan. Bank loans are limited because banks are usually not willing to lend more than some fraction of the amount an owner(s) puts into a business.

If bank loans do not add up to sufficient funds, then the company usually has two options. One option is the sale of financial securities such as stocks and bonds through stock exchanges that specialize in small, speculative companies. Another option is venture capital. Venture capitalists are investors who specialize in investing in new companies. The cost of evaluating new companies is usually high and so is the risk of investing in them. Together, these factors usually lead venture capitalists to want to put enough money into a small company so that they will have enough control over the company.

In general, new equity investment is very expensive for small companies. Studies have shown that venture capitalists typically require the expectation of at least a 35 percent rate of return after tax. Raising funds on a stock exchange is usually even more expensive than getting funding from a venture capitalist.

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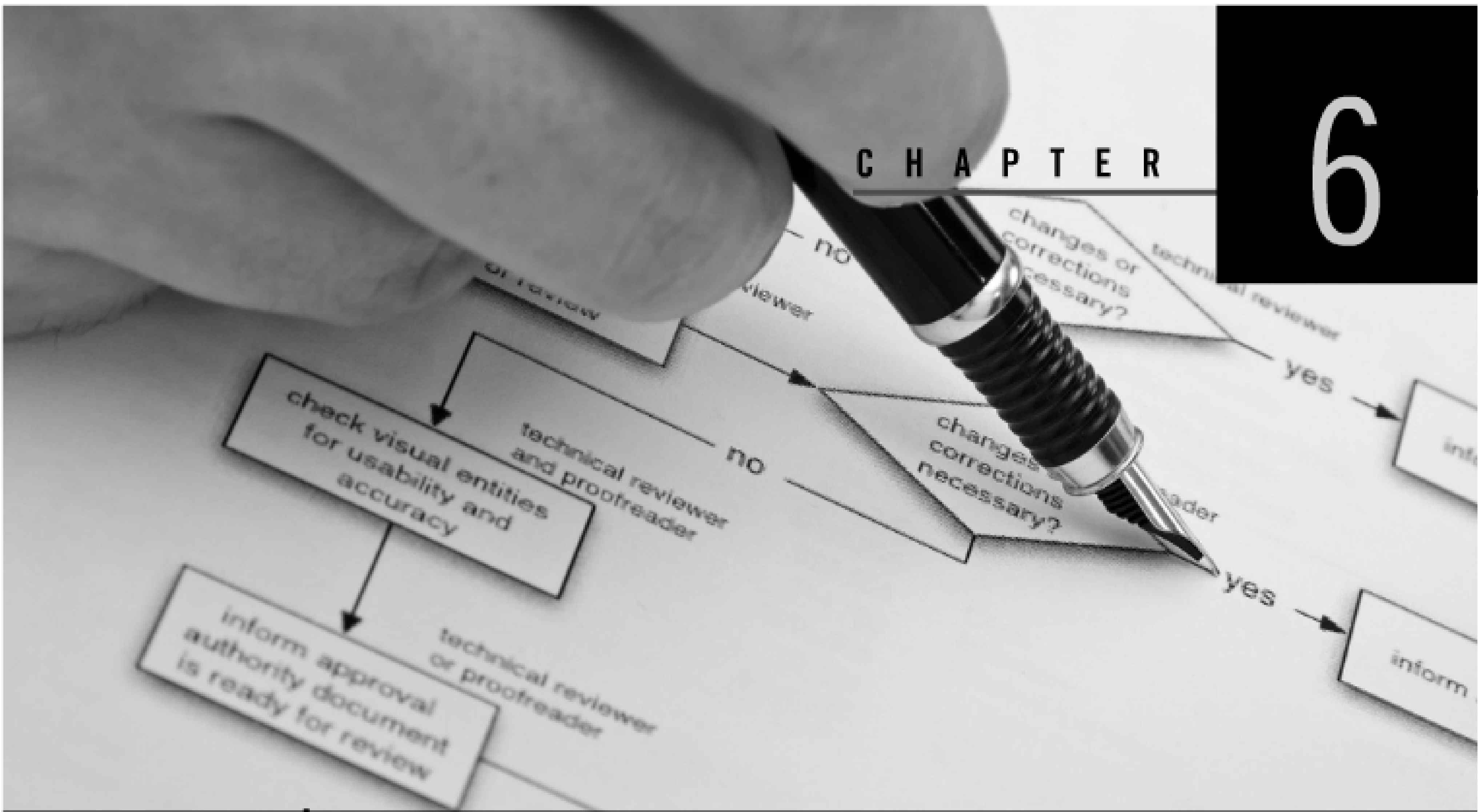

CHAPTER 6

Comparison Methods Part 2

Taken from *Engineering Economics: Financial Decision Making for Engineers*, Fifth Edition by Niall M. Fraser and Elizabeth M. Jewkes.

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ENGINEERING ECONOMICS IN ACTION, PART 6A

What's Best? Revisited

Clem had said, "I have to make a recommendation to Ed Burns and Anna Kulkowski for their Wednesday meeting on this forging hammer in the South Shop. I'd like you to handle it." Dave Sullivan, who had started the project, had gone to Florida to see his sick father-in-law. Naomi welcomed the opportunity, but she still had to figure out exactly what to recommend.

Naomi looked carefully at the list of seven mutually exclusive alternatives for replacing or refurbishing the machine. Present worth could tell her which of the seven was "best," but present worth was just one of several comparison methods. Which method should she use?

Dave would help more, if she asked him. In fact, he could no doubt tell her exactly what to do, if she wanted. But this one she knew she could handle, and it was a matter of pride to do it herself. Opening her engineering economics textbook, she read on.

6.1 Introduction

In Chapter 5, we showed how to structure projects so that they were either independent or mutually exclusive. The present worth, annual worth, and payback period methods for evaluating projects were also introduced. This chapter continues on the theme of comparing projects by presenting a commonly used but somewhat more complicated comparison method called the *internal rate of return*, or IRR.

Although the IRR method is widely used, all the comparison methods have value in particular circumstances. Selecting which method to use is also covered in this chapter. It is also shown that the present worth, annual worth, and IRR methods all result in the same recommendations for the same problem. We close this chapter with a chart summarizing the strengths and weaknesses of the four comparison methods presented in Chapters 5 and 6.

6.2 The Internal Rate of Return

Investments are undertaken with the expectation of a return in the form of future earnings. One way to measure the return from an investment is as a rate of return per dollar invested—in other words, as an interest rate. The rate of return usually calculated for a project is known as the *internal rate of return (IRR)*. The adjective *internal* refers to the fact that the internal rate of return depends only on the cash flows due to the investment. The internal rate of return is that interest rate at which a project just breaks even. The meaning of the IRR is most easily seen with a simple example.

EXAMPLE 6.1

Suppose $100 is invested today in a project that returns $110 in one year. We can calculate the IRR by finding the interest rate at which $100 now is equivalent to $110 at the end of one year:

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$$P = F(P/F, i^*, 1)$$

$$100 = 110(P/F, i^*, 1)$$

$$100 = \frac{110}{1 + i^*}$$

where i^* is the internal rate of return.

Solving this equation gives a rate of return of 10 percent. In a simple example like this, the process of finding an internal rate of return is finding the interest rate that makes the present worth of benefits equal to the first cost. This interest rate is the IRR. ■

Of course, cash flows associated with a project will usually be more complicated than in the example above. A more formal definition of the IRR is stated as follows. The **internal rate of return (IRR)** on an investment is the interest rate, i^*, such that, when all cash flows associated with the project are discounted at i^*, the present worth of the cash inflows equals the present worth of the cash outflows. That is, the project just breaks even. An equation that expresses this is

$$\sum_{t=0}^{T} \frac{(R_t - D_t)}{(1 + i^*)^t} = 0 \tag{6.1}$$

where

R_t = the cash inflow (receipts) in period t
D_t = the cash outflow (disbursements) in period t
T = the number of time periods
i^* = the internal rate of return

Since Equation (6.1) can also be expressed as

$$\sum_{t=0}^{T} R_t(1 + i^*)^{-t} = \sum_{t=0}^{T} D_t(1 + i^*)^{-t}$$

it can be seen that, in order to calculate the IRR, one sets the disbursements equal to the receipts and solves for the unknown interest rate. For this to be done, the disbursements and receipts must be comparable as a present worth, a uniform series, or a future worth. That is, use

PW(disbursements) = PW(receipts) and solve for the unknown i^*,
AW(disbursements) = AW(receipts) and solve for the unknown i^*, or
FW(disbursements) = FW(receipts) and solve for the unknown i^*.

The IRR is usually positive, but it can be negative as well. A negative IRR means that the project is losing money rather than earning it.

We usually solve the equations for the IRR by trial and error, as there is no explicit means of solving Equation (6.1) for projects where the number of periods is large. A spreadsheet provides a quick way to perform trial-and-error calculations; most spreadsheet programs also include a built-in IRR function.

EXAMPLE 6.2

Clem is considering buying a tuxedo. It would cost \$500 but would save him \$160 per year in rental charges over its five-year life. What is the IRR for this investment?

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As illustrated in Figure 6.1, Clem's initial cash outflow for the purchase would be \$500. This is an up-front outlay relative to continuing to rent tuxedos. The investment would create a saving of \$160 per year over the five-year life of the tuxedo. These savings can be viewed as a series of receipts relative to rentals. The IRR of Clem's investment can be found by determining what interest rate makes the present worth of the disbursements equal to the present worth of the cash inflows.

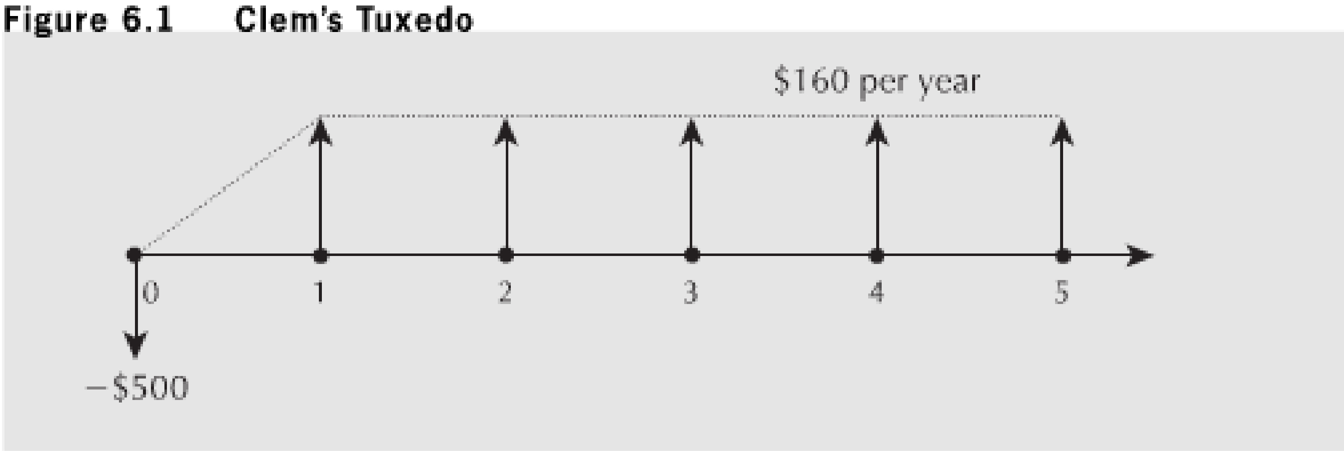
Present worth of disbursements = 500

Present worth of receipts = $160(P/A,i^*,5)$

Setting the two equal,

$$500 = 160(P/A,i^*,5)$$
$$(P/A,i^*,5) = 500/160$$
$$= 3.125$$

Figure 6.1 Clem's Tuxedo



From the interest factor tables, we find that

$$(P/A,15\%,5) = 3.3521$$
$$(P/A,20\%,5) = 2.9906$$

Interpolating between $(P/A,15\%,5)$ and $(P/A,20\%,5)$ gives

$$i^* = 15\% + (5\%)[(3.125 - 3.3521)/(2.9906 - 3.3521)]$$
$$= 18.14\%$$

An alternative way to get the IRR for this problem is to convert all cash outflows and inflows to equivalent annuities over the five-year period. This will yield the same result as when present worth was used.

Annuity equivalent to the disbursements = $500(A/P,i^*,5)$

Annuity equivalent to the receipts = 160

Again, setting the two equal,

$$500(A/P,i^*,5) = 160$$
$$(A/P,i^*,5) = 160/500$$
$$= 0.32$$

From the interest factor tables,

$$(A/P,15\%,5) = 0.29832$$
$$(A/P,20\%,5) = 0.33438$$

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An interpolation gives

$$i^* = 15\% + 5\%[(0.32 - 0.29832)/(0.33438 - 0.29832)]$$
$$\cong 18.0\%$$

Note that there is a slight difference in the answers, depending on whether the disbursements and receipts were compared as present worths or as annuities. This difference is due to the small error induced by the linear interpolation. With Excel, the IRR is found as follows:

$$i^* = \text{IRR (A1:A6)} = 18.031\%$$

where cells A1:A6 are (−500,160,160,160,160,160), respectively. ■

6.3 Internal Rate of Return Comparisons

In this section, we show how the internal rate of return can be used to decide whether a project should be accepted. We first show how to use the IRR to evaluate independent projects. Then we show how to use the IRR to decide which of a group of mutually exclusive alternatives to accept. We then show that it is possible for a project to have more than one IRR. Finally, we show how to handle this difficulty by using an *external rate of return*.

6.3.1 IRR for Independent Projects

Recall from Chapter 5 that projects under consideration are evaluated using the MARR, and that any independent project that has a present or annual worth equal to or exceeding zero should be accepted. The principle for the IRR method is analogous. We will invest in any project that has an IRR equal to or exceeding the MARR. Just as projects with a zero present or annual worth are marginally acceptable, projects with IRR = MARR have a marginally acceptable rate of return (by definition of the MARR).

Also analogous to Chapter 5, when we perform a rate of return comparison on several independent projects, the projects must have equal lives. If this is not the case, then the approaches covered in Section 5.4.4 on page 171 (Comparison of Alternatives With Unequal Lives) must be used.

EXAMPLE 6.3

The High Society Baked Bean Co. is considering a new canner. The canner costs \$120 000 and will have a scrap value of \$5000 after its 10-year life. Given the expected increases in sales, the total savings due to the new canner, compared with continuing with the current operation, will be \$15 000 the first year, increasing by \$5000 each year thereafter. Total extra costs due to the more complex equipment will be \$10 000 per year. The MARR for High Society is 12 percent. Should it invest in the new canner?

The cash inflows and outflows for this problem are summarized in Figure 6.2. We need to compute the internal rate of return in order to decide if High Society should buy the canner. There are several ways we can do this. In this problem, equating annual outflows and receipts appears to be the easiest approach, because most of the cash flows are already stated on a yearly basis.

$$5000(A/F,i^*,10) + 15\,000 + 5000(A/G,i^*,10)$$
$$-120\,000(A/P,i^*,10) - 10\,000 = 0$$

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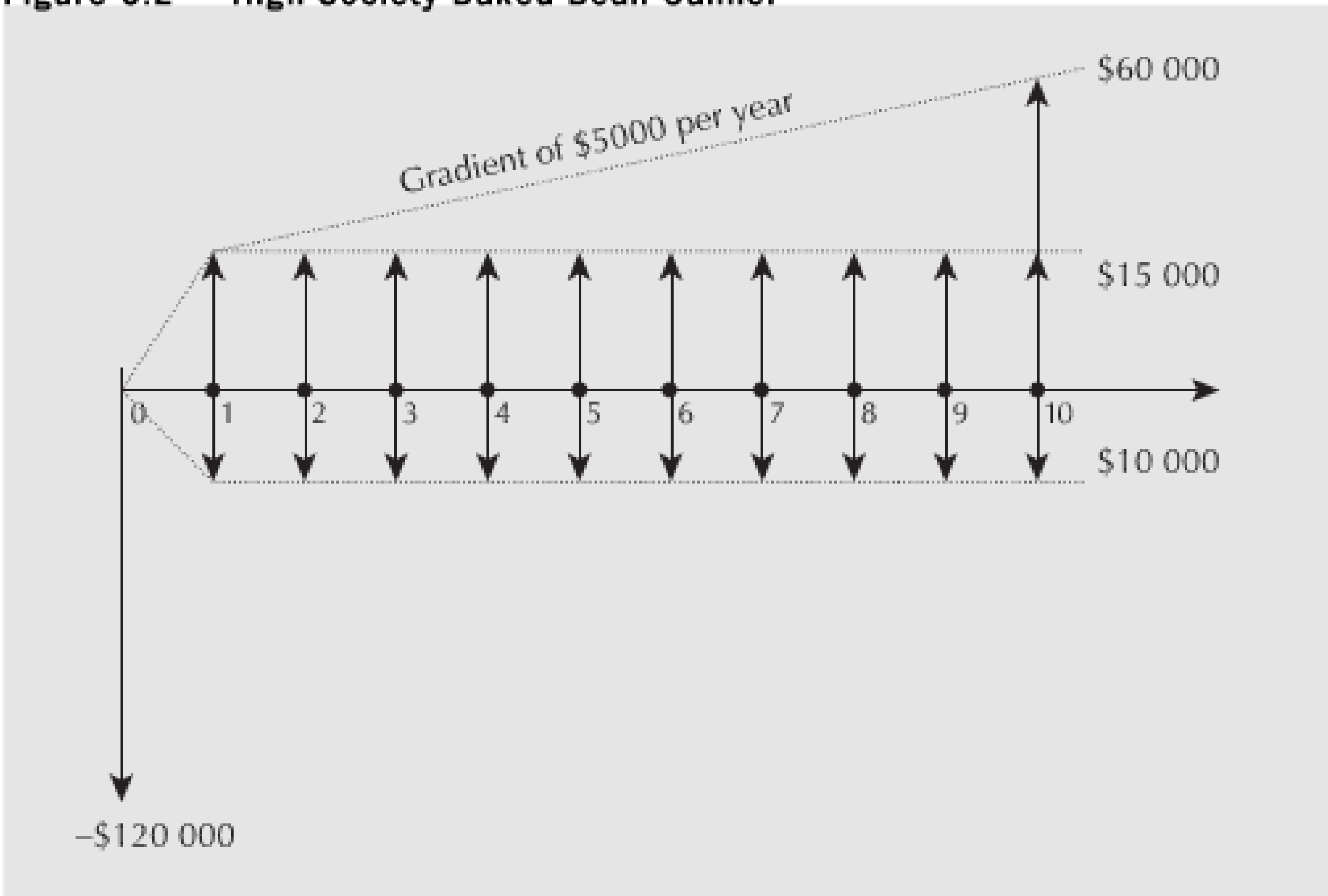
Figure 6.2 High Society Baked Bean Canner

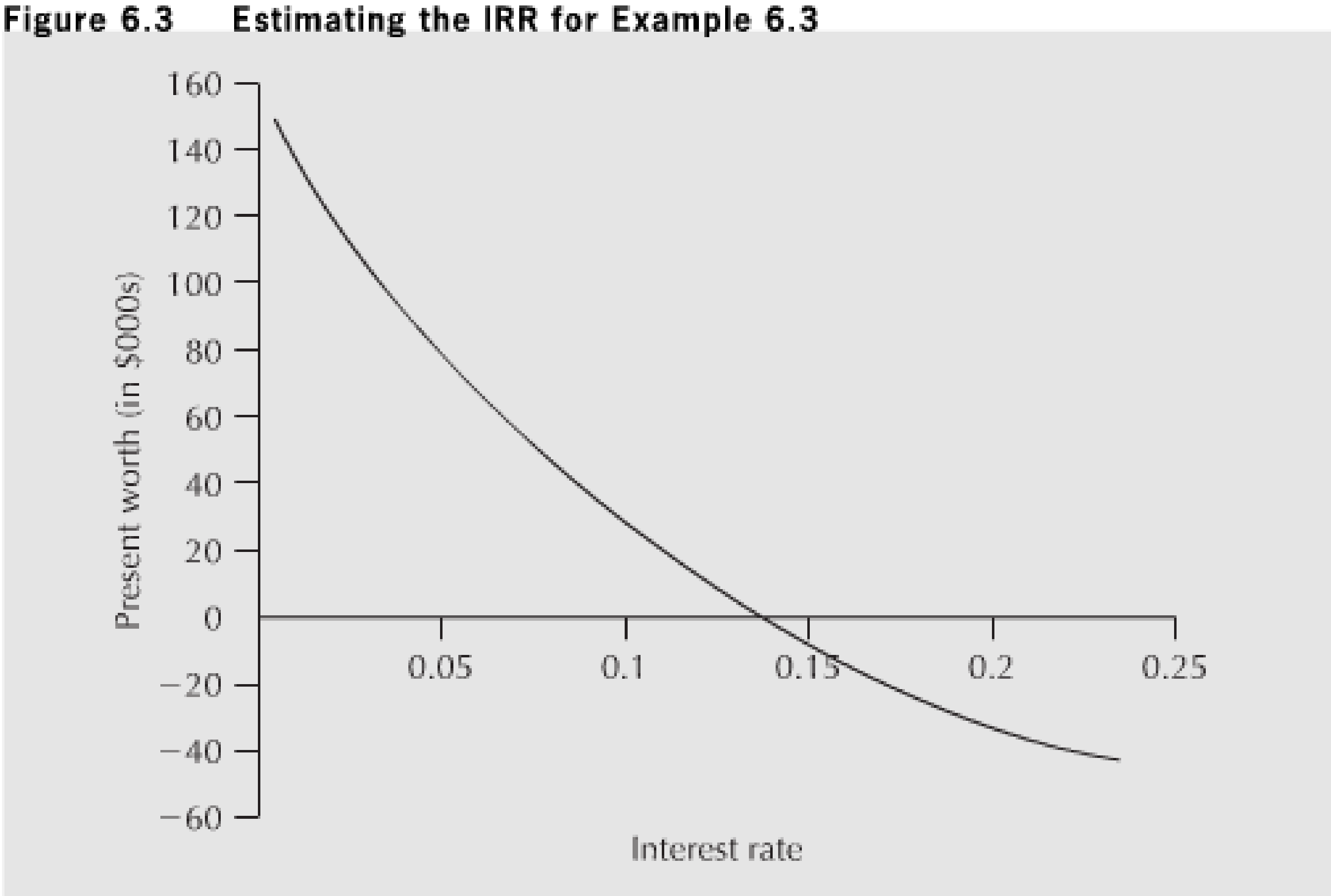


Dividing by 5000,

$$(A/F,i^*,10) + 1 + (A/G,i^*,10) - 24(A/P,i^*,10) = 0$$

The IRR can be found by trial and error alone, by trial and error and linear interpolation, or by a spreadsheet IRR function. A trial-and-error process is particularly easy using a spreadsheet, so this is often the best approach. A good starting point for the process is at zero interest. A graph (Figure 6.3) derived from the spreadsheet indicates that the IRR is between 13 percent and 14 percent. This may be good enough for a decision, since it exceeds the MARR of 12 percent.

Figure 6.3 Estimating the IRR for Example 6.3



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If finer precision is required, there are two ways to proceed. One way is to use a finer grid on the graph—for example, one that covers 13 percent to 14 percent. The other way is to interpolate between 13 percent and 14 percent. We shall first use the interest factor tables to show that the IRR is indeed between 13 percent and 14 percent. Next we will interpolate between 13 percent and 14 percent.

First, at $i = 13$ percent, we have

$$(A/F,13\%,10) + 1 + (A/G,13\%,10) - 24(A/P,13\%,10)$$
$$= 0.05429 + 1 + 3.5161 - 24(0.18429)$$
$$\cong 0.1474$$

The result is a bit too high. A higher interest rate will reduce the annual worth of the benefits more than the annual worth of the costs, since the benefits are spread over the life of the project while most of the costs are early in the life of the project.

At $i = 14$ percent, we have

$$(A/F,14\%,10) + 1 + (A/G,14\%,10) - 24(A/P,14\%,10)$$
$$= 0.05171 + 1 + 3.4489 - 24(0.19171)$$
$$\cong -0.1004$$

This confirms that the IRR of the investment is between 13 percent and 14 percent. A good approximation to the IRR can be found by linearly interpolating:

$$i^* = 13\% + (0 - 0.1474)/(0.1004 - 0.1474)$$
$$\cong 13.6\%$$

To find the IRR using Excel, compute the net cash flows for each period, and then apply the IRR function to the range of cells containing cash flows, as shown in the tables below.

	A	B	C	D	E	F
1	IRR =	13.60%				
2		Net	First		Additional	Salvage
3	Period	Cash Flow	Cost	Savings	Expenses	Value
4	0	-120 000	-120 000			
5	1	5 000		15 000	-10 000	
6	2	10 000		20 000	-10 000	
7	3	15 000		25 000	-10 000	
8	4	20 000		30 000	-10 000	
9	5	25 000		35 000	-10 000	
10	6	30 000		40 000	-10 000	
11	7	35 000		45 000	-10 000	
12	8	40 000		50 000	-10 000	
13	9	45 000		55 000	-10 000	
14	10	55 000		60 000	-10 000	5 000

	A	B	C	D	E	F
1	IRR =	=IRR(B4:B14)				
2		Net	First		Additional	Salvage
3	Period	Cash Flow	Cost	Savings	Expenses	Value
4	0	=SUM(C4:F4)	-120000	0		
5	1	=SUM(C5:F5)		=15000+(A5-1)*5000	-10000	
6	2	=SUM(C6:F6)		=15000+(A6-1)*5000	-10000	
7	3	=SUM(C7:F7)		=15000+(A7-1)*5000	-10000	
8	4	=SUM(C8:F8)		=15000+(A8-1)*5000	-10000	
9	5	=SUM(C9:F9)		=15000+(A9-1)*5000	-10000	
10	6	=SUM(C10:F10)		=15000+(A10-1)*5000	-10000	
11	7	=SUM(C11:F11)		=15000+(A11-1)*5000	-10000	
12	8	=SUM(C12:F12)		=15000+(A12-1)*5000	-10000	
13	9	=SUM(C13:F13)		=15000+(A13-1)*5000	-10000	
14	10	=SUM(C14:F14)		=15000+(A14-1)*5000	-10000	5000

The IRR for the investment is approximately 13.6 percent. Since this is greater than the MARR of 12 percent, the company should buy the new canner. Note again that it was not actually necessary to determine where in the range of 13 percent to 14 percent the IRR fell. It was enough to demonstrate that it was 12 percent or more. ■

In summary, if there are several independent projects, the IRR for each is calculated separately, and, in the absence of budget constraints, those having an IRR equal to or exceeding the MARR should be chosen.

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6.3.2 IRR for Mutually Exclusive Projects

Choice among mutually exclusive projects using the IRR is a bit more involved. Some insight into the complicating factors can be obtained from an example that involves two mutually exclusive alternatives. It illustrates that the best choice is not necessarily the alternative with the highest IRR.

EXAMPLE 6.4

Consider two investments. The first costs \$1 today and returns \$2 in one year. The second costs \$1000 and returns \$1900 in one year. Which is the preferred investment? Your MARR is 70 percent.

The first project has an IRR of 100 percent:

$$-1 + 2(P/F,i^*,1) = 0$$
$$(P/F,i^*,1) = 1/2 = 0.5$$
$$i^* = 100\%$$

The second has an IRR of 90 percent:

$$-1000 + 1900(P/F,i^*,1) = 0$$
$$(P/F,i^*,1) = 1000/1900 = 0.52631$$
$$i^* = 90\%$$

If these were independent projects, both would be acceptable since their IRRs exceed the MARR. If one of the two projects must be chosen, it might be tempting to choose the first project, the alternative with the larger rate of return. However, this approach is incorrect because it can overlook projects that have a rate of return equal to or greater than the MARR, but don't have the maximum IRR. In the example, the correct approach is to first observe that the least cost investment provides a rate of return that exceeds the MARR. The next step is to find the rate of return on the more expensive investment to see if the *incremental* investment has a rate of return equal to or exceeding the MARR. The incremental investment is the additional \$999 that would be invested if the second investment was taken instead of the first:

$$-(1000 - 1) + (1900 - 2)(P/F,i^*,1) = 0$$
$$(P/F,i^*,1) = 999/1898 = 0.52634$$
$$i^* = 89.98\%$$

Indeed, the incremental investment has an IRR exceeding 70 percent and thus the second investment should be chosen. ■

The next example illustrates the process again, showing this time how an incremental investment is not justified.

EXAMPLE 6.5

Monster Meats can buy a new meat slicer system for \$50 000. The company estimates it will save \$11 000 per year in labour and operating costs. The same system with an automatic loader is \$68 000, and will save approximately \$14 000 per year. The life of either system is thought to be eight years. Monster Meats has three feasible alternatives:

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Alternative	First Cost	Annual Savings
"Do nothing"	$ 0	$ 0
Meat slicer alone	50 000	11 000
Meat slicer with automatic loader	68 000	14 000

Monster Meats uses a MARR of 12 percent for this type of project. Which alternative is better?

We first consider the system without the loader. Its IRR is 14.5 percent, which exceeds the MARR of 12 percent. This can be seen by solving for i^* in

$$-50\,000 + 11\,000(P/A,i^*,8) = 0$$

$$(P/A,i^*,8) = 50\,000/11\,000$$

$$(P/A,i^*,8) = 4.545$$

From the interest factor tables, or by trial and error with a spreadsheet,

$$(P/A,14\%,8) = 4.6388$$

$$(P/A,15\%,8) = 4.4873$$

By interpolation or further trial and error,

$$i^* \cong 14.6 \text{ percent}$$

The slicer alone is thus economically justified and is better than the "do nothing" alternative.

We now consider the system with the slicer and loader. Its IRR is 12.5 percent, which may be seen by solving for i^* in

$$-68\,000 + 14\,000(P/A,i^*,8) = 0$$

$$(P/A,i^*,8) = 68\,000/14\,000$$

$$(P/A,i^*,8) = 4.857$$

$$(P/A,12\%,8) = 4.9676$$

$$(P/A,13\%,8) = 4.7987$$

$$i^* \cong 12.5\%$$

The IRR of the meat slicer and automatic loader is about 12.5 percent, which on the surface appears to meet the 12 percent MARR requirement. But, on the incremental investment, Monster Meats would be earning only 7 percent. This may be seen by looking at the IRR on the *extra*, or *incremental*, $18 000 spent on the loader.

$$-(68\,000 - 50\,000) + (14\,000 - 11\,000)(P/A,i^*,8) = 0$$

$$-18\,000 + 3000(P/A,i^*,8) = 0$$

$$(P/A,i^*,8) = 18\,000/3000$$

$$(P/A,i^*,8) = 6$$

$$i^* \cong 7\%$$

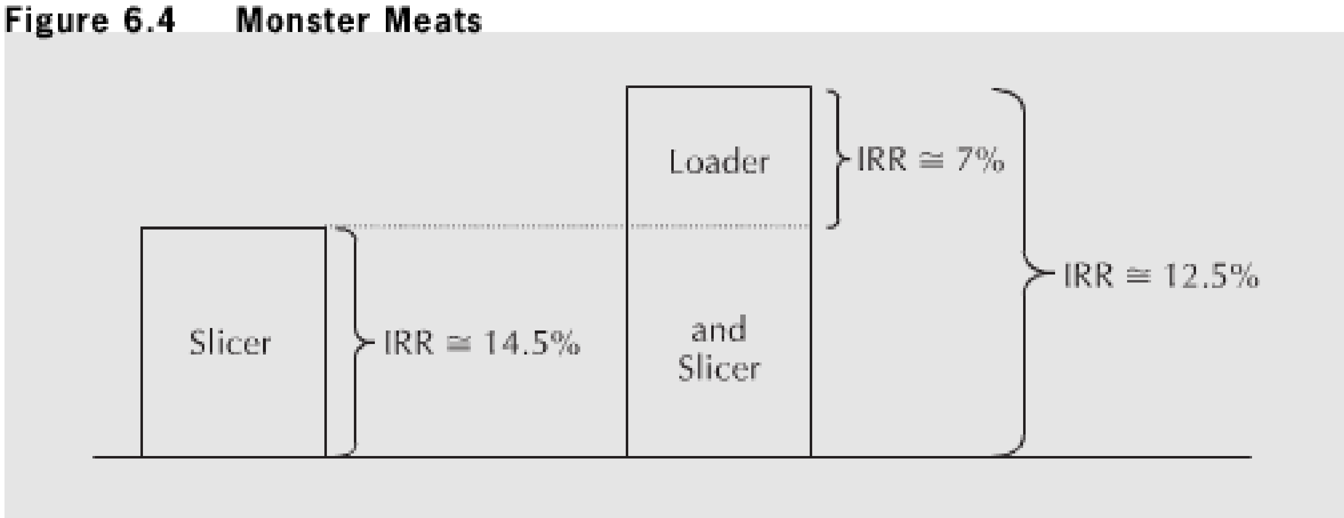
This is less than the MARR; therefore, Monster Meats should not buy the automated loader.

To find the IRR using Excel, compute the net cash flows for each period, and then apply the IRR function to the range of cells containing the cash flows, as shown below:

	A	B	C	D
1	Time	Meat	Slicer with	Incremental
2	Period	Slicer	Loader	Cash Flow
3	0	- 50 000	- 68 000	- 18 000
4	1	11 000	14 000	3 000
5	2	11 000	14 000	3 000
6	3	11 000	14 000	3 000
7	4	11 000	14 000	3 000
8	5	11 000	14 000	3 000
9	6	11 000	14 000	3 000
10	7	11 000	14 000	3 000
11	8	11 000	14 000	3 000
12	IRR	14.61%	12.65%	6.88%

When the IRR was calculated for the system including the loader, the surplus return on investment earned by the slicer alone essentially subsidized the loader. The slicer investment made enough of a return so that, even when it was coupled with the money-losing loader, the whole machine still seemed to be a good buy. In fact, the extra $18 000 would be better spent on some other project at the MARR or higher. The relation between the potential projects is shown in Figure 6.4. ■

Figure 6.4 Monster Meats



The fundamental principle illustrated by the two examples is that, to use the IRR to compare two or more mutually exclusive alternatives properly, we cannot make the decision on the basis of the IRRs of individual alternatives alone; we must take the IRRs of the *incremental* investments into consideration. In order to properly assess the worthiness of the incremental investments, it is necessary to have a systematic way to conduct pair-wise comparisons of projects. Note that before undertaking a systematic analysis of mutually exclusive alternatives with the IRR method, you should ensure that the alternatives have equal lives. If they do not have equal lives, then the methods of Section 5.4.4 (study period or repeated lives methods) must be applied first to set up comparable cash flows.

The first step in the process of comparing several mutually exclusive alternatives using the IRR is to order the alternatives from the smallest first cost to the largest first

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cost. Since one alternative must be chosen, accept the alternative with the smallest first cost (which may be the "do nothing" alternative with zero first cost) as the *current best alternative* regardless of its IRR exceeding the MARR. This means that the current best alternative may have an IRR *less* than the MARR. Even if that's the case, a proper analysis of the IRRs of the incremental investments will lead us to the *correct* best overall alternative. For this reason, we don't have to check the IRR of any of the individual alternatives.

The second step of the analysis consists of looking at the incremental investments of alternatives that have a higher first cost than the current best alternative. Assume that there are n projects and they are ranked from 1 (the current best) to n, in increasing order of first costs. The current best is "challenged" by the project ranked second. One of two things occurs:

1. The incremental investment to implement the challenger does not have an IRR at least equal to the MARR. In this case, the challenger is excluded from further consideration and the current best is challenged by the project ranked third.
2. The incremental investment to implement the challenger has an IRR at least as high as the MARR. In this case, the challenger replaces the current best. It then is challenged by the alternative ranked third.

The process then continues with the next alternative challenging the current best until all alternatives have been compared. The current best alternative remaining at the end of the process is then selected as the best overall alternative. Figure 6.5 on page 211 summarizes the incremental investment analysis for the mutually exclusive projects.

EXAMPLE 6.6 (REPRISE OF EXAMPLE 5.4)

Fly-by-Night Aircraft must purchase a new lathe. It is considering one of four new lathes, each of which has a life of 10 years with no scrap value. Given a MARR of 15 percent, which alternative should be chosen?

Lathe	1	2	3	4
First cost	$100 000	$150 000	$200 000	$255 000
Annual savings	25 000	34 000	46 000	55 000

The alternatives have already been ordered from lathe 1, which has the smallest first cost, to lathe 4, which has the greatest first cost. Since one lathe must be purchased, accept lathe 1 as the current best alternative. Calculating the IRR for lathe 1, although not necessary, is shown as follows:

$$100\ 000 = 25\ 000(P/A,i^*,10)$$

$$(P/A,i^*,10) = 4$$

An approximate IRR is obtained by trial and error with a spreadsheet.

$$i^* \cong 21.4\%$$

The current best alternative is then challenged by the first challenger, lathe 2, which has the next-highest first cost. The IRR of the incremental investment from lathe 1 to lathe 2 is calculated as follows:

$$(150\ 000 - 100\ 000) - (34\ 000 - 25\ 000)(P/A,i^*,10) = 0$$

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or

$$[150\,000 - 34\,000(P/A,i^*,10)] - [100\,000 - 25\,000(P/A,i^*,10)] = 0$$

$$(P/A,i^*,10) = 50\,000/9000 = 5.556$$

An approximate IRR is obtained by trial and error.

$$i^* \cong 12.4\%$$

Since the IRR of the incremental investment falls below the MARR, lathe 2 fails the challenge to become the current best alternative. The reader can verify that lathe 2 alone has an IRR of approximately 18.7 percent. Even so, lathe 2 is not considered a viable alternative. In other words, the incremental investment of $50 000 could be put to better use elsewhere. Lathe 1 remains the current best and the next challenger is lathe 3.

As before, the incremental IRR is the interest rate at which the present worth of lathe 3 less the present worth of lathe 1 is zero:

$$[200\,000 - 46\,000(P/A,i^*,10)] - [100\,000 - 25\,000(P/A,i^*,10)] = 0$$

$$(P/A,i^*,10) = 100\,000/21\,000 = 4.762$$

An approximate IRR is obtained by trial and error.

$$i^* \cong 16.4\%$$

The IRR on the incremental investment exceeds the MARR, and therefore lathe 3 is preferred to lathe 1. Lathe 3 now becomes the current best. The new challenger is lathe 4. The IRR on the incremental investment is

$$[255\,000 - 55\,000(P/A,i^*,10)] - [200\,000 - 46\,000(P/A,i^*,10)] = 0$$

$$(P/A,i^*,10) = 55\,000/9000 = 6.11$$

$$i^* \cong 10.1\%$$

The additional investment from lathe 3 to lathe 4 is not justified. The reader can verify that the IRR of lathe 4 alone is about 17 percent. Once again, we have a challenger with an IRR greater than the MARR, but it fails as a challenger because the incremental investment from the current best does not have an IRR at least equal to the MARR. The current best remains lathe 3. There are no more challengers, and so the best overall alternative is lathe 3. ■

In the next section, the issue of multiple IRRs is discussed, and methods for identifying and eliminating them are given. Note that the process described in Figure 6.5 requires that a single IRR (or ERR, as discussed later) be determined for each incremental investment. If there are multiple IRRs, they must be dealt with for *each* increment of investment.

6.3.3 Multiple IRRs

A problem with implementing the internal rate of return method is that there may be more than one internal rate of return. Consider the following example.

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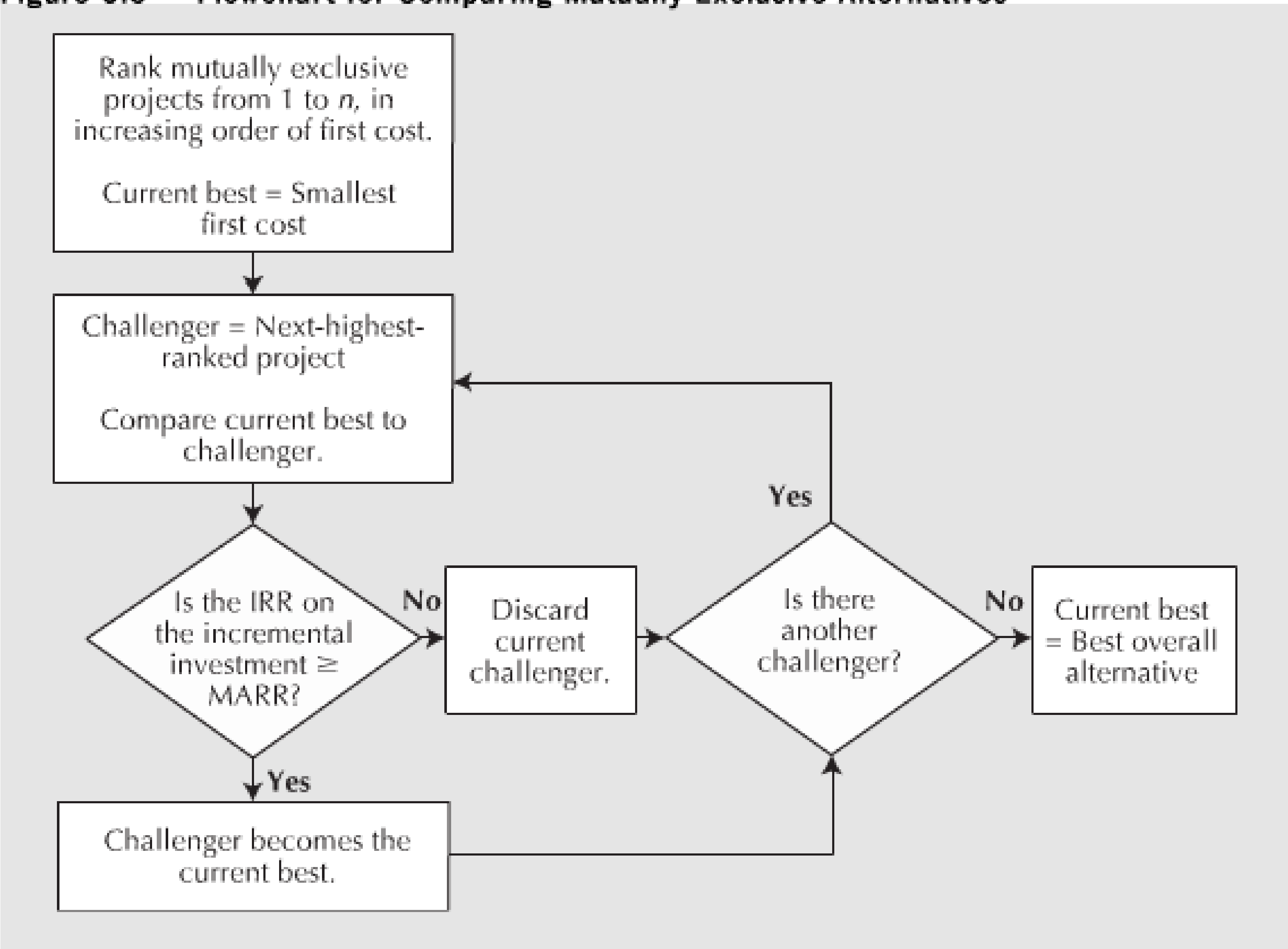
Figure 6.5 Flowchart for Comparing Mutually Exclusive Alternatives



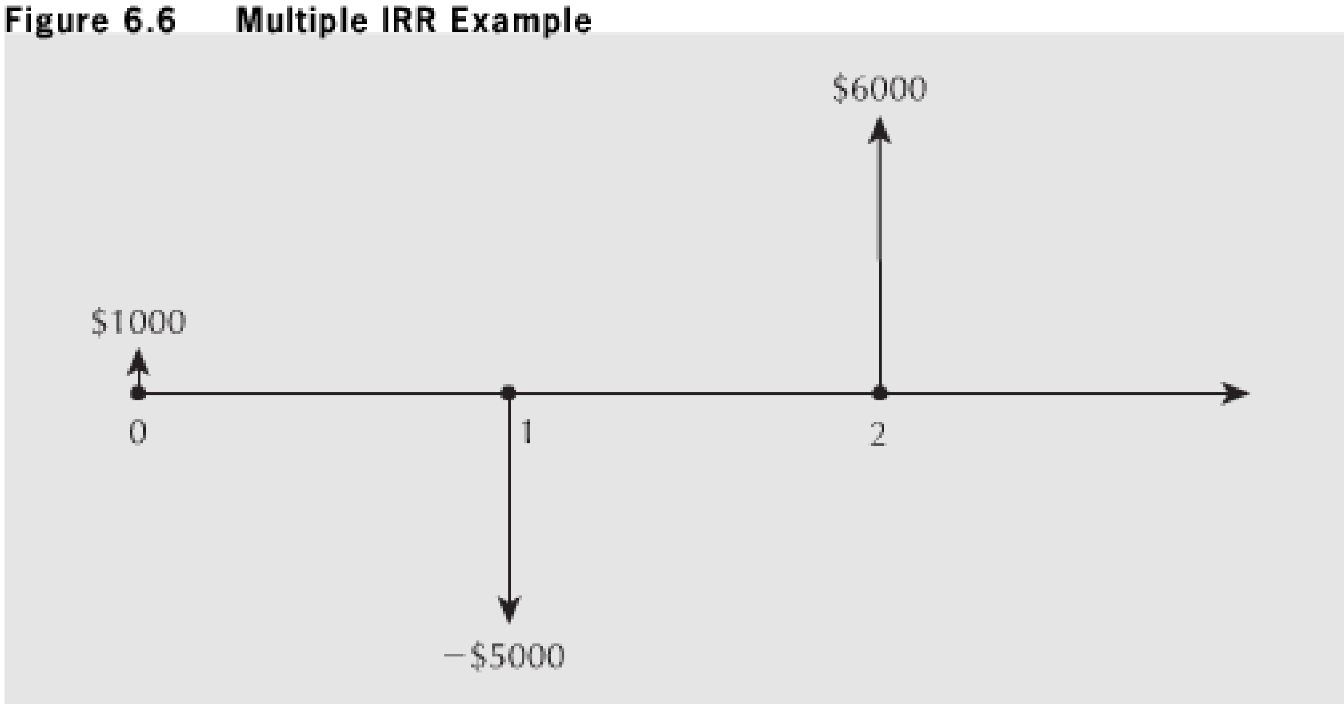
EXAMPLE 6.7

A project pays \$1000 today, costs \$5000 a year from now, and pays \$6000 in two years. (See Figure 6.6.) What is its IRR?

Equating the present worths of disbursements and receipts and solving for the IRR gives the following:

$$1000 - 5000(P/F,i^*,1) + 6000(P/F,i^*,2) = 0$$

Figure 6.6 Multiple IRR Example



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Recalling that $(P/F,i^*,N)$ stands for $1/(1 + i^*)^N$, we have

$$1 - \frac{5}{1 + i^*} + \frac{6}{(1 + i^*)^2} = 0$$

$$(1 + i^*)^2 - 5(1 + i^*) + 6 = 0$$

$$(1 + 2i^* + i^{*2}) - 5i^* + 1 = 0$$

$$i^{*2} - 3i^* + 2 = 0$$

$$(i^* - 1)(i^* - 2) = 0$$

The roots of this equation are $i^*_1 = 1$ and $i^*_2 = 2$. In other words, this project has two IRRs: 100 percent and 200 percent! ■

The multiple internal rates of return problem may be stated more generally. Consider a project that has cash flows over T periods. The **net cash flow**, A_t, associated with period t is the difference between cash inflows and outflows for the period (i.e., $A_t = R_t - D_t$, where R_t is cash inflow in period t and D_t is cash outflow in period t). We set the present worth of the net cash flows over the entire life of the project equal to zero to find the IRR(s). We have

$$A_0 + A_1(1 + i)^{-1} + A_2(1 + i)^{-2} + \ldots + A_T(1 + i)^{-T} = 0 \tag{6.2}$$

Any value of i that solves Equation (6.2) is an internal rate of return for that project. That there may be multiple solutions to Equation (6.2) can be seen if we rewrite the equation as

$$A_0 + A_1x + A_2x^2 + \ldots + A_Tx^T = 0 \tag{6.3}$$

where $x = (1 + i)^{-1}$.

Solving the Tth degree polynomial of Equation (6.3) is the same as solving for the internal rates of return in Equation (6.2). In general, when finding the roots of Equation (6.3), there may be as many positive real solutions for x as there are sign changes in the coefficients—the As. Thus, there may be as many IRRs as there are sign changes in the As.

We can see the meaning of multiple roots most easily with the concept of **project balance**. If a project has a sequence of net cash flows $A_0, A_1, A_2, \ldots, A_T$, and the interest rate is i', there are $T + 1$ project balances—$B_0, B_1, B_2, \ldots, B_T$, one at the end of each period t, $t = 0, 1, \ldots, T$. A project balance, B_t, is the accumulated future value of all cash flows up to the end of period t, compounded at the rate, i'. That is,

$$B_0 = A_0$$

$$B_1 = A_0(1 + i') + A_1$$

$$B_2 = A_0(1 + i')^2 + A_1(1 + i') + A_2$$

$$B_T = A_0(1 + i')^T + A_1(1 + i')^{T-1} + \ldots + A_T$$

Table 6.1 shows the project balances at the end of each year for both 100 percent and 200 percent interest rates for the project in Example 6.7. The project starts with a cash inflow of \$1000. At a 100 percent interest rate, the \$1000 increases to \$2000 over the first year. At the end of the first year, there is a \$5000 disbursement, leaving a negative project balance of \$3000. At 100 percent interest, this negative balance increases to \$6000

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Table 6.1 Project Balances for Example 6.7

End of Year	At i' = 100%	At i' = 200%
0	1000	1000
1	$1000(1 + 1) - 5000 = -3000$	$1000(1 + 2) - 5000 = -2000$
2	$-3000(1 + 1) + 6000 = 0$	$-2000(1 + 2) + 6000 = 0$

over the second year. This negative $6000 is offset exactly by the $6000 inflow. This makes the project balance zero at the end of the second year. The project balance at the end of the project is the future worth of all the cash flows in the project. When the future worth at the end of the project life is zero, the present worth is also zero. This verifies that the 100 percent is an IRR.

Now consider the 200 percent interest rate. Over the first year, the $1000 inflow increases to $3000. At the end of the first year, $5000 is paid out, leaving a negative project balance of $2000. This negative balance grows at 200 percent to $6000 over the second year. This is offset exactly by the $6000 inflow so that the project balance is zero at the end of the second year. This verifies that the 200 percent is also an IRR!

Looking at Table 6.1, it's actually fairly obvious that an important assumption is being made about the initial $1000 received. The IRR computation implicitly assumes that the $1000 is *invested* during the first period at either 100 percent or 200 percent, one of the two IRRs. However, during the first period, the project is not an investment. The project balance is positive. The project is *providing* money, not using it. This money cannot be reinvested immediately in the project. It is simply cash on hand. The $1000 must be invested elsewhere for one year if it is to earn any return. It is unlikely, however, that the $1000 provided by the project in this example would be invested in something else at 100 percent or 200 percent. More likely, it would be invested at a rate at or near the company's MARR.

NET VALUE 6.1

Additional Project Comparison Resources

The internet can be an excellent source of information and examples about the project comparison methods presented in Chapters 5 and 6. However, there is a wide range of perspectives and terminologies that can make it challenging to get clear and consistent information from the web for these methods. At the highest level, a search for information on "capital budgeting" or "corporate finance" will likely be more fruitful than a search for "engineering economics." In the Wikipedia article on capital budgeting, the annual worth method is referred to as the equivalent annuity method. Broadly, present worth is commonly referred to as net present value, or NPV. IRR is a widely used term. An alternative for ERR is MIRR, or modified internal rate of return.

With recognition of the different terms and perspectives, one can find examples or explanations for a variety of circumstances. For example, a recent search for "IRR in construction" using Google gave several useful examples along with a lengthy discussion on the details of using Excel for an IRR calculation in a construction problem. A search for "should I use NPV or IRR?" produced hundreds of arguments about when one technique is preferred to another over a wide range of industries.

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6.3.4 External Rate of Return Methods

To resolve the multiple IRR difficulty, we need to consider what return is earned by money associated with a project that is not invested in the project. The usual assumption is that the funds are invested elsewhere and earn an *explicit rate of return* equal to the MARR. This makes sense, because when there is cash on hand that is not invested in the project under study, it will be used elsewhere. These funds would, by definition, gain interest at a rate at least equal to the MARR. The **external rate of return (ERR)**, denoted by i^*_e, is the rate of return on a project where any cash flows that are not invested in the project are assumed to earn interest at a predetermined explicit rate (usually the MARR). For a given explicit rate of return, a project can have only one value for its ERR.

It is possible to calculate a precise ERR that is comparable to the IRRs of other projects using an explicit interest rate when necessary. Because the cash flows of Example 6.7 are fairly simple, let us use them to illustrate how to calculate the ERR precisely.

EXAMPLE 6.8 (EXAMPLE 6.7 REVISITED: ERR)

A project pays \$1000 today, costs \$5000 a year from now, and pays \$6000 in two years. What is its rate of return? Assume that the MARR is 25 percent.

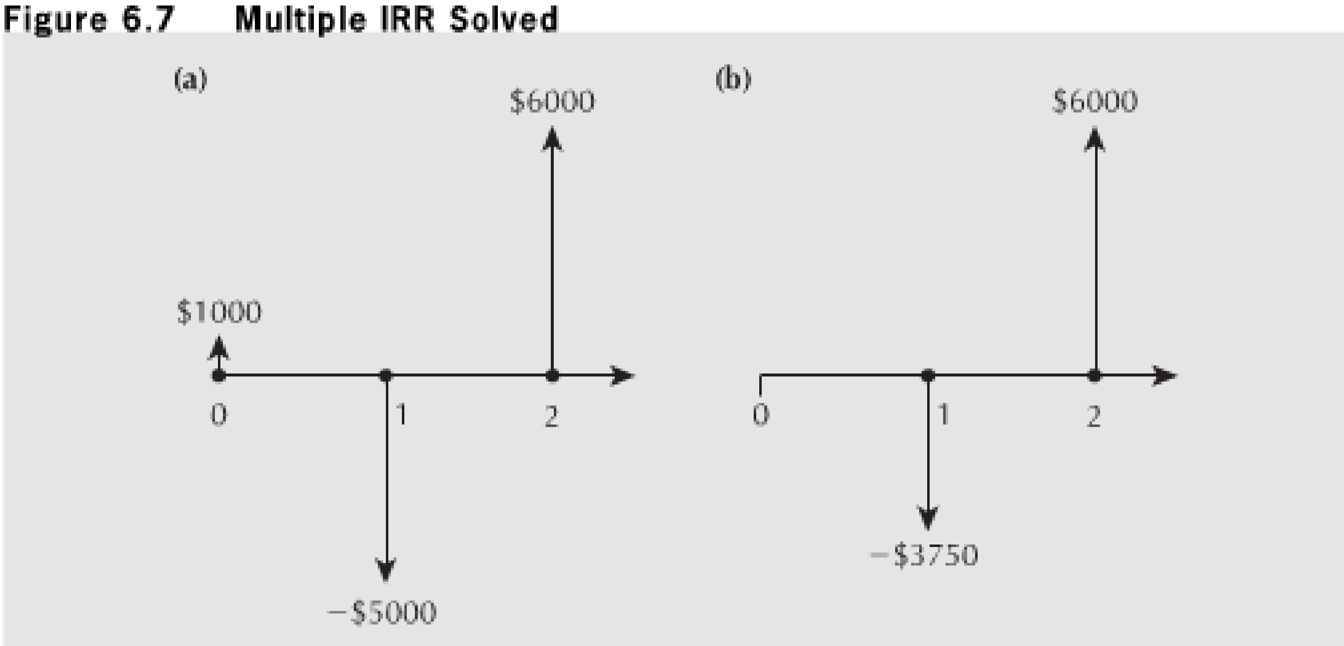
The first \$1000 is not invested immediately in the project. Therefore, we assume that it is invested outside the project for one year at the MARR. Thus, the cumulative cash flow for year 1 is

$$1000(F/P,25\%,1) - 5000 = 1250 - 5000 = -\$3750$$

With this calculation, we transform the cash flow diagram representing this problem from that in Figure 6.7(a) to that in Figure 6.7(b). These cash flows provide a single (precise) ERR, as follows:

$$-3750 + 6000(P/F,i^*_e,1) = 0$$
$$(P/F,i^*_e,1) = 3750/6000 = 0.625$$
$$\frac{1}{1+i^*_e} = 0.625$$
$$1+i^*_e = \frac{1}{0.625} = 1.6$$
$$i^*_e = 0.6$$
$$ERR = 60\%$$ ■

Figure 6.7 Multiple IRR Solved



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In general, computing a precise ERR can be a complex procedure because of the difficulty in determining exactly when the explicit interest rate should be applied. In order to do such a calculation, project balances have to be computed for trial ERRs. In periods in which project balances are positive for the trial ERR, the project is a source of funds. These funds would have to be invested outside the project at the MARR. During periods when the project balance is negative for the trial ERR, any receipts would be invested in the project and will typically yield more than the MARR. Whether the project balances are negative or positive will depend on the trial ERRs. This implies that the calculation process requires much experimenting with trial ERRs before an ERR is found that makes the future worth zero. A more convenient, but approximate, method is to use the following procedure:

1. Take all *net* receipts forward at the MARR to the time of the last cash flow.
2. Take all *net* disbursements forward at an unknown interest rate, i^*_{ea}, also to the time of the last cash flow.
3. Equate the future value of the receipts from Step 1 to the future value of the disbursements from Step 2 and solve for i^*_{ea}.
4. The value for i^*_{ea} is the *approximate ERR* for the project.

While Excel does have a modified IRR function called MIRR, it is not the same as the approximate ERR. The Excel MIRR function requires that you specify the rate at which positive cash flows are reinvested, whereas the approximate ERR estimates the return obtained on positive balances.

EXAMPLE 6.9 (EXAMPLE 6.7 REVISITED AGAIN: AN APPROXIMATE ERR)

To approximate the ERR, we compute the interest rate that gives a zero future worth at the end of the project when all receipts are brought forward at the MARR. In Example 6.7, the \$1000 is thus assumed to be reinvested at the MARR for two years, the life of the project. The disbursements are taken forward to the end of the two years at an unknown interest rate, i^*_{ea}. With a MARR of 25 percent, the revised calculation is

$$1000(F/P,25\%,2) + 6000 = 5000(F/P,i^*_{ea},1)$$

$$(F/P,i^*_{ea},1) = [1000(1.5625) + 6000]/5000$$

$$(F/P,i^*_{ea},1) = 1.5125$$

$$1 + i^*_{ea} = 1.5125$$

$$i^*_{ea} = 0.5125 \text{ or } 51.25\%$$

$$ERR \cong 51\%$$ ■

The ERR calculated using this method is an approximation, since all receipts, not just those that occur when the project balance is positive, are assumed to be invested at the MARR. Note that the precise ERR of 60 percent is different from the approximate ERR of 51 percent. Fortunately, it can be shown that the approximate ERR will always be between the precise ERR and the MARR. This means that whenever the precise ERR is above the MARR, the approximate ERR will also be above the MARR, and whenever the precise ERR is below the MARR, the approximation will be below the MARR as well. This implies that using the approximate ERR will always lead to the correct decision. It should also be noted that an acceptable project will earn *at least* the rate given by the approximate ERR. Therefore, even though an approximate ERR is inaccurate, it is often used in practice because it provides the correct decision as well as a lower bound on the return on an investment, while being easy to calculate.

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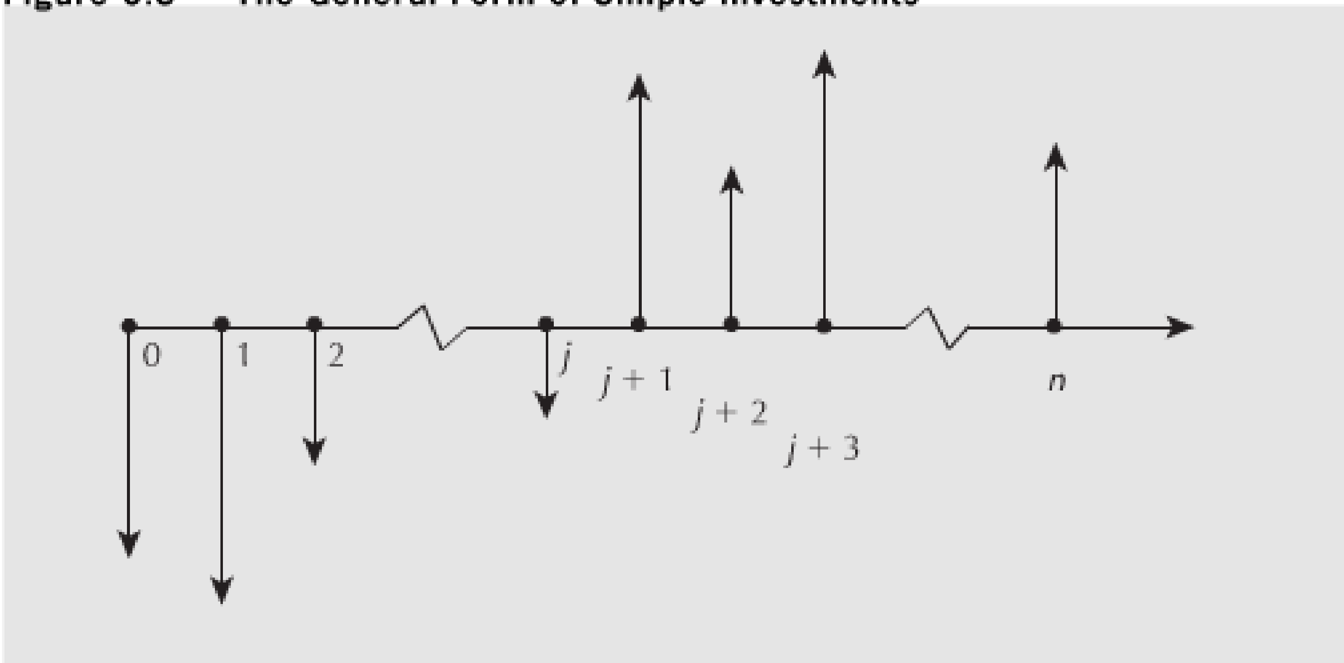
Figure 6.8 The General Form of Simple Investments



6.3.5 When to Use the ERR

The ERR (approximate or precise) must be used whenever there are multiple IRRs possible. Unfortunately, it can be difficult to know in advance whether there will be multiple IRRs. On the other hand, it is fortunate that most ordinary projects have a structure that precludes multiple IRRs.

Most projects consist of one or more periods of outflows at the start, followed only by one or more periods of inflows. Such projects are called **simple investments**. The cash flow diagram for a simple investment takes the general form shown in Figure 6.8. In terms of Equations (6.2) and (6.3), there is only one change of sign, from negative to positive in the *A*s, the sequence of coefficients. Hence, a simple investment always has a unique IRR.

If a project is not a simple investment, there may or may not be multiple IRRs—there is no way of knowing for sure without further analysis. In practice, it may be reasonable to use an approximate ERR whenever the project is not a simple investment. Recall from Section 6.3.4 that the approximate ERR will always provide a correct decision, whether its use is required or not, since it will understate the true rate of return.

However, it is generally desirable to compute an IRR whenever it is possible to do so, and to use an approximate ERR only when there may be multiple IRRs. In this way, the computations will be as accurate as possible.

To reiterate, the approximate ERR can be used to evaluate any project, whether it is a simple investment or not. However, the approximate ERR will tend to be a less accurate rate than the IRR. The inaccuracy will tend to be similar for projects with cash flows of a similar structure, and either method will result in the same decision in the end.

SPREADSHEET SAVVY

Depending on your approach to doing an economic analysis, the spreadsheet layout may take on a completely different look. The two tables below illustrate how Example 6.6 on page 209 might be answered using (1) the Excel IRR function, and (2) compound interest factors. In the top table, the cash flows for each of the 10 years are listed on each row. The columns represent the alternatives and the incremental cash flows. The second row entries contain the IRR results, as computed using the Excel IRR function. The IRR function has as its arguments the range of cells in which the cash flows are found and an initial guess at the IRR (which is optional).

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	Cash Flows for the Individual Lathes				Incremental Cash Flows		
	(1)	(2)	(3)	(4)	(2)-(1)	(3)-(1)	(4)-(3)
IRR:	21.41%	18.52%	18.94%	17.13%	12.41%	**16.40%**	10.13%
Period	Cash Flows:						
0	- 100 000	- 150 000	- 200 000	- 255 000	- 50 000	- 100 000	- 55 000
1	25 000	34 000	46 000	55 000	9 000	21 000	9 000
:	25 000	34 000	46 000	55 000	9 000	21 000	9 000
10	25 000	34 000	46 000	55 000	9 000	21 000	9 000

In the second table, basic computations are used to compute the present worth of each alternative. The rows are used to vary the interest rate. For example, the IRR for lathe 1 is between 21 percent and 22 percent because the present worth becomes zero at some point between these two interest rates. This is sufficient information to move on to compute the IRR on the incremental investment for lathe 2. The IRR on the incremental investment is between 12 percent and 13 percent, which is less than the MARR.

	PW of Cash Flows for the Individual Lathes				PW of Incremental Cash Flows		
i	(1)	(2)	(3)	(4)	(2)-(1)	(3)-(1)	(4)-(3)
0.10	53 614	58 915	82 650	82 951	5 301	29 036	301
0.11	47 231	50 234	70 905	68 908	3 003	23 674	-1 997
0.12	41 256	42 108	59 910	55 762	852	18 655	-4 148
0.13	35 656	34 492	49 607	43 443	-1 164	13 951	-6 164
0.14	30 403	27 348	39 941	31 886	-3 055	9 538	-8 055
0.15	25 469	20 638	30 863	21 032	-4 831	5 394	-9 831
0.16	20 831	14 330	22 328	10 828	-6 501	1 498	-11 501
0.17	16 465	8 393	14 296	1 223	-8 073	-2 169	-13 073
0.18	12 352	2 799	6 728	-7 825	-9 553	-5 624	-14 553
0.19	8 473	-2 476	- 409	-16 359	-10 950	-8 882	-15 950
0.20	4 812	-7 456	-7 146	-24 414	-12 268	-11 958	-17 268
0.21	1 352	-12 161	-13 512	-32 026	-13 513	-14 864	-18 513
0.22	-1 920	-16 612	-19 534	-39 225	-14 691	-17 613	-19 691

Either approach leads to the conclusion that lathe 3 is the preferred alternative.

6.4 Rate of Return and Present/Annual Worth Methods Compared

A comparison of rate of return and present/annual worth methods leads to two important conclusions:

1. The two sets of methods, when properly used, give the same decisions.
2. Each set of methods has its own advantages and disadvantages.

Let us consider each of these conclusions in more detail.

6.4.1 Equivalence of Rate of Return and Present/Annual Worth Methods

If an independent project has a unique IRR, the IRR method and the present worth method give the same decision. Consider Figure 6.9. It shows the present worth as a function of the interest rate for a project with a unique IRR. The maximum of the curve lies at the vertical axis (where the interest rate = zero) at the point given by the sum of

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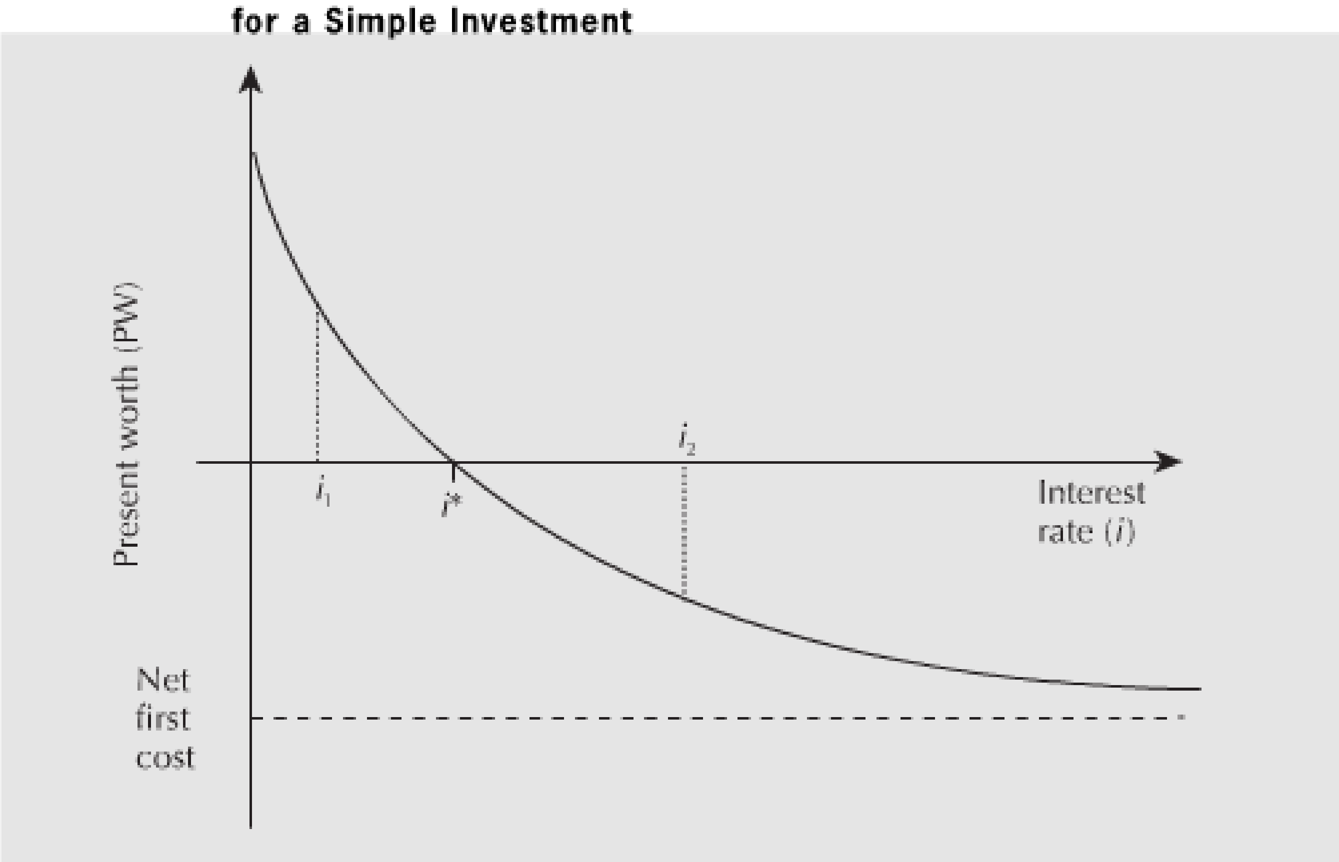
Figure 6.9 Present Worth (PW) as a Function of Interest Rate *(i)* for a Simple Investment



all undiscounted net cash flows. (We assume that the sum of all the undiscounted net cash flows is positive.) As the interest rate increases, the present worth of all cash flows after the first cost decreases. Therefore, the present worth curve slopes down to the right. To determine what happens as the interest rate increases indefinitely, let us recall the general equation for present worth:

$$\text{PW} = \sum_{t=0}^{T} A_t(1 + i)^{-t} \tag{6.4}$$

where

i = the interest rate

A_t = the net cash flow in period t

T = the number of periods

Letting $i \to \infty$, we have

$$\lim_{i \to \infty} \frac{1}{(1 + i)^t} = 0 \text{ for } t = 1, 2, \ldots, T$$

Therefore, as the interest rate becomes indefinitely large, all terms in Equation (6.4) approach zero except the first term (where $t = 0$), which remains at A_0. In Figure 6.9, this is shown by the asymptotic approach of the curve to the first cost, which, being negative, is below the horizontal axis.

The interest rate at which the curve crosses the horizontal axis (i^* in Figure 6.9), where the present worth is zero, is, by definition, the IRR.

To demonstrate the equivalence of the rate of return and the present/annual worth methods for decision making, let us consider possible values for the MARR. First, suppose the MARR = i_1, where $i_1 < i^*$. In Figure 6.9, this MARR would lie to the left of the IRR. From the graph we see that the present worth is positive at i_1. In other words, we have

IRR > MARR

and

PW > 0

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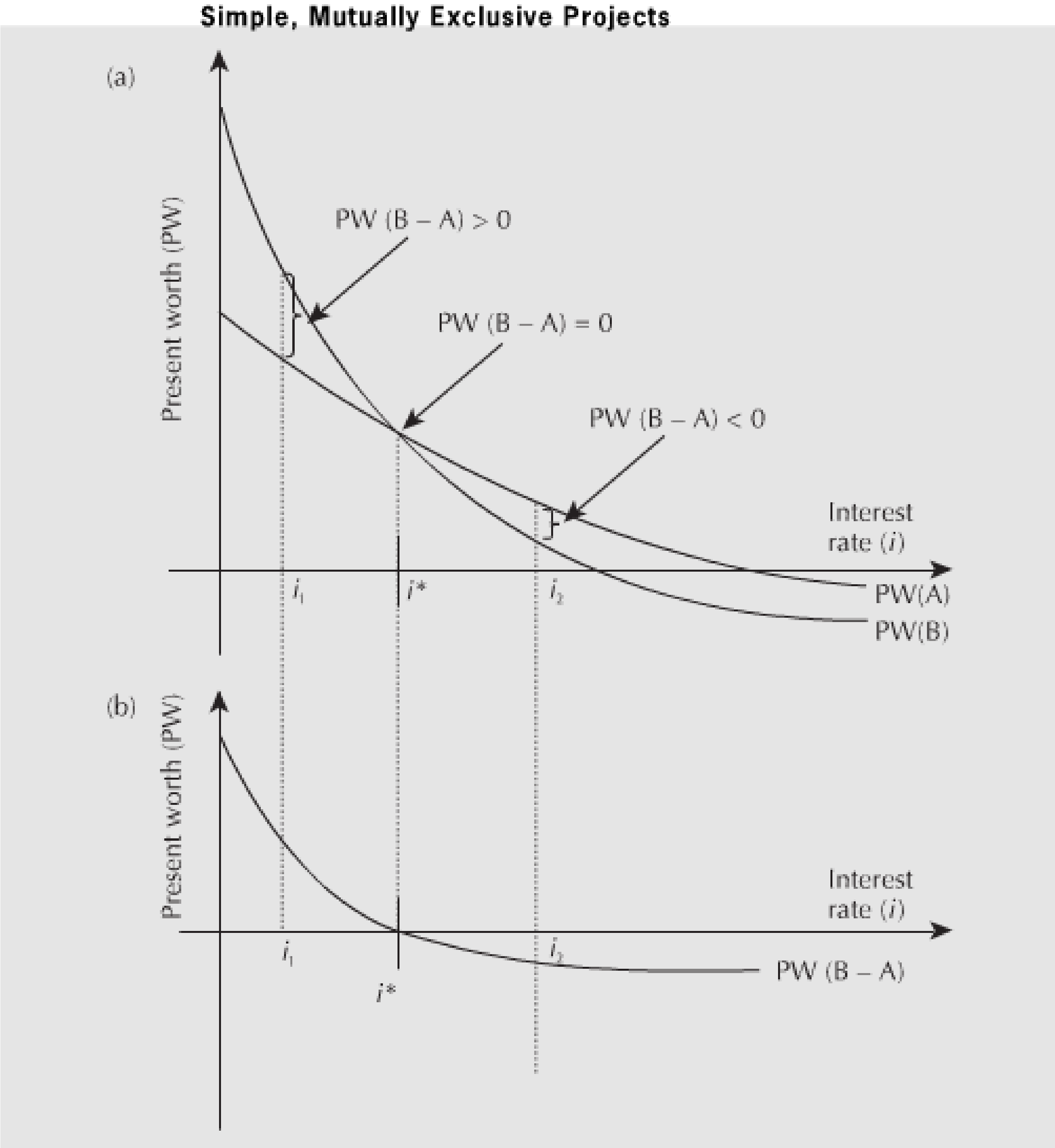
Figure 6.10 Present Worth as a Function of Interest Rate (*i*) for Two Simple, Mutually Exclusive Projects



Thus, in this case, both the IRR and PW methods lead to the same conclusion: Accept the project.

Second, suppose the MARR = i_2, where $i_2 > i^*$. In Figure 6.9, this MARR would lie to the right of the IRR. From the graph we see that, at i_2, the present worth is negative. Thus we have

$$\text{IRR} < \text{MARR}$$

and

$$\text{PW} < 0$$

Here, too, the IRR and the PW method lead to the same conclusion: Reject the project.

Now consider two simple, mutually exclusive projects, A and B, where the first cost of B is greater than the first cost of A. If the increment from A to B has a unique IRR, then we can readily demonstrate that the IRR and PW methods lead to the same decision. See Figure 6.10(a), which shows the present worths of projects A and B as a function of the interest rate. Since the first cost of B is greater than that of A, the curve for project B asymptotically approaches a lower present worth than does the curve for project A as the interest rate becomes indefinitely large, and thus the two curves must cross at some point.

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To apply the IRR method, we must consider the increment (denoted by B − A). The present worth of the increment (B − A) will be zero where the two curves cross. This point of intersection is marked by the interest rate, i^*. We have plotted the curve for the increment (B − A) in Figure 6.10(b) to clarify the relationships.

Let us again deal with possible values of the MARR. First, suppose the MARR (i_1) is less than i^*. Then, as we see in Figure 6.10(b), the present worth of (B − A) is positive at i_1. That is, the following conditions hold:

$$\text{IRR(B} - \text{A)} > \text{MARR}$$

and

$$\text{PW(B} - \text{A)} > 0$$

Thus, according to both the IRR method and the PW method, project B is better than project A.

Second, suppose the MARR = i_2, where $i_2 > i^*$. Then we see from Figure 6.10(b) that the present worth of the increment (B − A) is negative at i_2. In other words, the following conditions hold:

$$\text{IRR(B} - \text{A)} < \text{MARR}$$

and

$$\text{PW(B} - \text{A)} < 0$$

Thus, according to both methods, project A is better than project B.

In a similar fashion, we could show that the approximate ERR method gives the same decisions as the PW method in those cases where there may be multiple IRRs.

We already noted that the annual worth and present worth methods are equivalent. Therefore, by extension, our demonstration of the equivalence of the rate of return methods and the present worth methods means that the rate of return and the annual worth methods are also equivalent.

EXAMPLE 6.10

A tourist-area resort is considering adding either a parasailing operation or kayak rentals to their other activities. Available space limits them to one of these two choices. The initial costs for parasailing will be \$100 000, with net returns of \$15 000 annually for the 15-year life of the project. Initial costs for kayaking will be \$10 000, with net returns of \$2000 per year for its 15-year life. Assume that both projects have a \$0 salvage value after 15 years, and the MARR is 10 percent.

(a) Using present worth analysis, which alternative is better?

(b) Using IRR, which alternative is better?

(a) The present worths of the two projects are calculated as follows:

$$\begin{aligned} PW_{\text{para}} &= -100\,000 + 15\,000(P/A,10\%,15) \\ &= -100\,000 + 15\,000(7.6061) \\ &= 14\,091.50 \\ PW_{\text{kayak}} &= -10\,000 + 2000(P/A,10\%,15) \\ &= -10\,000 + 2000(7.6061) \\ &= 5212.20 \end{aligned}$$

The parasailing venture has a higher present worth at about \$14 000 and is thus preferred.

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(b) The IRRs of the two projects are calculated as follows:

Parasailing

$$100\,000 = 15\,000(P/A,i^*,15)$$

$$(P/A,i^*,15) = 100\,000/15\,000 = 6.67 \rightarrow i^*_{\text{para}} = 12.4\%$$

Kayaking

$$10\,000 = 2000(P/A,i^*,15)$$

$$(P/A,i^*,15) = 5 \rightarrow i^*_{\text{kayak}} = 18.4\%$$

One might conclude that, because $\text{IRR}_{\text{kayak}}$ is larger, the resort should invest in the kayaking project, but this is *wrong*. When done correctly, a present worth analysis and an IRR analysis will always agree. The error here is that the parasailing project was assessed without consideration of the increment from the kayaking project. Checking the IRR of the increment (denoted by the subscript "kayak-para"):

$$(100\,000 - 10\,000) = (15\,000 - 2000)(P/A,i^*,15)$$

$$(P/A,i^*,15) = 90\,000/13\,000 = 6.923 \rightarrow i^*_{\text{kayak-para}} = 11.7\%$$

Since the increment from the kayaking project also exceeds the MARR, the larger parasailing project should be taken. ■

6.4.2 Why Choose One Method Over the Other?

Although rate of return methods and present worth/annual worth methods give the same decisions, each set of methods has its own advantages and disadvantages. The choice of method may depend on the way the results are to be used and the sort of data the decision makers prefer to consider. In fact, many companies, by policy, require that several methods be applied so that a more complete picture of the situation is presented. A summary of the advantages and disadvantages of each method is given in Table 6.2.

Table 6.2 Advantages and Disadvantages of Comparison Methods

Method	Advantages	Disadvantages
IRR	Facilitates comparisons of projects of different sizes Commonly used	Relatively difficult to calculate Multiple IRRs may exist
Present worth	Gives explicit measure of profit contribution	Difficult to compare projects of different sizes
Annual worth	Annual cash flows may have familiar meanings to decision makers	Difficult to compare projects of different sizes
Payback period	Very easy to calculate Commonly used Takes into account the need to have capital recovered quickly	Discriminates against long-term projects Ignores time value of money Ignores the expected service life

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Rate of return methods state results in terms of *rates*, while present/annual worth methods state results in absolute figures. Many managers prefer rates to absolute figures because rates facilitate direct comparisons of projects whose sizes are quite different. For example, a petroleum company comparing performances of a refining division and a distribution division would not look at the typical values of present or annual worth for projects in the two divisions. A refining project may have first costs in the range of hundreds of *millions*, while distribution projects may have first costs in the range of *thousands*. It would not be meaningful to compare the absolute profits of a refining project and a distribution project. The absolute profits of refining projects will almost certainly be larger than those of distribution projects. Expressing project performance in terms of rates of return permits understandable comparisons. A disadvantage of rate of return methods, however, is the possible complication that there may be more than one rate of return. Under such circumstances, it is necessary to calculate an ERR.

In contrast to a rate of return, a present or annual worth computation gives a direct measure of the profit provided by a project. A company's main goal is likely to earn profits for its owners. The present and annual worth methods state the contribution of a project toward that goal. Another reason that managers prefer these methods is that present worth and annual worth methods are typically easier to apply than rate of return methods.

For completeness of coverage, we note that the payback period method may not give results consistent with rate of return or present/annual worth methods as it ignores the time value of money and the service life of projects. It is, however, a method commonly used in practice due to its ease of use and intuitive appeal.

EXAMPLE 6.11

Each of the following scenarios suggests a best choice of comparison method.

1. Edward has his own small firm that will lease injection-moulding equipment to make polyethylene containers. He must decide on the specific model to lease. He has estimates of future monthly sales.

   The annual worth method makes sense here because Edward's cash flows, including sales receipts and leasing expenses, will probably all be on a monthly basis. As a sole proprietor, Edward need not report his conclusions to others.

2. Ramesh works for a large power company and must assess the viability of locating a transformer station at various sites in the city. He is looking at the cost of the building lot, power lines, and power losses for the various locations. He has fairly accurate data about costs and future demand for electricity.

   As part of a large firm, Ramesh will likely be obliged to use a specific comparison method. This would probably be IRR. A power company makes many large and small investments, and the IRR method allows them to be compared fairly. Ramesh has the data necessary for the IRR calculations.

3. Sehdev must buy a relatively inexpensive log splitter for his agricultural firm. There are several different types that require a higher or lower degree of manual assistance. He has only rough estimates of how this machine will affect future cash flows.

   This relatively inexpensive purchase is a good candidate for the payback period method. The fact that it is inexpensive means that extensive data gathering and analysis are probably not warranted. Also, since future cash flows are

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relatively uncertain, there is no justification for using a particularly precise comparison method.

4. Ziva will be living in the Arctic for six months, testing her company's equipment under hostile weather conditions. She needs a field office and must determine which of the following choices is economically best: (1) renting space in an industrial building, (2) buying and outfitting a trailer, (3) renting a hotel room for the purpose.

   For this decision, a present worth analysis would be appropriate. The cash flows for each of the alternatives are of different types, and bringing them to present worth would be a fair way to compare them. It would also provide an accurate estimate to Ziva's firm of the expected cost of the remote office for planning purposes. ■

REVIEW PROBLEMS

REVIEW PROBLEM 6.1

Wei-Ping's consulting firm needs new quarters. A downtown office building is ideal. The company can either buy or lease it. To buy the office building will cost \$6 000 000. If the building is leased, the lease fee is \$400 000 payable at the beginning of each year. In either case, the company must pay city taxes, maintenance, and utilities.

Wei-Ping figures that the company needs the office space for only 15 years. Therefore, it will either sign a 15-year lease or buy the building. If it buys the building, it will then sell the building after 15 years. The value of the building at that time is estimated to be \$15 000 000.

What rate of return will Wei-Ping's firm receive by buying the office building instead of leasing it?

ANSWER

The rate of return can be calculated as the IRR on the incremental investment necessary to buy the building rather than lease it.

The IRR on the incremental investment is found by solving for i^* in

$$(6\ 000\ 000 - 400\ 000) - 15\ 000\ 000(P/F,i^*,15) = 400\ 000(P/A,i^*,14)$$
$$4(P/A,i^*,14) + 150(P/F,i^*,15) = 56$$

For $i^* = 11$ percent, the result is

$$4(P/A,11\%,14) + 150(P/F,11\%,15)$$
$$= 4(6.9819) + 150(0.20900)$$
$$= 59.2781$$

For $i^* = 12$ percent,

$$4(P/A,12\%,14) + 150(P/F,12\%,15)$$
$$= 4(6.6282) + 150(0.1827)$$
$$= 53.9171$$

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A linear interpolation between 11 percent and 12 percent gives the IRR

$$i^* = 11\% + (59.2781 - 56)/(59.2781 - 53.9171) = 11.6115\%$$

By investing its money in buying the building rather than leasing, Wei-Ping's firm is earning an IRR of about 11.6 percent. ■

REVIEW PROBLEM 6.2

The Real S. Tate Company is considering investing in one of four rental properties. Real S. Tate will rent out whatever property it buys for four years and then sell it at the end of that period. The data concerning the properties is shown below:

Rental Property	Purchase Price	Net Annual Rental Income	Sale Price at the End of Four Years
1	$100 000	$ 7200	$100 000
2	120 000	9600	130 000
3	150 000	10 800	160 000
4	200 000	12 000	230 000

On the basis of the purchase prices, rental incomes, and sale prices at the end of the four years, answer the following questions.

(a) Which property, if any, should Tate invest in? Real S. Tate uses a MARR of 8 percent for projects of this type.

(b) Construct a graph that depicts the present worth of each alternative as a function of interest rates ranging from 0 percent to 20 percent. (A spreadsheet would be helpful in answering this part of the problem.)

(c) From your graph, determine the range of interest rates for which your choice in part (a) is the best investment. If the MARR were 9 percent, which rental property would be the best investment? Comment on the sensitivity of your choice to the MARR used by the Real S. Tate Company.

ANSWER

(a) Since the "do nothing" alternative is feasible and it has the least first cost, it becomes the current best alternative. The IRR on the incremental investment for property 1 is given by:

$$-100\,000 + 100\,000(P/F,i^*,4) + 7200(P/A,i^*,4) = 0$$

The IRR on the incremental investment is 7.2 percent. Because this is less than the MARR of 8 percent, property 1 is discarded from further consideration.

Next, the IRR for the incremental investment for property 2, the alternative with the next-highest first cost, is found by solving for i^* in

$$-120\,000 + 130\,000(P/F,i^*,4) + 9600(P/A,i^*,4) = 0$$

The interest rate that solves the above equation is 9.8 percent. Since an IRR of 9.8 percent exceeds the MARR, property 2 becomes the current best alternative. Now the incremental investments over and above the first cost of property 2 are analyzed.

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Next, property 3 challenges the current best. The IRR on the incremental investment for property 3 is

$$(-150\,000 + 120\,000) + (160\,000 - 130\,000)(P/F,i^*,4)$$
$$+ (10\,800 - 9600)(P/A,i^*,4) = 0$$
$$-30\,000 + 30\,000(P/F,i^*,4) + 1200(P/A,i^*,4) = 0$$

This gives an IRR of only 4 percent, which is below the MARR. Property 2 remains the current best alternative and property 3 is discarded.

Finally, property 4 challenges the current best. The IRR on the incremental investment from property 2 to property 4 is

$$(-200\,000 + 120\,000) + (230\,000 - 130\,000)(P/F,i^*,4)$$
$$+ (12\,000 - 9600)(P/A,i^*,4) = 0$$
$$-80\,000 + 100\,000(P/F,i^*,4) + 2400(P/A,i^*,4) = 0$$

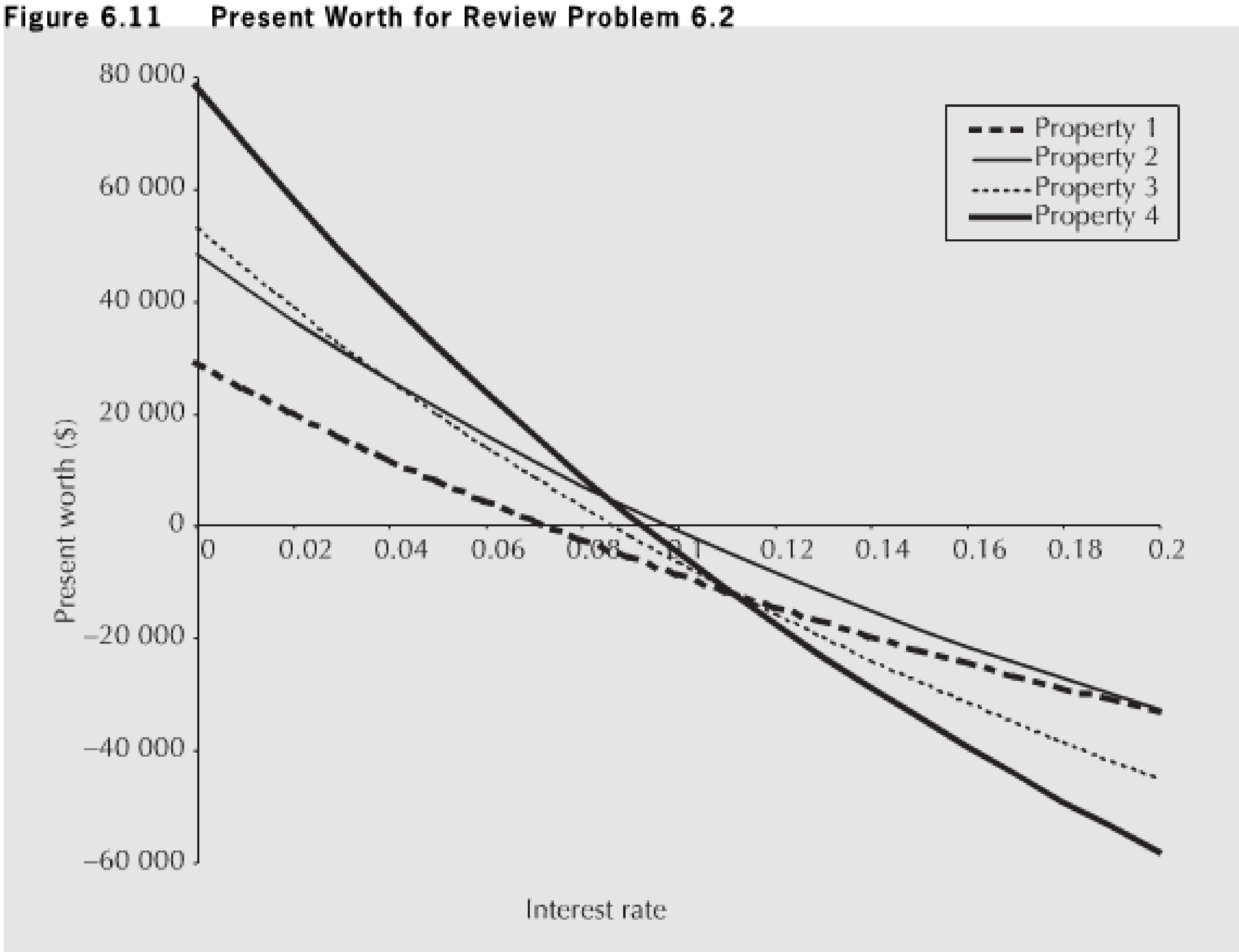
The IRR on the incremental investment is 8.5 percent, which is above the MARR. Property 4 becomes the current best choice. Since there are no further challengers, the choice based on IRR is the current best, property 4.

(b) The graph for part (b) is shown in Figure 6.11.

(c) From the graph, one can see that property 4 is the best alternative provided that the MARR is between 0 percent and 8.5 percent. This is the range of interest rates over which property 4 has the largest present worth.

If the MARR is 9 percent, the best alternative is property 2. This can be seen by going back to the original IRR computations and observing that the

Figure 6.11 Present Worth for Review Problem 6.2



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results of the analysis are essentially the same, except that the incremental investment from property 2 to property 4 no longer has a return exceeding the MARR. This can be confirmed from the diagram (Figure 6.11) as well, since the property with the largest present worth at 9 percent is property 2.

With respect to sensitivity analysis, the graph shows that, for a MARR between 0 percent and 8.5 percent, property 4 is the best choice, and for a MARR between 8.5 percent and 9.8 percent, property 2 is the best choice. If the MARR is above 9.8 percent, no property has an acceptable return on investment, and the "do nothing" alternative would be chosen. ■

REVIEW PROBLEM 6.3

You are in the process of arranging a marketing contract for a new Java applet you are writing. It still needs more development, so your contract will pay you $5000 today to finish the prototype. You will then get royalties of $10 000 at the end of each of the second and third years. At the end of each of the first and fourth years, you will be required to spend $20 000 and $10 000 in upgrades, respectively. What is the (approximate) ERR on this project, assuming a MARR of 20 percent? Should you accept the contract?

ANSWER

To calculate the approximate ERR, set

$$\text{FW(receipts @ MARR)} = \text{FW(disbursements @ ERR)}$$

$$5000(F/P,20\%,4) + 10\,000(F/P,20\%,2) + 10\,000(F/P,20\%,1)$$
$$= 20\,000(F/P,i^*_{ea},3) + 10\,000$$

$$5000(2.0736) + 10\,000(1.44) + 10\,000(1.2)$$
$$= 20\,000(F/P,i^*_{ea},3) + 10\,000$$

$$(F/P,i^*_{ea},3) = 1.3384$$

$$(1 + i^*_{ea})^3 = 1.3384$$

$$i^*_{ea} = (1.3384)^{(1/3)} - 1$$
$$= 10.2\%$$

The (approximate) ERR is 10.2 percent. Since this is below the MARR of 20 percent, the contract should not be accepted. ■

SUMMARY

This chapter presented the IRR method for evaluating projects and also discussed the relationship among the present worth, annual worth, payback period, and IRR methods.

The IRR method consists of determining the rate of return for a sequence of cash flows. For an independent project, the calculated IRR is compared with a MARR, and if

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it is equal to or exceeds the MARR it is an acceptable project. To determine the best project of several mutually exclusive ones, it is necessary to determine the IRR of each increment of investment.

The IRR selection procedure is complicated by the possibility of having more than one rate of return because of a cash flow structure that, over the course of a project, requires that capital, eventually invested in the project at some point, be invested externally. Under such circumstances, it is necessary to calculate an ERR.

The present worth and annual worth methods are closely related, and both give results identical to those of the IRR method. Rate of return measures are readily understandable, especially when comparing projects of unequal sizes, whereas present/annual worth measures give an explicit expression of the profit contribution of a project. The main advantage of the payback period method is that it is easy to implement and understand, and takes into account the need to have capital recovered quickly.

ENGINEERING ECONOMICS IN ACTION, PART 6B

The Invisible Hand

"Hello." Dave's voice was clear enough over the phone that he could have been in his office down the hall, but Naomi could tell from his relaxed tone that the office was not on his mind.

"Hi, Dave, it's Naomi. Can I bend your ear about that drop forge project again?"

"Oh, hi, Naomi. Sure, what have you got?"

"Well, as I see it, IRR has got to be the way to go. Of course, present worth or annual worth will give the same answer, but I'm sure Ed Burns and Anna Kulkowski would prefer IRR. They have to compare potential investments across different parts of the organization. It's kind of hard to compare net present worths of investments in information systems, where you rarely get above a first cost of $100 000, with forge investments where you can easily get up to a few hundred thousand first cost. And, as I said before, the drop forge operation isn't one in which the annual cost has any particular significance."

There was a short pause. Naomi suddenly regretted speaking as if she was so sure of herself—but, darn it, she was sure on this one.

"Exactly right," Dave replied. Naomi could feel an invisible hand pat her on the back. "So how exactly would you proceed?"

"Well, I have the options ranked by first cost. The first one is just refurbishing the existing machine. There is no test on that one unless we are willing to stop making our own parts, and Clem told me that was out . . . "

Dave interjected with "You don't mean that you're automatically going to refurbish the existing machine, do you?"

"No, no. The simple refurbishing option is the base. I then go to the next option, which is to refurbish the drop forging hammer and replace the materials-handling system. I compare this with the just-refurbish option by looking at the incremental first cost. I will check to see if the additional first cost has an IRR of at least 15 percent after tax, which, Clem tells me, is the minimum acceptable rate of return. If the incremental first cost has an IRR of at least 15 percent, the combination of refurbishing and replacing the materials-handling system is better than just refurbishing. I then consider the next option, which is to buy the manually operated mechanical press with no change in materials handling. I look at the incremental investment here and see if its IRR is at least 15 percent. To go back a step, if the IRR on replacing materials handling plus refurbishing the old machine did not pay off at 15 percent, I would have rejected that and compared the manually operated mechanical press with the first option, just refurbishing the old machine. I then work my way, option by option, up to the seventh. How does that sound?"

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"Well, that sounds great, as far as it goes. Have you checked for problems with multiple IRRs?"

"Well, so far each set of cash flows has been a simple investment, but I will be careful."

"I would also compute payback periods for them in case we are having cash flow problems. If the payback is too long, they may not necessarily take an option even with the incremental IRR being above their 15 percent MARR."

Naomi considered this for a second. "One other question, Dave. What should I do about intangibles?"

"You mean the noise from the forging hammer?"

"Yes. It's important, but you can't evaluate it in dollars and cents."

"Just remind them of it in your report. If they want a more formal analysis, they'll come back to you."

"Thanks, Dave. You've been a big help."

As Naomi hung up the phone, she couldn't help smiling ruefully to herself. She had ignored the payback period altogether—after all, it didn't take either interest or service life into account. "I guess that's what they call practical experience," she said to herself as she got out her laptop.

PROBLEMS

A. Key Concepts

6.1 Corral Cartage leases trucks to service its shipping contracts. Larger trucks have cheaper operating costs if there is sufficient business, but are more expensive if they are not full. CC has estimates of monthly shipping demand. What comparison method(s) would be appropriate for choosing which trucks to lease?

6.2 The bottom flaps of shipping cartons for Yonge Auto Parts are fastened with industrial staples. Yonge needs to buy a new stapler. What comparison method(s) would be appropriate for choosing which stapler to buy?

6.3 Joan runs a dog kennel. She is considering installing a heating system for the interior runs, which will allow her to operate all year. What comparison method(s) would be appropriate for choosing which heating system to buy?

6.4 A large food company is considering replacing a scale on its packaging line with a more accurate one. What comparison method(s) would be appropriate for choosing which scale to buy?

6.5 Mona runs a one-person company producing custom paints for hobbyists. She is considering buying printing equipment to produce her own labels. What comparison method(s) would be appropriate for choosing which equipment to buy?

6.6 Peter is the president of a rapidly growing company. There are dozens of important things to do, and cash flow is tight. What comparison method(s) would be appropriate for Peter to make acquisition decisions?

6.7 Lemuel is an engineer working for the electric company. He must compare several routes for transmission lines from a distant nuclear plant to new industrial parks north of the city. What comparison method(s) is he likely to use?

6.8 Vicky runs a music store that has been suffering from thefts. She is considering installing a magnetic tag system. What comparison method(s) would be best for her to use to choose among competing leased systems?

6.9 Thanh's company is growing very fast and has a hard time meeting its orders. An opportunity to purchase additional production equipment has arisen. What comparison method(s) would Thanh use to justify to her manager that the equipment purchase is prudent?

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6.10 What is the IRR for a $1000 investment that returns $200 at the end of each of the next

(a) 7 years?

(b) 6 years?

(c) 100 years?

(d) 2 years?

6.11 New windows are expected to save $400 per year in energy costs over their 30-year life for Fab Fabricating. At an initial cost of $8000 and zero salvage value, using IRR, are they a good investment? Fab's MARR is 8 percent.

6.12 An advertising campaign will cost $200 000 for planning and $40 000 in each of the next six years. It is expected to increase revenues permanently by $40 000 per year. Additional revenues will be gained in the pattern of an arithmetic gradient with $20 000 in the first year, declining by $5000 per year to zero in the fifth year. What is the IRR of this investment? If the company's MARR is 12 percent, is this a good investment?

6.13 Refer to Review Problem 5.22 on page 188. Assuming the four investments are independent, use the IRR method to select which, if any, should be chosen. Use a MARR of 8 percent.

6.14 Aline has three contracts from which to choose. The first contract will require an outlay of $100 000 but will return $150 000 one year from now. The second contract requires an outlay of $200 000 and will return $300 000 one year from now. The third contract requires an outlay of $250 000 and will return $355 000 one year from now. Only one contract can be accepted. If her MARR is 20 percent, which one should she choose?

6.15 Fantastic Footwear can invest in one of two different automated clicker cutters. The first, A, has a $100 000 first cost. A similar one with many extra features, B, has a $400 000 first cost. A will save $50 000 per year over the cutter now in use. B will save $150 000 per year. Each clicker cutter will last five years. If the MARR is 10 percent, which alternative is better? Use an IRR comparison.

6.16 Six mutually exclusive projects, A, B, C, D, E, and F, are being considered. They have been ordered by first costs so that project A has the smallest first cost, F the largest. The data in the table below apply to these projects. The data can be interpreted as follows: the IRR on the incremental investment between project D and project C is 6 percent. Which project should be chosen using a MARR of 15 percent?

Project	IRR on Overall Investment	IRR on Increments of Investment Compared With Project A	B	C	D	E
A	20%					
B	15%	12%				
C	24%	30%	35%			
D	16%	18%	22%	6%		
E	17%	16%	19%	15%	16%	
F	21%	20%	21%	19%	18%	11%

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6.17 A cash flow sequence has a receipt of \$10 000 today, followed by a disbursement of \$8000 at the end of this year and again next year, and then a receipt of \$5500 three years from now. The MARR is 6 percent.

(a) What is the ERR for this set of cash flows?

(b) What is the approximate ERR for this set of cash flows?

(c) Would a project with these cash flows be a good investment?

6.18 Yee Swian has received an advance of \$20 000 on a software program she is writing. She will spend \$120 000 this year writing it (consider the money to have been spent at the end of year 1), and then receive \$100 000 at the end of the second year. The MARR is 12 percent.

(a) What is the IRR for this project? Does the result make sense?

(b) What is the precise ERR?

(c) What is the approximate ERR?

B. Applications

6.19 CB Electronix must buy a piece of equipment to place electronic components on the printed circuit boards it assembles. The proposed equipment has a 10-year life with no scrap value.

The supplier has given CB several purchase alternatives. The first is to purchase the equipment for \$850 000. The second is to pay for the equipment in 10 equal installments of \$135 000 each, starting one year from now. The third is to pay \$200 000 now and \$95 000 at the end of each year for the next 10 years.

(a) Which alternative should CB choose if its MARR is 11 percent per year? Use an IRR comparison approach.

(b) Below what MARR does it make sense for CB to buy the equipment now for \$850 000?

6.20 The following table summarizes information for four projects:

Project	First Cost	IRR on Overall Investment	IRR on Increments of Investment Compared With Project 1	2	3
1	\$100 000	19%			
2	175 000	15%	9%		
3	200 000	18%	17%	23%	
4	250 000	16%	12%	17%	13%

The data can be interpreted in the following way: The IRR on the incremental investment between project 4 and project 3 is 13 percent.

(a) If the projects are independent, which projects should be undertaken if the MARR is 16 percent?

(b) If the projects are mutually exclusive, which project should be undertaken if the MARR is 15 percent? Indicate what logic you have used.

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(c) If the projects are mutually exclusive, which project should be undertaken if the MARR is 17 percent? Indicate what logic you have used.

6.21 There are several mutually exclusive ways Grazemont Dairy can meet a requirement for a filling machine for its creamer line. One choice is to buy a machine. This would cost \$65 000 and last for six years with a salvage value of \$10 000. Alternatively, it could contract with a packaging supplier to get a machine free. In this case, the extra costs for packaging supplies would amount to \$15 000 per year over the six-year life (after which the supplier gets the machine back with no salvage value for Grazemont). The third alternative is to buy a used machine for \$30 000 with zero salvage value after six years. The used machine has extra maintenance costs of \$3000 in the first year, increasing by \$2500 per year. In all cases, there are installation costs of \$6000 and revenues of \$20 000 per year. Using the IRR method, determine which is the best alternative. The MARR is 10 percent.

6.22 The following cash flows result from a potential construction contract for Erstwhile Engineering.

1. Receipts of \$500 000 at the start of the contract and \$1 200 000 at the end of the fourth year
2. Expenditures at the end of the first year of \$400 000 and at the end of the second year of \$900 000
3. A net cash flow of zero at the end of the third year

Using an appropriate rate of return method, for a MARR of 25 percent, should Erstwhile Engineering accept this project?

6.23 Samiran has entered into an agreement to develop and maintain a computer program for symbolic mathematics. Under the terms of the agreement, he will pay \$900 000 in royalties to the investor at the end of the fifth, tenth, and fifteenth years, with the investor paying Samiran \$450 000 now, and then \$650 000 at the end of the twelfth year.

Samiran's MARR for this type of investment is 20 percent. Calculate the ERR of this project. Should he accept this agreement on the basis of these disbursements and receipts alone? Are you sure that the ERR you calculated is the only ERR? Why? Are you sure that your recommendation to Samiran is correct? Justify your answer.

6.24 Refer to Example 5.6 on page 171, in which a mechanical engineer has decided to introduce automated materials-handling equipment to a production line. Use a present worth approach with an IRR analysis to determine which of the two alternatives is best. The MARR is 9 percent. Use the repeated lives method to deal with the fact that the service lives of the two alternatives are not equal.

6.25 Refer to Problem 5.28 on page 190. Val has determined that the salvage value of the XJ3 after two years of service is \$1900. Using the IRR method, which display panel is the better choice? Use a two-year study period. She must choose one of the alternatives.

6.26 Three construction jobs are being considered by Clam City Construction (see the following table). Each is characterized by an initial deposit paid by the client to Clam City Construction (CCC), a yearly cost incurred by CCC at the end of each of three years, and a final payment to CCC by the client at the end of three years. CCC has the capacity to do only one of these contracts. Use an appropriate rate of return method to determine which it should do. The company's MARR is 10 percent.

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Job	Deposit ($)	Cost per Year ($)	Final Payment ($)
1	100 000	75 000	200 000
2	150 000	100 000	230 000
3	175 000	150 000	300 000

6.27 Kool Karavans is considering three investment proposals. Each of them is characterized by an initial cost, annual savings over four years, and no salvage value, as illustrated in the following table. The company can only invest in two of these proposals. If its MARR is 12 percent, which two should it choose?

Proposal	First Cost ($)	Annual Savings ($)
A	40 000	20 000
B	110 000	30 000
C	130 000	45 000

6.28 Development projects done by Standalone Products are subsidized by a government grant program. The program pays 30 percent of the total cost of the project (costs summed without discounting—i.e., the interest rate is zero), half at the beginning of the project and half at the end, up to a maximum of $100 000. There are two projects being considered. One is a customized checkweigher for cheese products, and the other is an automated production scheduling system. Each project has a service life of five years. Costs and benefits for both projects, not including grant income, are shown below. Only one can be done, and the grant money is certain. PTR has a MARR of 15 percent for projects of this type. Using an appropriate rate of return method, which project should be chosen?

	Checkweigher	Scheduler
First cost	$30 000	$10 000
Annual costs	5 000	12 000
Annual benefits	14 000	17 000
Salvage value	8 000	0

6.29 Jacob is considering the replacement of the heating system for his building. There are three alternatives. All are natural-gas-fired furnaces, but they vary in energy efficiency. Model A is leased at a cost of $500 per year over a 10-year study period. There are installation charges of $500 and no salvage value. It is expected to provide energy savings of $200 per year. Model B is purchased for a total cost of $3600, including installation. It has a salvage value of $1000 after 10 years of service, and is expected to provide energy savings of $500 per year. Model C is also purchased, for a total cost of $8000, including installation. However, half of this cost is paid now and the other half is paid at the end of two years. It has a salvage value of $1000 after 10 years and is expected to provide energy savings of $1000 per year. For a MARR of

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12 percent and using a rate of return method, which heating system should be installed? One model must be chosen.

C. More Challenging Problems

6.30 Project X has an IRR of 16 percent and a first cost of \$20 000. Project Y has an IRR of 17 percent and a first cost of \$18 000. The MARR is 15 percent. What can be said about which (if either) of the two projects should be undertaken if (a) the projects are independent and (b) the projects are mutually exclusive?

6.31 Charlie has a project for which he had determined a present worth of \$56 740. He now has to calculate the IRR for the project, but unfortunately he has lost complete information about the cash flows. He knows only that the project has a five-year service life and a first cost of \$180 000, that a set of equal cash flows occurred at the end of each year, and that the MARR used was 10 percent. What is the IRR for this project?

6.32 Lucy's project has a first cost P, annual savings A, and a salvage value of \$1000 at the end of the 10-year service life. She has calculated the present worth as \$20 000, the annual worth as \$4000, and the payback period as three years. What is the IRR for this project?

6.33 Patti's project has an IRR of 15 percent, first cost P, and annual savings A. She observed that the salvage value S at the end of the five-year life of the project was exactly half of the purchase price, and that the present worth of the project was exactly double the annual savings. What was Patti's MARR?

6.34 Jerry has an opportunity to buy a bond with a face value of \$10 000 and a coupon rate of 14 percent, payable semiannually.

(a) If the bond matures in five years and Jerry can buy one now for \$3500, what is his IRR for this investment?

(b) If his MARR for this type of investment is 20 percent, should he buy the bond?

6.35 Refer to Problem 5.15 on page 187. Find which alternative is preferable using the IRR method and a MARR of 5 percent. Assume that one of the alternatives must be chosen. Answer the following questions by using present worth computations to find the IRRs. Use the least common multiple of service lives.

(a) What are the cash flows for each year of the comparison period (i.e., the least common multiple of service lives)?

(b) Are you able to conclude that there is a single IRR on the incremental investment? Why or why not?

(c) Which of the two alternatives should be chosen? Use the ERR method if necessary.

6.36 Refer to Problem 5.16 on page 187. Use an IRR analysis to determine which of the two alternatives is best. The MARR is 8 percent. Use the repeated lives method to deal with the unequal service lives of the two alternatives.

6.37 Zhe develops truss analysis software for civil engineers. He has the opportunity to contract with at most one of two clients who have approached him with development proposals. One contract pays him \$15 000 immediately and then \$22 000 at the end of the project three years from now. The other possibility pays \$20 000 now and \$5000 at the end of each of the three years. In either case, his expenses will be \$10 000 per year. For a MARR of 10 percent, which project should Zhe accept? Use an appropriate rate of return method.

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6.38 The following table summarizes cash flows for a project:

Year	Cash Flow at End of Year
0	−$5000
1	3000
2	4000
3	−1000

(a) Write out the expression you need to solve to find the IRR(s) for this set of cash flows. Do not solve.

(b) What is the maximum number of solutions for the IRR that could be found in part (a)? Explain your answer in one sentence.

(c) You have found that an IRR of 14.58 percent solves the expression in part (a). Compute the project balances for each year.

(d) Can you tell (without further computations) if there is a unique IRR from this set of cash flows? Explain in one sentence.

6.39 Pepper Properties screens various projects using the payback period method. For renovation decisions, the minimum acceptable payback period is five years. Renovation projects are characterized by an immediate investment of P dollars, which is recouped as an annuity of A dollars per year over 20 years. The company is considering changing to the IRR method for such decisions. If it changed to the IRR method, what MARR would result in exactly the same decisions as its current policy using payback period?

6.40 Three mutually exclusive designs for a bypass are under consideration. The bypass has a 10-year life. The first design incurs a cost of $1.2 million for a net savings of $300 000 per annum. The second design would cost $1.5 million for a net savings of $400 000 per annum. The third has a cost of $2.1 million for a net savings of $500 000 per annum. For each of the alternatives, what range of values for the MARR results in its being chosen? It is not necessary that any be chosen.

6.41 Linus's project has cash flows at times 0, 1, and 2. He notices that for a MARR of 12 percent, the ERR falls exactly halfway between the MARR and the IRR, while for a MARR of 18 percent, the ERR falls exactly one-quarter of the way between the MARR and the IRR. If the cash flow is $2000 at time 2 and negative at time 0, what are the possible values of the cash flow at time 1?

6.42 Charro Environmental is considering taking over a contaminated building site on a former military base. In return for $10 000 000 from the government, it will invest $8 000 000 per year for the following three years to clean up the site. Once the site is clean (end of year 3), it will receive a further $15 000 000 from the government. Over the following two years it will invest $5 000 000 per year constructing a new commercial building on the site. The new building will last forever and net $5 000 000 per year for Charro from tenant leases (starting at the end of year 6). If Charro's MARR is 10 percent, what is the exact ERR for this project? Should Charro proceed with the project? (*Note:* All disbursements can be assumed to occur at the end of the year.)

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MINI-CASE 6.1

The Galore Creek Project

NovaGold Resources is a former gold exploration company that has recently been transforming itself into a gold producer. Its first independent development is the Galore Creek Project. It is also involved as a partner with Placer Dome in another project, and with Rio Tinto in a third. Galore Creek is expected to produce an average of 7650 kilograms of gold, 51 030 kilograms of silver, and 5 670 000 kilograms of copper over its first five years.

In a news release, NovaGold reported that an independent engineering services company calculated that the project would pay back the US$500 million mine capital costs in 3.4 years of a 23-year life. They also calculated a pre-tax rate of return of 12.6 percent and an undiscounted after-tax NPV of US$329 million. All of these calculations were done at long-term average metal prices. At then-current metal prices the pre-tax rate of return almost doubles to 24.3 percent and the NPV (net present value = present worth) increases to US$1.065 billion.

Source: "Higher Grades and Expanded Tonnage Indicated by Drilling at Galore Creek Gold–Silver–Copper Project," news release, August 18, 2004, NovaGold Resources Inc. site, www.novagold.net, accessed May 11, 2008.

Discussion

Companies have a choice of how to calculate the benefits of a project in order to determine if it is worth doing. They also have a choice of how to report the benefits of a project to others.

NovaGold is a publicly traded company. Because of this, when a large and very important project is being planned, not only does NovaGold want to make good business decisions, but it also must maintain strong investor confidence and interest.

In this news release, payback period, IRR, and NPV were used to communicate the value of the Galore Creek project. However, you need to look carefully at the wording to ensure that you can correctly interpret the claims about the economic viability of the project.

Questions

1. "[A]n independent engineering services company calculated that the project would pay back the US$500 million mine capital costs in 3.4 years of a 23-year life." There are a variety of costs associated with any project. The payback period here is calculated with respect to "mine capital costs." This suggests that there might be "non-mine" capital costs—for example, administrative infrastructure, transportation system, etc. It also means that operating costs are not included in this calculation. What do you think is the effect of calculating the payback period on "mine capital costs" alone?
2. "They also calculated a pre-tax rate of return of 12.6 percent. . . ." Taxes reduce the profit from an enterprise and correspondingly reduce the rate of return. As will be seen in Chapter 7, a 50 percent corporate tax rate is fairly common. Thus, if the pre-tax rate is 12.6 percent, the after-tax rate would be about 6.3 percent. Does 6.3 percent seem to you a sufficient return for a capital-intensive, risky project of this nature, given other investment opportunities available?
3. "[A]nd an 'undiscounted' after-tax NPV of US$329 million." The term *undiscounted* means that the present worth of the project was calculated with an interest rate of 0 percent. Using a spreadsheet, construct a graph showing the present worth of the project for a range of interest rates from 0 percent to 20 percent, assuming the annual returns

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for the project are evenly distributed over the 23-year life of the project. Does the reported value of $US329 million fairly represent a meaningful NPV for the project?

4. The returns for the Galore Creek Project are much more attractive at then-current metal prices, which were significantly higher than long-term average metal prices. Which metal prices are more sensible to use when evaluating the worth of the project?
5. Did NovaGold report its economic evaluation of the Galore Creek Project in an ethical manner?

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7.2 Personal Income Taxes and Corporate Income Taxes Compared

There are substantial differences between personal income taxes and corporate income taxes. Most adults are familiar with the routine of filing income tax returns. For most people, the procedure is rather simple: An employer provides a statement reporting the person's income, income tax already paid, and other amounts for the previous year. These amounts are assembled on the tax form and are used to calculate the total tax owed or the amount of a refund. The tax return is then submitted to the appropriate government tax agency for processing.

Corporate taxes are similar in some ways, but there are several substantial differences. One main difference has to do with the tax rate. Personal income taxes usually exhibit a **progressive tax rate**, meaning that people who earn more are charged a larger percentage of their income. For example, if a person's taxable income is very low, he or she might not pay any income taxes. At a moderate income, an individual might be expected to pay, say, 25 percent of his or her income as income tax. A very-high-income individual in some countries might pay 50 percent or more of his or her income in income tax. Although the exact rate of taxation changes from year to year, and varies from country to country, individual income taxes in developed countries are almost always progressive.

In contrast, corporate taxes are typically levied according to a proportional or "flat" tax. This means that corporations pay the same tax rate, regardless of their income level. Again, rates can change over time and between countries, but the rate will be the same whether a company makes a small profit or a very large profit. The main exception is that most countries give smaller companies favourable tax treatment to encourage new businesses. However, once the business is of a certain size, the tax rate is constant.

Another difference between personal income tax and corporate income tax has to do with how the tax is calculated. The income used to determine the taxes an individual pays is reduced by deductions or **tax credits**, which are real or nominal costs that are not taxed or are taxed at a reduced rate. For example, excess medical expenses, tuition fees, and pension plan contributions are generally all considered eligible deductions, along with a substantial "basic personal amount." Thus an individual's "taxable income" can be quite a bit less than his or her actual income.

A corporation's taxes are calculated in quite a different manner. Net income for tax purposes is calculated by subtracting **expenses**, which are either real costs associated with performing the corporation's business or a portion of the capital expense for an asset, from gross income. Consequently, a company that makes no profit (income less expenses) may pay no income taxes.

Finally, personal and corporate taxes differ in complexity. In particular, a company's taxes will usually be complicated by issues concerning **capital expenses**, which are purchases of assets of significant value. Such assets have a strong effect on the income taxes paid by a company, but how they are treated for tax purposes is complex. This is usually not an issue of concern to individuals.

7.3 Corporate Tax Rates

In this chapter, we are concerned only with corporate taxes, and in particular the impact of corporate income taxes on the viability of an engineering project. Table 7.1 compares corporate taxes among several countries, but the actual tax rate applied in any circumstance can be fairly complicated and can depend on the size of the firm, whether it is a

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Table 7.1 Corporate Tax Rates Around the World

Argentina	35%	Germany	25%
Australia	30%	India	30–40%
Austria	25%	Ireland	12.5%
Brazil	34%	Israel	31%
Canada	36.1%	South Africa	29%
China	25%	United Kingdom	28%
France	33.33%	United States	15–35%

manufacturer, its location, and a variety of other factors. Comparing the tax rates in different countries is difficult. For example, some countries provide a full range of health-care services from their tax revenues, while others do not. Certain health-care costs may be, instead, a significant expense for a company. In some countries the total corporate tax is a combination of federal tax and state or provincial tax. Tax rates change over time, and there are sometimes short-term tax reductions or incentives (see Close-Up 7.1) for companies in specific industries. Rather than focusing on the implications of such differences, our concern here is with the basic approach used in determining the impact of taxes on a project. For special tax rules, it is best to check with the appropriate tax agency or a tax specialist.

It is also worth noting that tax rules can change suddenly. For example, in the past 30 years there have been fundamental changes to the corporate tax rules in Canada and other countries. These changes can and have had a significant impact on investments made by companies. Less-significant new rules are introduced every year due to changes in technology, current economic conditions, or political factors. In particular, there are usually opportunities for small technological companies to take advantage of beneficial tax rules, as detailed in Close-Up 7.2.

CLOSE-UP 7.1 Incentives

Governments sometimes try to influence corporate behaviour through the use of *incentives.* These incentives include grants to certain types of projects; for example, projects undertaken in particular geographic areas, or projects providing employment to certain categories of people.

Other incentives take the form of tax relief. For example, several countries allow pollution equipment to be fully expensed in the year of purchase. The ability to depreciate pollution equipment quickly makes it a more desirable investment for a company and a beneficial investment for society as a whole.

The exact form of incentives changes from year to year as governments change and as the political interests of society change. In most companies there is an individual or department that keeps track of possible programs affecting company projects.

Incentives must be considered when assessing the viability of a project. Grant incentives provide additional cash flow to the project that can be taken into account like any other cash flow element. Tax incentives may be more difficult to assess since sometimes, for example, they use other forms of depreciation or may result in different tax rates for different parts of the project.

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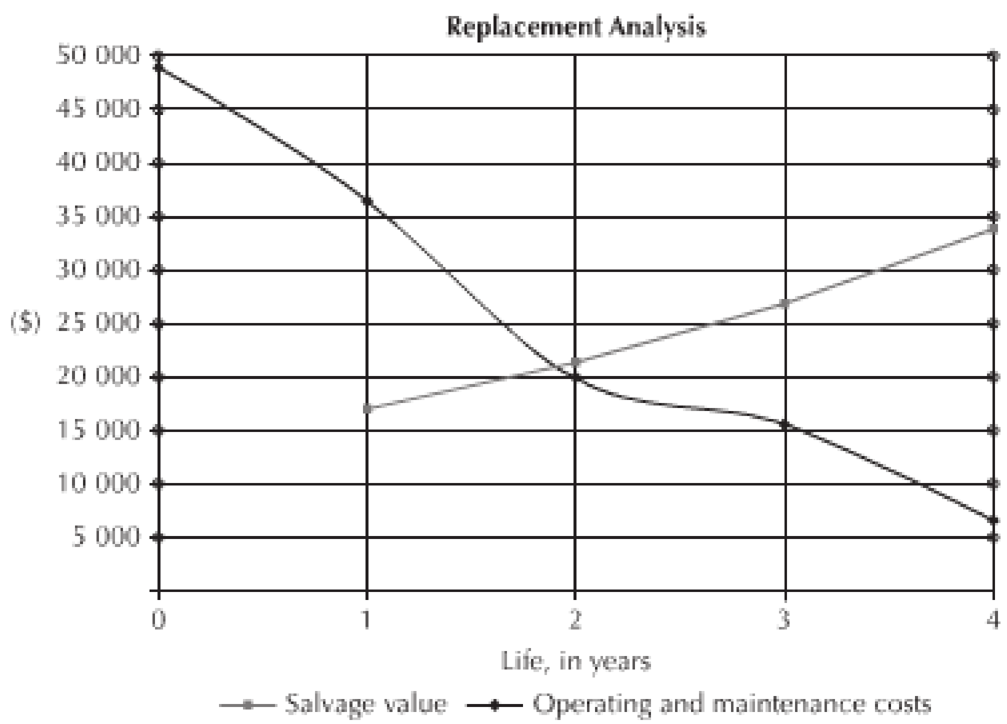
CLOSE-UP 7.2 Small Company Tax Rules

Special tax advantages are given to smaller companies, such as a technically oriented start-up. This may be of particular interest to engineers interested in starting their own firm rather than working for a larger company. The purpose of these incentives is to give a strong motivation to incorporate a new company and provide more after-tax income for reinvestment and expansion.

In Canada, the **small business deduction** applies to small Canadian-controlled private corporations and reduces the effective tax rate for a small Canadian company to less than 20 percent.

SPREADSHEET SAVVY

In Chapters 7 and 9, the Spreadsheet Savvy feature will focus on the use of Excel charts and formatting features useful in the preparation of engineering reports. Spreadsheet software is an excellent tool for preparing charts to summarize the results of an economic analysis. Creating charts with Excel is straightforward. Probably the most commonly used is the X–Y (scatter) chart. It plots a series of Y values as a function of corresponding X values. The scatter chart below was created from the Chapter 8 Spreadsheet Savvy table.



To begin, highlight cells B3:D8 containing the titles and data for Life in Years, Salvage Value, and Operating and Maintenance Costs. Select Insert from the ribbon, and then X–Y (scatter) as the desired chart type. Of the options, the chart above shows "straight lines and markers." By default, the chart will be inserted as an object into the current worksheet. By clicking anywhere on the chart, the ribbon will indicate three chart editing options: Design, Layout, and Format. Under Design, the layout and style of an existing chart can be changed, as well as its location. Under the Layout tab on the ribbon, the location of the legend was changed to below the chart, and the font was changed to enlarge it from its default value. Also under Layout, the gridlines were adjusted to

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show both horizontal and vertical gridlines for the major axis markers. Finally, a chart title was added, as well as both horizontal and vertical axis labels. These options all appear under the Layout tab on the ribbon.

The formatting of the X and Y axes was also changed. When the chart was first made, the maximum Y value displayed was 60 000, and for the X axis it was 5. By hovering over either of the axes or the axes labels and right-clicking, several editing options become available. With the font option for the Y axis, the decimal points were removed and the font size enlarged (to 12pt Arial) and italicized. Under format axis, the maximum value displayed was set to 50 000. Similar changes were made to the X axis, with the maximum value set to 4 and the font size changed to 12pt Arial, italicized. With some practice, most analysts find charts to be a fast and effective tool for summarizing and communicating results from an economic analysis.

7.4 Before- and After-Tax MARR

Taxes have a significant effect on engineering decision making, so much so that they cannot be ignored. In this text, so far, it seems as though no specific tax calculations have been done. In fact, they have been implicitly incorporated into the computations through the use of a before-tax MARR, though we have not called it such.

The basic logic is as follows. Since taxes have the effect of reducing profits associated with a project, we need to make sure that we set an appropriate MARR for project acceptability. If we do not explicitly account for the impact of taxes in the project cash flows, then we need to set a MARR high enough to recognize that taxes will need to be paid. This is the *before-tax* MARR. If, on the other hand, the impact of taxes is explicitly accounted for in the cash flows of a project (i.e., reduce the cash flows by the tax rate), then the MARR used for the project should be lower, since the cash flows already take into account the payment of taxes. This is the *after-tax* MARR.

In fact, we can express an approximate relationship:

$$\text{MARR}_{\text{after-tax}} \cong \text{MARR}_{\text{before-tax}} \times (1 - t) \tag{7.1}$$

where t is the corporate tax rate. The *before-tax* MARR means that the MARR has been chosen high enough to provide an acceptable rate of return without explicitly considering taxes. In other words, since all profits are taxed at the rate t, the *before-tax* MARR has to include enough returns to meet the *after-tax* MARR and, in addition, provide the amount to be paid in taxes. As we can see from the above equation, the after-tax MARR will generally be lower than the before-tax MARR. We will see later in this chapter how the relationship given in this equation is a simplification but a reasonable approximation of the effect of taxes. In practice, the before- and after-tax MARRs are often chosen independently and are not directly related by this equation. Generally speaking, if a MARR is given without specifying whether it is on a before- or after-tax basis, it can be assumed to be a before-tax MARR.

EXAMPLE 7.1

Saskatchewan Gold Mines (SGM) has been selecting projects for investment on the basis of a before-tax MARR of 12 percent. Sherri feels that some good projects have been missed because the effects of taxation on the projects have not been examined in enough detail, so she proposed reviewing the projects on an after-tax basis. What would be a good choice of after-tax MARR for her review? SGM pays 45 percent corporate taxes.

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Although the issue of selecting an after-tax MARR is likely to be more complicated, a reasonable choice for Sherri would be to use Equation (7.1) as a way of calculating an after-tax MARR for her review. This gives

$$\text{MARR}_{\text{after-tax}} = 0.12 \times (1 - 0.45) = 0.066 = 6.6\%$$

A reasonable choice for after-tax MARR would be 6.6 percent. ■

It is important to know when to use the after-tax MARR and when to use a before-tax MARR. In general, if you are doing an approximate calculation without taking taxes into account explicitly, then you should use a before-tax MARR. Thus, all the examples in this book up to this point were appropriately done using a before-tax MARR, boosted to account for the fact that profits would be taxed. However, when considering taxes explicitly in calculations, the after-tax MARR should be used. There is no need to increase the decision threshold when the profits that are lost to taxes are already taken into account.

7.5 The Effect of Taxation on Cash Flows

There is a set of cash flows that arises whenever an investment is made. Consider the following example.

EXAMPLE 7.2(a)

Ebcon Corp. is considering purchasing a small device used to test printed circuit boards that has a first cost of \$45 000. The tester is expected to reduce labour costs and improve the defect detection rate so as to bring about savings of \$23 000 per year. Additional operating costs are expected to be \$7300 per year. The salvage value of the tester will be \$5000 in five years. The corporate tax rate is $t = 42$ percent and the after-tax MARR is 12 percent. ■

There are three key cash flow elements in this example.

- First cost: the \$45 000 investment. This is a negative cash flow made at time zero.
- Net annual savings: the \$23 000 per year savings less the \$7300 additional operating costs for a net \$15 700 positive cash flow at the end of each of years one to five.
- Salvage value: the \$5000 residual value of the tester at the end of its service life in five years.

Each of these cash flow elements is affected by taxes, and in different ways.

In this section we will explore the influence of corporate taxes on the cash flows for this investment under simplified tax rules that are not very common in Canada. The actual rules of the Canadian tax system are quite complicated—probably the most complicated in the world—and are better dealt with after the basic principles have been established.

7.5.1 The Effect of Taxes on First Cost

Companies are taxed on net profits, which are revenues less expenses. Consequently, when an expense is incurred, less tax is paid. From this perspective, although the tester in

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Example 7.2(A) had a first cost of \$45 000, if this first cost could be recognized as an immediate expense, there would be a tax savings of \$45 000 × 0.42 = \$18 900. However, the tax benefits are usually claimed at the end of a tax year. Assuming that the tester was purchased at the beginning of the year, and the tax savings accrue at the end of that same year, then the present worth of the first cost of the tester would only be −\$45 000 + \$18 900(P/F,12%,1) = −\$45 000 + \$18 900 (0.89286) ≅ −\$28 000.

However, by tax rules, capital purchases such as production equipment cannot usually be fully claimed as an expense in the year in which the purchase occurred. The logic is based on the idea of depreciation. Assets retain value over time. Their loss in value, as opposed to their cost, is what tax rules generally recognize as an eligible expense.

Given a choice, a firm would want to write off (i.e., depreciate) an investment as quickly as possible. Since depreciation is considered an expense and offsets revenue, the earlier the expense is recognized, the earlier the tax savings will accrue. Since money earlier in time is worth more than the same amount of money later in time, there is good reason to depreciate capital assets as quickly as allowable. This effect of reducing taxes can be considerable.

Although companies would, of course, like to reduce taxes by writing off their assets as quickly as possible, there are also undesirable effects of doing this. For one thing, it may lead to accounting documents that are not representative of a firm's actual financial situation. For example, if valuable capital assets are assigned—for tax reasons—to have an excessively low book value, this may underrepresent the true value of the company as a whole. It may also create an opportunity for inefficient business decisions. From the perspective of the government imposing the taxes, it can lead to companies improperly exploiting the tax rules.

To counter these undesirable effects, tax authorities have carefully defined the depreciation methods they permit for use in computing taxes. The permitted methods for claiming depreciation expenses may not reflect the true depreciation of an asset, as they are rule-oriented rather than truly attempting to recognize the diminishment in value of an asset. Consequently, the depreciation charge is referred to by a different name—the *capital cost allowance*—to recognize that the book value implied by the taxation-related depreciation charges does not necessarily represent a good estimate of the asset's market value. However, there is usually a fair correspondence between capital cost allowance and depreciation, and many firms do not distinguish between them in calculations for their financial statements. It is therefore reasonable to think of them as being the same thing for most purposes.

EXAMPLE 7.2(B)

Tax rules for Ebcon Corp. (see Example 7.2(A)) specify that the capital allowance for the tester be calculated as straight-line depreciation over the life of the tester. What is the present worth of the tester's first cost?

This seems like an odd question, but it results from the fact that in a taxed company, the first cost immediately gives rise to future tax savings. This example is consistent with one of the depreciation methodologies occasionally permitted as an investment incentive in Canada.

As illustrated in Figure 7.1, the first cost of \$45 000 gives rise to benefits in the form of an annuity of 45 000 × 0.42/5 = \$3780. In a sense, the presence of taxes transforms the \$45 000 purchase into a more complex set of cash flows consisting of not only the first cost but also a substantial annuity.

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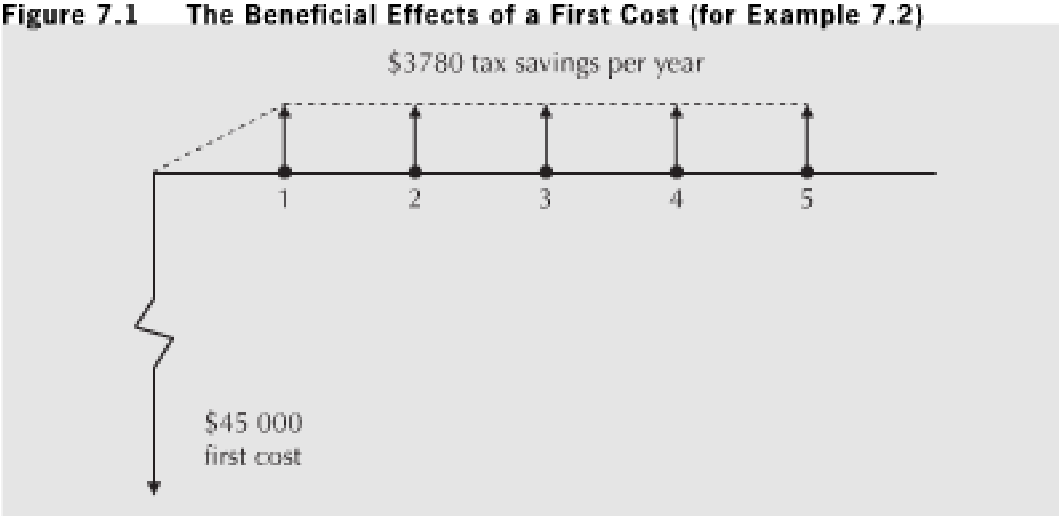
Figure 7.1 The Beneficial Effects of a First Cost (for Example 7.2)



The present worth of the first cost is then:

$$PW_{\text{first cost}} = -45\ 000 + 3780(P/A,12\%,5) = -45\ 000 + 3780(3.6048) \cong -31\ 400$$

The present worth of the tester's first cost is about −$31 400. ■

Note that this result is more costly for Ebcon by about $31 400 − $28 000 = $3400 than if Ebcon could expense the entire tester in the year of purchase. This difference is the present worth of the increased taxes that the government receives by not allowing Ebcon to count the tester as an expense in the year that it was purchased.

7.5.2 The Effect of Taxes on Savings

Although in a taxed business environment the first cost is reduced, this is balanced by the fact that the savings from the investment are also reduced. An underlying assumption is that any investment decision is made in a profitable company for which this decision is a relatively small part of the overall business. Consequently, if any money is saved, those savings increase the profits of the firm. And since profits are taxed at the tax rate, the net savings are reduced proportionally.

EXAMPLE 7.2(C)

What is the present worth of the annual net savings created by the tester?

The approach used is to reduce the net annual savings of the tester by the tax rate, as illustrated in Figure 7.2, and then bring the amount to a present worth:

$$\begin{aligned} PW_{\text{savings}} &= (23\ 000 - 7300) \times (1 - 0.42) \times (P/A,12\%,5) \\ &= 15\ 700 \times 0.58 \times 3.6048 \\ &\cong 32\ 800 \end{aligned}$$

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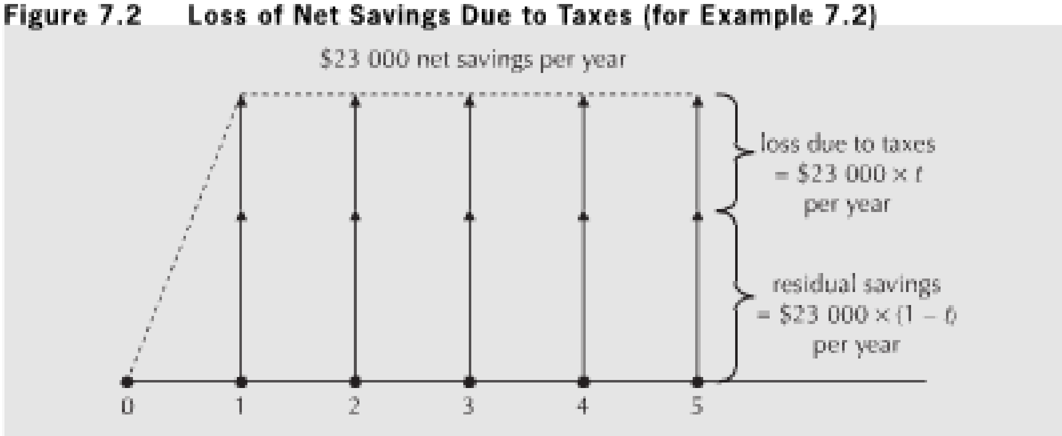
Figure 7.2 Loss of Net Savings Due to Taxes (for Example 7.2)

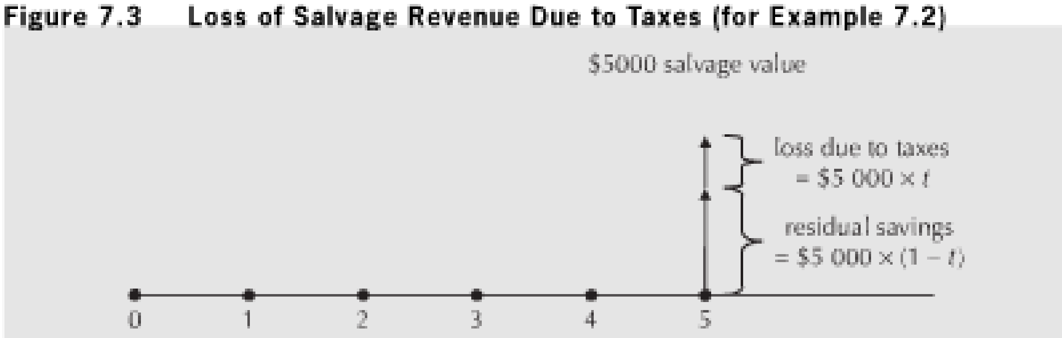


The present worth of net savings created by the tester is about $32 800. ■

7.5.3 The Effect of Taxes on Salvage or Scrap Value

When an asset is salvaged or scrapped, unless the value received is zero, money comes into the firm as income (we do not deal with the complications of negative salvage values in this text). Any money received that is in excess of the asset's remaining book value is new revenue and is taxable. Under the depreciation scheme described for Example 7.2, at the end of the tester's service life, its book value for tax purposes is zero. In this case, all money obtained by salvaging or selling it counts as revenue and is taxed at the tax rate. This is illustrated in Figure 7.3.

Figure 7.3 Loss of Salvage Revenue Due to Taxes (for Example 7.2)



In other circumstances, at the time an asset is sold, it may have remaining book value for taxation purposes. In this case, different things happen depending on the jurisdiction. The specific treatment in Canada will be discussed later.

However, for Example 7.2, the situation is straightforward.

EXAMPLE 7.2(D)

What is the present worth of the salvage value of the tester?

This amount is fully taxable since the book value of the tester will be zero. The approach used is to reduce the amount by the tax rate and then bring the result to a present worth:

$$\begin{aligned} PW_{salvage} &= 5000 \times (1 - 0.42) \times (P/F, 12\%, 5) \\ &= 5000 \times 0.58 \times 0.56743 \\ &= 1646 \end{aligned}$$

The present worth of the salvage value of the tester is $1646. ■

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7.6 Present Worth and Annual Worth Tax Calculations

As seen in the previous three sections, a complete tax calculation consists of recognizing how the existence of taxes affects each of the components of an investment. For a present worth comparison, each of the component cash flows is converted to a present worth and summed. In particular:

First cost: Add the present worth of tax savings due to depreciation expenses to the first cost.

Savings or expenses: Multiply by $(1 - t)$ and convert to present worth.

Salvage or Scrap value: For this simple example, multiply by $(1 - t)$ and convert to present worth. In general, things are more complicated, as we will see once we look at the details of the Canadian tax system.

EXAMPLE 7.2(E)

What is the present worth of the tester investment decision?

$$\begin{aligned}
PW_{\text{first cost}} &= -45\,000 + 3780(P/A,12\%,5) \\
&= -45\,000 + 3780(3.6048) \\
&= -31\,374 \\
PW_{\text{savings}} &= (23\,000 - 7300) \times (1 - 0.42) \times (P/A,12\%,5) \\
&= 15\,700 \times 0.58 \times 3.6048 \\
&= 32\,825 \\
PW_{\text{salvage}} &= 5000 \times (1 - 0.42) \times (P/F,12\%,5) \\
&= 5000 \times 0.58 \times 0.56743 \\
&= 1646 \\
PW_{\text{total}} &= -31\,374 + 32\,825 + 1646 \\
&= 3097
\end{aligned}$$

The present worth of the tester is \$3097. This is an acceptable investment at the given after-tax MARR. ■

Very similar calculations can be done if an annual worth comparison is desired, except that each of the component cash flows is converted to an annual worth and summed. In particular:

First cost: Convert the first cost to an annuity and add it to the annual tax savings due to depreciation expenses.

Savings or expenses: Multiply by $(1 - t)$ and convert to annual worth.

Salvage or Scrap value: For this simple example, multiply by $(1 - t)$ and convert to annual worth. In general, things are more complicated, as we will see once we look at the details of the Canadian tax system.

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EXAMPLE 7.2(F)

What is the annual worth of the tester?

$$\begin{aligned}
AW_{\text{first cost}} &= -45\,000(A/P,12\%,5) + 3780 \\
&= -45\,000 \times (0.27741) + 3780 \\
&= -8703 \\
AW_{\text{savings}} &= (23\,000 - 7300) \times (1 - 0.42) \\
&= 15\,700 \times 0.58 \\
&= 9106 \\
AW_{\text{salvage}} &= 5000 \times (1 - 0.42) \times (A/F,12\%,5) \\
&= 5000 \times 0.58 \times 0.15741 \\
&= 456 \\
AW_{\text{total}} &= -8703 + 9106 + 456 \\
&= 859
\end{aligned}$$

The annual worth of the tester is $859 per year. This is an acceptable investment at the given after-tax MARR. ■

7.7 IRR Tax Calculations

7.7.1 Accurate IRR Tax Calculations

As has been demonstrated, the effect of taxation is to modify the pre-tax cash flows. The after-tax IRR is simply the IRR calculated on the after-tax cash flows.

EXAMPLE 7.2(G)

What is the accurate after-tax IRR of the tester investment decision?

We answer this question by setting the sum of present worth of receipts and the present worth of disbursements to zero and solving for the unknown interest rate, i^*:

$$\begin{aligned}
45\,000 &= (45\,000/5) \times 0.42 \times (P/A,i^*,5) + 15\,700 \\
&\quad \times (1 - 0.42) \times (P/A,i^*,5) + 5000(1 - 0.42)(P/F,i^*,5) \\
45\,000 &= (3780 + 15\,700 \times 0.58) \\
&\quad \times (P/A,i^*,5) + 5000 \times 0.58 \times (P/F,i^*,5)
\end{aligned}$$

Solving through trial and error results in: $i^* = IRR_{\text{after-tax}} = 14.7\%$

This exceeds the acceptance threshold of after-tax MARR of 12 percent and therefore is an acceptable investment.

Alternatively, set the sum of the annual worth of receipts and the annual worth of the disbursements to zero and solve for i^*:

$$\begin{aligned}
45\,000(A/P,i^*,5) &= 45\,000/5 \times 0.42 + 15\,700 \\
&\quad \times (1 - 0.42) + 5000(1 - 0.42) \times (A/F,i^*,5)
\end{aligned}$$

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$$45\,000 = [3780 + 15\,700 \times 0.58 + 5000 \times 0.58 \times (A/F,i^*,5)]/(A/P,i^*,5)$$
$$= [12\,886 + 5000 \times 0.58 \times (A/F,i^*,5)]/(A/P,i^*,5)$$

Solving through trial and error results in: $i^* = \text{IRR}_{\text{after-tax}} = 14.7\%$

This exceeds the acceptance threshold of after-tax MARR of 12 percent and therefore is an acceptable investment. ■

7.7.2 Approximate After-Tax Rate-of-Return Calculations

The IRR is probably one of the most popular means of assessing the desirability of an investment. Unfortunately, a detailed analysis can be somewhat involved. However, an approximate IRR analysis when taxes are explicitly considered can be very easy. The formula to use is:

$$\text{IRR}_{\text{after-tax}} \cong \text{IRR}_{\text{before-tax}} \times (1 - t) \tag{7.2}$$

The reasons for this are exactly the same as described in Section 7.4 for the before- and after-tax MARR. It is an approximation that works because the IRR represents the percentage of the total investment that is net income. Since the tax rate is applied to net income, it correspondingly reduces the IRR by the same proportion. It is not exactly correct because it assumes that expenses offset receipts in the year that they occur. Consequently, if the after-tax IRR is close to the after-tax MARR, a more precise calculation is advisable so that the correct decision is made.

EXAMPLE 7.2(H)

What is the approximate after-tax IRR of the tester investment?

We first find the before-tax IRR by setting the present worth of the disbursements equal to the receipts and solving for the interest rate:

$$45\,000 = 15\,700(P/A,i,5) + 5000(P/F,i,5)$$

Through trial and error, we find that the before-tax IRR is 23.8 percent. The after-tax IRR is then calculated as:

$$\text{IRR}_{\text{after-tax}} = \text{IRR}_{\text{before-tax}} \times (1 - t)$$
$$= 0.238(1 - 0.42)$$
$$= 0.13804$$

The approximate IRR of 13.8 percent is somewhat lower than the accurate IRR of 14.7 percent. If the after-tax MARR were 14 percent rather than 12 percent, it would have given rise to an incorrect investment decision. ■

When doing an after-tax IRR computation in practice, the approximate after-tax IRR can be used as a first pass on the IRR computation. If the approximate after-tax IRR turns out to be close to the after-tax MARR, a precise after-tax IRR computation may be required to make a fully informed decision about the project.

EXAMPLE 7.3

Essen Industries pays 40 percent corporate income taxes. Its after-tax MARR is 18 percent. A project has a before-tax IRR of 24 percent. Should the project be approved? What would your decision be if the after-tax MARR were 14 percent?

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$$\begin{aligned}\text{IRR}_{\text{after-tax}} &= \text{IRR}_{\text{before-tax}} \times (1 - t)\\ &= 0.24(1 - 0.40)\\ &= 0.144\end{aligned}$$

The after-tax IRR is approximately 14.4 percent. For an after-tax MARR of 18 percent, the project should not be approved. However, for an after-tax MARR of 14 percent, since the after-tax IRR is an approximation, a more detailed examination would be advisable. ■

In summary, we can simplify after-tax IRR computations by using an easy approximation. The approximate after-tax IRR may be adequate for decision making in many cases, but in others a detailed after-tax analysis may be necessary.

7.8 Specific Tax Rules in Canada

The tax calculations illustrated in Examples 7.2(A) through 7.2(G) were based on a tester that was subject to straight-line depreciation over its life. It would be convenient if the Canadian tax system permitted straight-line depreciation for all investments, as is the case in some countries, but our system is more complex. In Canada, most assets must be depreciated using the declining-balance method where the depreciation rate depends on the type of asset. The regulations are set out in the capital cost allowance (CCA) system.

7.8.1 The Capital Cost Allowance System

When a firm buys a depreciable asset for use in its business, a capital expense is incurred. This is the expenditure associated with the purchase of a long-term depreciable asset. (Almost all tangible assets are depreciable; the primary exception to this is land.) Since the capital asset loses value over time, the firm may deduct the capital expense over a period of years by claiming a depreciation expense each year of the asset's useful life. The depreciation is recorded in two ways. First, it is recorded in the firm's balance sheet as a reduction in the book value of the asset. Second, it is recorded as a depreciation expense on the income statement. In this way, depreciation reduces the before-tax income even though there has been no out-of-pocket cash expense.

NET VALUE 7.1

Canada Revenue Agency Website

The Canada Revenue Agency website (www.cra-arc.gc.ca) is a very rich and complete source of information about tax rules. However, because there are so many different types of users and special cases, it is not always easy to find the information you are looking for.

There is a built-in search engine that can be very helpful but may provide more hits than are useful, and the order of the responses may not be convenient. For example, a recent key phrase of "CCA rates" gave CCA rates of interest to farmers and fishers, along with several other more specific rates, before presenting a link to a description of CCA rates generally applicable in business.

Another approach may be to seek out publications directed at your area of interest. For example, the publication TA4002(E) Business and Professional Income provides very good information about taxes for businesses that would be of interest to anyone who would like to start their own business.

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In general, a firm will want to "write off" (i.e., depreciate) a capital investment as quickly as possible. This is because depreciation is considered an expense that offsets revenue and thus reduces net income. Since net income is taxed, taxes can be deferred or reduced by depreciating assets quickly. The effect of deferring taxes can be considerable. To counter this effect, the Canadian tax system defines a specific amount of depreciation that companies may claim in any year for any one depreciable asset. This amount is called the **capital cost allowance, CCA**. In this section, we demonstrate how to apply CCA rules to investment decisions and compare the CCA to depreciation claimed for accounting records.

EXAMPLE 7.4

In the imaginary country of Monovia, companies can depreciate their capital asset purchases as fast as they wish. Clive Cutler, owner of Monovia Manufacturing, has just bought equipment worth \$200 000. Two spreadsheets (Tables 7.2 and 7.3) illustrate the effect of different depreciation strategies over a five-year period assuming the following:

1. Income is \$300 000 per year.
2. Expenses excluding depreciation are \$100 000 per year.
3. The tax rate is 50 percent.
4. Available cash is invested at 10 percent interest.
5. The salvage value of the equipment after five years is zero.

Table 7.2 illustrates the case in which the equipment is fully depreciated in the first year, although it generates revenue over its five-year life. In Table 7.3, straight-line depreciation is used over the five-year life.

When we look at the effects of depreciation on economic analyses, it is important to distinguish between expenses that represent a cash outflow and expenses that do not. Purchasing an asset such as a piece of equipment will produce a cash outflow at the time the purchase is made. In particular, the balance sheet will reflect a transfer out of current assets (cash) and a transfer into fixed assets (equipment) and perhaps to current liabilities (bank loan).

Depreciation, on the other hand, does not actually represent a cash outflow, although it is recorded as an expense in the income statement. For example, in Table 7.2, writing off the entire cost of the equipment in its first year produced a depreciation expense of \$200 000 in that year. There was no actual cash outflow due to the depreciation (although there was for the actual purchase of the asset), but depreciation caused the net income to be reduced to zero for that year, even though \$200 000 in cash was actually available.

Table 7.2 Full Depreciation in One Year

Year	1	2	3	4	5
Income	\$300 000	\$300 000	\$300 000	\$300 000	\$300 000
Expenses excluding depreciation	100 000	100 000	100 000	100 000	100 000
Depreciation expense	200 000	0	0	0	0
Net income	0	200 000	200 000	200 000	200 000
Taxes	0	100 000	100 000	100 000	100 000
Profit	0	100 000	100 000	100 000	100 000
Cash	200 000	100 000	100 000	100 000	100 000
Accumulated cash	200 000	320 000	452 000	597 200	756 920

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Table 7.3 Straight-Line Depreciation Over Five Years

Year	1	2	3	4	5
Income	$300 000	$300 000	$300 000	$300 000	$300 000
Expenses excluding depreciation	100 000	100 000	100 000	100 000	100 000
Depreciation expense	40 000	40 000	40 000	40 000	40 000
Net income	160 000	160 000	160 000	160 000	160 000
Taxes	80 000	80 000	80 000	80 000	80 000
Profit	80 000	80 000	80 000	80 000	80 000
Cash	120 000	120 000	120 000	120 000	120 000
Accumulated cash	120 000	252 000	397 200	556 920	732 612

Investing the $200 000 for the second year at 10 percent interest produces an accumulated cash amount of $220 000. Adding this to the profit of $100 000 for the second year gives accumulated cash of $320 000 at the end of the second year. Continuing in this fashion produces accumulated cash of $756 920 at the end of the five-year period.

In contrast, if the equipment is depreciated on a straight-line basis over five years, only $732 612 in cash is accumulated. This can be seen by working through the expenses, net income, taxes, and profit for each year. For example, in year 1, a (straight-line) depreciation expense of $200 000/5 = $40 000 is claimed. This reduces net income by $40 000 to $160 000 and leaves after-tax profits of $80 000. Now, as before, the depreciation expense of $40 000 is not a cash outflow, so the cash actually available to invest at the end of the first year is the $80 000 profit plus $40 000. Since the depreciation expense is constant with the straight-line method, a cash amount of $120 000 will be available for investment at the end of each of the five years. As such, at the end of five years, the accumulated cash will be $732 612. This is $24 308 less than when the equipment was fully depreciated in the first year because taxes were delayed by depreciating more of the asset's value earlier. The extra income that was available earlier for investment allowed more interest to accumulate over the five-year period. The $24 308 is significant and illustrates why faster depreciation is preferred to slower depreciation.

There are several generally accepted depreciation methods. The most prevalent methods in Canada are straight-line and declining-balance. For the purposes of preparing financial statements for investors, a firm may use any or all of the generally accepted methods for calculating depreciation expenses, provided that the method used is the same from period to period. However, if companies had the freedom to depreciate as they wanted to for tax purposes, they would depreciate their assets immediately, since they would get the largest benefit because of tax savings.

Governments have a different perspective. They would prefer to receive taxes as quickly as possible and would want companies to depreciate assets as slowly as possible to keep taxable income as high as possible and produce the most taxes. In order to limit the depreciation amount that companies use for tax purposes, the Canadian government has established a maximum level of capital cost expense (i.e., depreciation) that a company can claim each year, referred to as the firm's CCA. The CCA system specifies the amount and timing of depreciation expenses on capital assets. According to this system, the declining-balance method of depreciation must be used for claiming capital costs associated with most tangible assets. Straight-line depreciation is only used for certain intangible assets. We are mainly concerned with tangible assets, so our discussion will focus on the declining-balance method of depreciation.

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Table 7.4 Sample CCA Rates and Classes

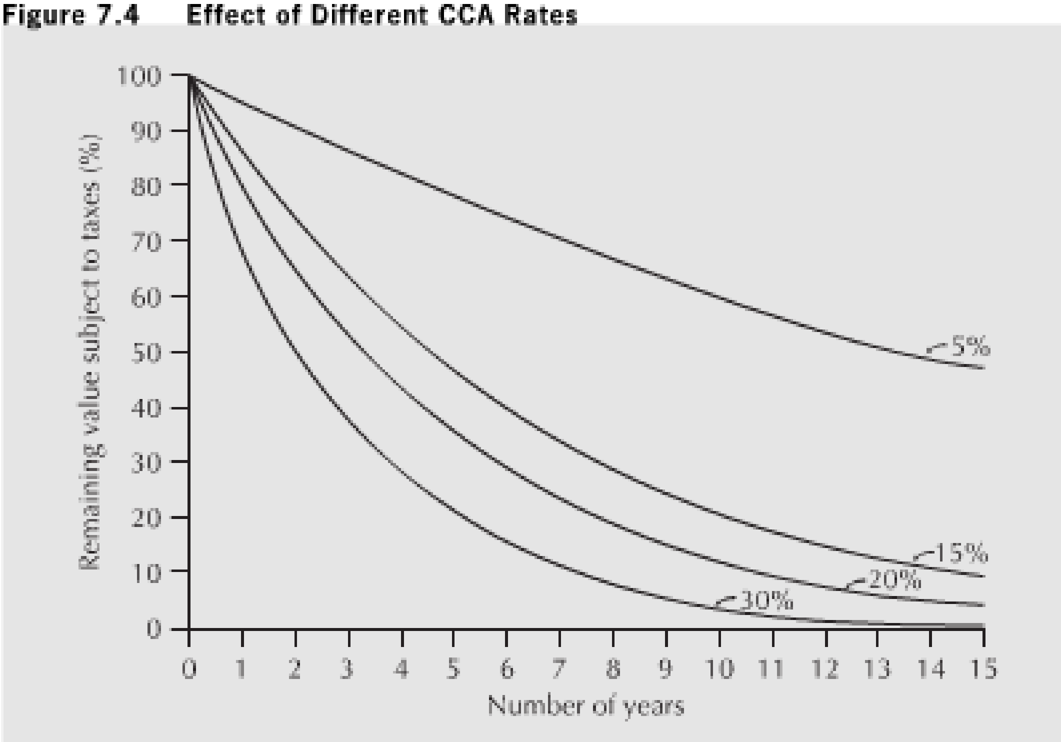
CCA Rate (%)	Class	Description
4 to 10	1, 3, 6	Buildings and additions
20	8	Machinery, office furniture, and equipment
25	9	Aircraft, aircraft furniture, and equipment
30	10	Passenger vehicles, vans, trucks, computers, and systems software
40	16	Taxis, rental cars, and freight trucks; coin-operated video games
100	12	Dies, tools, and instruments that cost less than $500; computer software other than systems software

The **CCA system** specifies the maximum rate a firm can use to depreciate its assets for tax purposes—the **CCA rate**. To implement the CCA system, a firm's assets are grouped by **CCA asset class**, for which a specified CCA rate is used to compute the CCA. For example, all assets classified as office equipment (desks, chairs, filing cabinets, copiers, and the like) are grouped together, and depreciation expenses are based on the total remaining undepreciated cost of all assets in that class. Some examples of CCA rates and CCA asset classes are given in Table 7.4.

In addition to these standard rates, special rates may be set by the government to encourage certain kinds of investments as an incentive. Close-up 7.2 on page 241 discussed the general idea of government incentives.

Figure 7.4 illustrates how the remaining value of an asset subject to taxes diminishes within the standard range of CCA rates.

Figure 7.4 Effect of Different CCA Rates



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While the capital cost allowance and depreciation expenses are conceptually similar, it is important to distinguish between the two. In determining net income, depreciation expenses are deducted from revenues. This is the net income for accounting purposes. For tax purposes, however, we need to determine taxable net income. We start with the accounting net income, add back the depreciation expense for accounting purposes, and then deduct the CCA. This will lead to a figure for net income that is different from that used for accounting purposes. Given the complexities of the tax system, it is possible that this difference can be a large amount. For our purposes, we need only to distinguish between the depreciation for accounting purposes and the depreciation the firm can claim via the capital cost allowance, which is depreciation for tax purposes. ■

7.8.2 Undepreciated Capital Cost and the Half-Year Rule

The basis for calculating the capital cost allowance for assets in a particular asset class is the total **undepreciated capital cost (UCC)** of the assets included in that class. The capital cost of an asset when it is purchased is the total cost of acquiring the asset. This includes the purchase price, installation cost, transportation cost, legal fees, accounting costs, and possibly other costs over and above the purchase price. As the asset is depreciated, companies keep track of the undepreciated portion of the original capital cost through a UCC account. The UCC is the remaining book value for the assets subject to depreciation for taxation purposes, which may or may not differ from the market or salvage value.

The undepreciated capital cost for each asset is not usually recorded individually within a class; instead, assets in each class are pooled and only one account is maintained for each asset class. The capital cost allowance for a particular asset class is then calculated from the CCA rate for that class and its UCC.

Prior to November 13, 1981, a company was allowed to include in its base for the calculation of CCA the full purchase price of an asset purchased within the year, regardless of when the asset was purchased during the taxation year. Consequently, there was considerable motivation for companies to purchase assets at the end of their fiscal year. Recognizing the substantial tax losses brought about in this manner, the Canadian government changed the rules effective Friday, November 13, 1981. Since that date, only half of the capital cost of acquiring an asset is considered in the CCA in the year of purchase of that asset, while the other half is included in the following year. This is commonly referred to as the "half-year rule" in the CCA system.

To see the effect of this change and to illustrate the UCC account, consider a company that has just purchased a $1 000 000 piece of equipment. For simplicity, we will assume that this equipment is the only equipment in its class. The CCA rate for the equipment is 20 percent and the company's tax rate is 50 percent. Table 7.5 shows the

Table 7.5 UCC Amounts Using Pre-1981 CCA Rules

Year	Adjustments to UCC from Purchases and Dispositions	Base UCC Amount for Capital Cost Allowance	Capital Cost Allowance	Remaining UCC	Tax Savings Due to the CCA
1	$1 000 000	$1 000 000	$200 000	$800 000	$100 000
2	0	800 000	160 000	640 000	80 000
3	0	640 000	128 000	512 000	64 000
4	0	512 000	102 400	409 600	51 200

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company's UCC amounts for the first four years of the asset's life, assuming that the purchase was made before the 1981 tax rule change. Table 7.6 shows equivalent figures assuming that the purchase was made after the 1981 tax change.

To explain some of the amounts, we will start with Table 7.5, showing the pre-1981 rules. The UCC at the end of the year in which the asset was bought, prior to claiming the CCA, was the purchase cost of the asset. The CCA rate for the equipment was 20 percent.

Thus the company could claim a capital cost allowance of 20 percent of the $1 000 000 for the first year, leaving a UCC of $800 000 at the end of the first year. In the second year, the CCA amount is 20 percent of the UCC from the end of the previous year: 20 percent of $800 000 = $160 000. The UCC of the asset thus declined by 20 percent of the current book value each year as the CCA rate is applied to the undepreciated capital cost from the previous year.

Table 7.6 shows what happens to the UCC account if it is assumed that the purchase occurred after the 1981 CCA tax regulation change. In the year of purchase, the full first cost of $1 000 000 can be added to the UCC account, but only half of that amount is subject to a CCA claim. Thus the CCA amount in the first year is 20 percent of $500 000, leaving a balance of $900 000 of undepreciated capital cost. The CCA amount for the second year is then 20 percent of $900 000, or $180 000. The remainder of the CCA calculations are computed as usual.

Table 7.6 UCC Amounts Using Post-1981 CCA Rules

Year	Adjustments to UCC from Purchases and Dispositions	Base UCC Amount for Capital Cost Allowance	Capital Cost Allowance	Remaining UCC	Tax Savings Due to the CCA
1	$1 000 000	$500 000	$100 000	$900 000	$50 000
2	0	900 000	180 000	720 000	90 000
3	0	720 000	144 000	576 000	72 000
4	0	576 000	115 200	460 800	57 600

Notice that the CCA expenses generate tax savings by reducing taxable income. At a 10 percent interest rate, the present worth of the tax savings using the pre-1981 rules is $240 079, while that for the post-1981 rules is only $213 271.

Since the change in the tax law pertaining to the half-year rule in 1981, there still remains an incentive to purchase equipment at the end of the (fiscal) year. However, the incentive has been reduced as the tax effects have been diminished.

The previous example illustrated a simple case in which only one asset was purchased. In fact, a company typically purchases assets over time and disposes of them when they are no longer required. It is important to note that, if an asset is disposed of in the same year that another one in the same CCA class is purchased, the disposal amount (for the class) is subtracted from the purchase amount (for the class) before applying the half-year rule. For any given year, the UCC balance can be calculated as follows:

$$UCC_{opening} + \text{additions} - \text{disposals} - CCA = UCC_{ending}$$

Table 7.7 summarizes the effect of the half-year rule under various circumstances.

To illustrate the use of UCC accounts when several assets of the same class are acquired and then disposed of, consider Example 7.5.

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Table 7.7 Summary: The Half-Year Rule

Component	Treatment
Purchase	Add only half of the purchase cost of an asset to the base UCC amount for its CCA class in the year of purchase. After the CCA calculation, add the other half to the remaining UCC (note that the second half is not considered an acquisition in the following year).
Disposition	Subtract the full amount received for a disposition of an asset from the base UCC amount for its CCA class.
Purchases and Dispositions in class Same year	Subtract total dispositions from total purchases for a CCA. If the remainder is positive, treat it as a purchase. If the remainder is negative, treat it as a disposition.

EXAMPLE 7.5

Egonomical Corporation, an injection-moulding firm, is planning to set up business. It will purchase two used injection moulders for \$5000 each in 2012, a new, full-featured moulder for \$20 000 in 2013, and a computer controller for the new moulder for \$5000 in 2017. One used moulder will be salvaged for \$2000 in 2017, and the other for the same amount in 2012. If the CCA rate for all these assets is 20 percent, determine the balance in the UCC account in years 2012 to 2019.

Table 7.8 illustrates the calculations for the UCC balance for Example 7.5. It can be assumed that the original balance is zero, since the company is just starting up. In 2012, purchases totalling \$10 000 were made. However, only half of that amount, \$5000, is used for the CCA calculations because of the half-year rule. At 20 percent, the CCA claim is then \$1000. The UCC account for that class is increased by the full amount of the purchase, so subtracting the \$1000 from the UCC results in a balance of \$9000. In 2013, a purchase of \$20 000 increases the amount subject to the UCC to \$19 000 (since

Table 7.8 UCC Computations with Several Changes in Asset Holdings

Year	Adjustments to UCC from Purchases and Dispositions	Base UCC Amount for Capital Cost Allowance	Capital Cost Allowance	Remaining UCC
2012	\$10 000	\$ 5 000	\$1 000	\$ 9 000
2013	20 000	19 000	3 800	25 200
2014	0	25 200	5 040	20 160
2015	0	20 160	4 032	16 128
2016	0	16 128	3 226	12 902
2017	3 000	14 402	2 880	13 022
2018	(2 000)	11 022	2 204	8 817
2019	0	8 817	1 763	7 054

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only half of the cost of the new purchase can be included in 2013), resulting in a CCA claim for that year of \$3800. The UCC balance is calculated as \$9000 + \$20 000 − \$3800 = \$25 200. For years 2014 to 2016, the CCA claim is simply 20 percent of the UCC balance for the previous year, since no acquisitions or disposals are made.

In 2017, two transactions occurred. A computer controller is purchased for \$5000 and a moulder is salvaged for \$2000. This results in a net positive adjustment to the UCC account of \$3000. It is this \$3000 that is subject to the half-year rule. The UCC amount for CCA calculations is half of this amount plus the UCC balance from the previous year: \$1500 + \$12 902 = \$14 402. The UCC balance at the end of 2017 includes the whole \$3000 amount: \$12 902 + \$3000 − \$2880 = \$13 022. The negative adjustment in 2018 is not subject to the half-year rule since the rule only applies to net purchases over the year, so the UCC amount for CCA calculations is \$2000 less than the previous year's balance. In 2019, there are no adjustments to the UCC account other than the CCA claim, leaving a final balance of \$7054. ■

7.8.3 The Capital Tax Factor and Capital Salvage Factor

From Tables 7.2 and 7.3, it is clear that the CCA creates tax savings. For example, if an asset with a CCA rate of 20 percent is purchased for \$100 000, this provides a CCA claim of \$10 000 in the year of purchase. With a tax rate of 50 percent, this deduction from income saves \$5000 in taxes that would not have occurred if the \$100 000 had not been spent for the asset in the first place. Therefore, the present worth equivalent of the first cost of the asset is actually less than \$100 000—it is reduced by the present worth of all of the tax savings that result from its depreciation in all future years. In this example, the tax savings for each year of the asset's life are shown in Table 7.9.

$$\begin{aligned}\text{Present worth of tax savings} &= \$5000(P/F,i,1) + \$9000(P/F,i,2)\\ &\quad + \$7200(P/F,i,3) + \$5760(P/F,i,4)\\ &\quad + \$4608(P/F,i,5) + \ldots\end{aligned}$$

The present worth of the tax savings essentially reduces the first cost of the investment because making the investment and depreciating it over time brings about tax benefits. The **capital tax factor (CTF)** is a value that summarizes the effect of the benefit of future tax savings due to CCA and allows analysts to take these benefits into account when calculating the present worth equivalent of an asset. The CTF is constant for a given CCA rate, interest rate, and tax rate, and allows the determination of

Table 7.9 Tax Savings Due to the CCA (50% Tax Rate)

Year	Base UCC Amount for Capital Cost Allowance	Capital Cost Allowance	Remaining UCC	Tax Savings Due to the CCA
1	\$50 000	\$10 000	\$90 000	\$5 000
2	90 000	18 000	72 000	9 000
3	72 000	14 400	57 600	7 200
4	57 600	11 520	46 080	5 760
5	46 080	9 216	36 864	4 608

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the present worth independently of the actual first cost of the asset. This makes it a very useful element.

Similarly, when an asset is salvaged or scrapped, there is an ongoing tax effect that can be captured and summarized. However, when an asset is salvaged or scrapped, the effect on the UCC is immediate and not subject to the half-year rule. The equivalent measure in this case is the **capital salvage factor (CSF)**.

The CSF and CTF are derived in Appendix 7A as:

$$\text{CSF} = 1 - \frac{td}{(i+d)} \qquad \text{CTF} = 1 - \frac{td\left(1+\frac{i}{2}\right)}{(i+d)(1+i)}$$

where:

t = taxation rate

d = CCA rate

i = after-tax interest rate

The present worth of the first cost (at the time of purchase) of an asset is found by multiplying the first cost by the CTF. This takes into account the tax benefits forever. When an asset is salvaged or scrapped, we need to terminate the remaining stream of tax savings. This is done by applying the CSF. Examples in Section 7.8.4 will clarify the process.

EXAMPLE 7.6

An automobile purchased by Lestev Corporation for \$25 000 has a CCA rate of 30 percent. Lestev is subject to a 43 percent corporate tax rate and the corporate (after-tax) MARR is 12 percent. What is the present worth of the first cost of this automobile, taking into account the future tax savings resulting from depreciation?

The car is an asset being purchased, so the CTF applies. The CTF is calculated as:

$$\text{CTF} = 1 - \frac{(0.43)(0.3)(1+0.06)}{(0.12+0.3)(1+0.12)}$$

$$= 0.709311$$

The present worth of the first cost of the car is then calculated as:

$$\text{PW} = 0.709311(\$25\ 000)$$

$$= \$17\ 733$$

The present worth of the first cost of the car, taking into account all future tax savings due to depreciation, is about \$17 733. The tax benefit due to claiming CCA has effectively reduced the cost of the car from \$25 000 to \$17 733 in terms of present worth. ■

It may seem strange that the effective cost of purchasing an asset is less than its first cost. However, bear in mind that the first cost is not the only impact that the purchase of an asset has on cash flows. The purchase will also likely generate savings. These savings are income, which is also taxed. Taking taxes into account when determining the present worth or annual worth of an asset will affect the present or annual worth positively

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because of the tax benefits resulting from future CCA, but also negatively because of the taxation of future savings.

7.8.4 Components of a Complete Tax Calculation

As discussed in Section 7.4, when evaluating projects with the explicit consideration of taxes, it is important to recognize that there is a difference between a before-tax MARR and an after-tax MARR. A before-tax MARR is chosen to reflect the fact that taxes are not explicitly taken into account in the economic calculations, and the after-tax MARR is used when taxes are explicitly taken into account.

Evaluating the economic impact of purchasing a depreciable asset goes beyond the impact of taxes on the first cost. There are two other components in a complete economic analysis. First, we need to assess the tax implications of the savings or additional expenses brought about by the asset over its useful life. Second, when the asset is disposed of, we no longer can take advantage of its CCA and thus must terminate the stream of tax savings resulting from depreciating the asset.

Each of these components has a tax effect that has to be taken into account when doing a cash flow analysis such as determining present worth or annual worth. A summary of the procedure for a present worth computation is shown in Table 7.10.

Table 7.10 Components of a Complete Present-Worth Tax Calculation

Component	Treatment
First cost	Multiply by the CTF.
Savings or expenses	Multiply by $(1 - t)$. Convert to present worth.
Salvage value	Multiply by the CSF. Convert to present worth.

First cost: As presented in Section 7.7, the first cost of an asset purchased after 1981 is reduced by the tax savings due to the CCA. Multiply the first cost by the CTF to find the after-tax first cost.

Savings or expenses: Reduce savings or expenses by the tax rate by multiplying by $(1 - t)$. There is an assumption that the company is making a profit, so taxes are paid on all the savings at the rate t, and expenses will reduce taxes at the rate t.

Salvage value: Apply the CSF. When an asset is disposed of, the salvage value reduces the UCC for the full amount in the year of disposal (at least in the absence of a corresponding purchase in the same year). The effect of reducing the UCC is the same in magnitude but opposite in sign as increasing the UCC. The CTF has built into it a delay in depreciating half of the value of the asset, whereas the full effect occurs immediately when disposing of an asset. Consequently, the CSF is the one to use at the time an asset is sold.

Note that, technically, when assets are disposed of in a given year, they are netted against any additions for the year before the half-year rule is applied. However, in project analysis, we generally want to evaluate the project independently, at least in preliminary evaluation. When we determine the salvage value, we do not consider the effects of other additions or disposals that the company may be planning for the same year. Nevertheless, it is worth noting that significant tax advantages can be made by properly planning the timing of investment additions and disposals. Our goal at this time is to decide on the merits of the project on a more basic level.

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EXAMPLE 7.7

The owner of a spring water bottling company in Erbsville has just purchased an automated bottle capper. What is the after-tax present worth of the new automated bottle capper if it costs \$10 000 and saves \$4000 per year over its five-year life? Assume a \$2000 salvage value and a 50 percent tax rate. The after-tax MARR is 12 percent.

A CCA rate is not given in this question. As production equipment, the new bottle capper can be assumed to be in CCA Class 8 with a rate of 20 percent.

The present worth of the first cost must take into account the tax benefits of CCA. The after-tax first cost is

$$\text{PW(first cost)} = -\$10\,000(\text{CTF})$$

where the CTF is calculated as:

$$\text{CTF} = 1 - \frac{(0.5)(0.2)(1 + 0.06)}{(0.12 + 0.2)(1 + 0.12)}$$

Therefore, the present worth of the first cost is

$$\begin{aligned}\text{PW(first cost)} &= -\$10\,000(0.70424)\\ &\cong -\$7042\end{aligned}$$

The annual savings are taxed at 50 percent, so the present worth of the savings is

$$\begin{aligned}\text{PW(annual savings)} &= \$4000(P/A,12\%,5)\,(1 - t)\\ &= \$4000(3.6047)(0.5)\\ &\cong \$7209\end{aligned}$$

The salvage value is not simply \$2000 five years from now. It reduces the UCC and thus diminishes the tax benefits resulting from the CCA on the original purchase. The after-tax benefits can be determined by applying the CSF:

$$\text{PW(salvage value)} = \$2000(P/F,12\%,5)\text{CSF}$$

$$\text{CSF} = 1 - \frac{(0.5)(0.2)}{(0.12 + 0.2)}$$

$$= 0.6875$$

$$\begin{aligned}\text{PW(salvage value)} &= \$2000(0.56743)(0.6875)\\ &\cong \$780\end{aligned}$$

Summing the present worths:

$$\begin{aligned}\text{PW} &= \text{PW(first cost)} + \text{PW(annual savings)} + \text{PW(salvage value)}\\ &= -\$7042 + \$7209 + \$780\\ &= \$947\end{aligned}$$

The present worth after taxes for the new bottle capper is \$947. ■

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Example 7.7 illustrated the complete effect of taxes for a present worth analysis. Similar adjustments are made to an annual worth computation, as illustrated in Table 7.11.

Table 7.11 Components of a Complete Annual-Worth Tax Calculation

Component	Treatment
First cost	Multiply by the CTF. Convert to annual worth.
Savings or expenses	Multiply by $(1 - t)$.
Salvage value	Multiply by the CSF. Convert to annual worth.

EXAMPLE 7.8

A small device used to test printed circuit boards has a first cost of \$45 000. The tester is expected to reduce labour costs and improve the defect detection rate to bring about savings of \$23 000 per year. Additional operating costs are expected to be \$7300 per year. The salvage value of the tester will be \$5000 in five years. With an after-tax MARR of 12 percent, a CCA rate of 20 percent, and a tax rate of 42 percent, what is the annual worth of the tester, taking into account the effect of taxes?

The basic process for adjusting for tax effects in an annual worth comparison is similar to a present worth analysis. First, we apply the CTF to the first cost and convert it into an annual amount over five years. Next, the annual savings and expenses are multiplied by $(1 - t)$. Finally, the salvage value at the end of five years is multiplied by CSF and then converted into an annual amount:

$$\begin{aligned}\text{AW(tester)} &= -\$45\,000(A/P,12\%,5)\text{CTF} + (\$23\,000 - \$7300)(1 - t)\\ &\quad + \$5000(A/F,12\%,5)\text{CSF}\end{aligned}$$

Using $d = 0.20$, $t = 0.42$, and $i = 0.12$, we have:

$$\text{CTF} = 0.7516$$

$$\text{CSF} = 0.7375$$

Therefore:

$$\begin{aligned}\text{AW(tester)} &= -\$45\,000(0.27741)(0.7516) + (\$23\,000 - \$7300)(0.58)\\ &\quad + \$5000(0.15741)(0.7375)\\ &\cong \$304\end{aligned}$$

The annual worth, taking into account taxes, is \$304. ■

As the last two examples show, taking taxes into account for present worth and annual worth analyses is relatively straightforward. IRR computations are a bit more involved, however, as the next example illustrates.

EXAMPLE 7.9

Find the after-tax IRR for the testing equipment described in Example 7.8.

First, observe that if we solve for i in AW(receipts) − AW(disbursements) = 0, or PW(receipts) − PW(disbursements) = 0, the resulting rate will be an after-tax IRR, since

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the amounts will have been adjusted for taxes. Since Example 7.8 was expressed in terms of annual amounts, we will find the after-tax IRR by solving for i in AW(receipts) − AW(disbursements) = 0 using the operations listed in Table 7.11:

$$(\$23\,000 - \$7300)(1 - t) + \$5000(A/F,i,5)\text{CSF} - \$45\,000(A/P,i,5)\text{CTF} = 0$$

In order to solve this equation, a trial-and-error approach is necessary because the interest rate, i, appears in the capital cost tax factors as well as in the compound interest factors. Table 7.12 shows the result of this process obtained through the use of a spreadsheet.

Table 7.12 Trial-and-Error Process for Finding the After-Tax IRR

i	AW(receipts) − AW(disbursements)
0.10	$997.54
0.11	651.37
0.12	304.36
0.13	−43.62
0.14	−392.68

From the spreadsheet computations, we can see that the after-tax IRR on the testing equipment is between 12 percent and 13 percent. Additional trial-and-error iterations with the spreadsheet program give an after-tax IRR of 12.87 percent. ■

REVIEW PROBLEMS

REVIEW PROBLEM 7.1

Angus and his sister Oona operate a small charter flight service that takes tourists on sightseeing tours over the beautiful Margaree River on Cape Breton Island. At the end of 2009, they had one four-seater plane in the aircraft asset class with a UCC of $30 000. In 2010, they purchased a second plane for $50 000. Business was going well in 2011, so they sold the old plane they had in 2009 for $15 000 and bought a newer version for $64 000. What was the UCC balance in the aircraft asset class at the end of 2012? The CCA rate for aircraft is 25 percent.

ANSWER

Table 7.13 shows the fluctuation in the UCC balance over time. At the end of 2009, the UCC for the aircraft asset class was $30 000. In 2010, half of the capital cost of the airplane purchased in 2010 ($25 000) contributed to the CCA calculation. The CCA rate of 25 percent gave a CCA amount of $13 750 and resulted in a UCC balance of $66 250 at the end of 2010. In 2011, the net positive adjustment to the UCC due to the capital cost of $64 000 for the new plane and the $15 000 benefit from the sale of the old plane was $49 000. Half of this amount, $24 500, contributed to the CCA calculation. After subtracting the CCA amount of $22 688 for 2010, the remaining UCC was $92 563 (66 250 + $49 000 − $22 688). In 2012, there were no further adjustments to the UCC, and after the CCA was deducted, the closing UCC account balance was $69 422. ■

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Table 7.13 Summary of UCC Computations for Review Problem 7.1

Year	Adjustments to UCC from Purchases or Dispositions	Base UCC Amount for Capital Cost Allowance	CCA Allowance	Remaining UCC
2009				$30 000
2010	$50 000	$55 000	$13 750	66 250
2011	49 000	90 750	22 688	92 563
2012	0	92 563	23 141	69 422

REVIEW PROBLEM 7.2

David Cosgrove has just started a management consulting firm that he operates out of his home at Paradise Lake. As part of his new business, David is considering buying a new $30 000 van, which will be used 100 percent of the time for earning business income. He estimates that the expenses associated with operating the van will be $3000 per year for gas, $1200 per year for insurance, $600 annually for parking, and maintenance costs of $1000 for the first year, rising by $400 per year thereafter. He expects to keep the van for five years. At the end of this time, he estimates a salvage value of $6000. The CCA rate for vans is 30 percent.

The alternative for David is to lease the van. With a lease arrangement, he will have to pay for parking, gas, and insurance, but the leasing company will pay for the repairs. The lease costs are $10 500 per year.

David estimates his after-tax cost of capital to be 12 percent per year and his tax rate is 40 percent. On the basis of an annual worth analysis over the five years, should David buy the van or lease it?

ANSWER

The approach will be to find the after-tax annual worth of each alternative. Since the parking, insurance, and gas costs are the same for both alternatives, we can exclude them from the analysis.

The after-tax annual costs of purchasing the van are:

$$\begin{aligned} \text{AW(van)} &= \$30\,000(A/P,12\%,5)\text{CTF} - \$6000(A/F,12\%,5)\text{CSF} \\ &\quad + [\$1000 + \$400(A/G,12\%,5)](1-t) \end{aligned}$$

We can calculate that:

$$\begin{aligned} \text{CTF} &= 1 - \frac{td\left(1+\frac{i}{2}\right)}{(i+d)(1+i)} \\ &= 1 - \frac{(0.4)(0.3)\left(1+\frac{0.12}{2}\right)}{(0.12+0.30)(1+0.12)} \\ &= 0.7296 \end{aligned}$$

$$\text{CSF} = 1 - \frac{td}{(i+d)}$$

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$$= 1 - \frac{(0.4)(0.3)}{(0.12 + 0.30)}$$

$$= 0.71429$$

Thus:

$$AW(\text{van}) = \$30\,000(0.27741)(0.7296) - \$6000(0.15741)(0.71429) + [\$1000 + \$400(1.7745)](1 - 0.4)$$

$$\cong \$6423$$

The annual cost of purchasing and operating the van over a five-year period is a little over $6400.

There is a large difference between buying and leasing. When we lease, we do not have a depreciable asset on which to claim depreciation expenses; we only have lease payment expenses. Therefore, the impact of taxes on the lease expense is simply to multiply the leasing costs by $(1 - t)$:

$$AW(\text{lease}) = \$10\,500(1 - 0.4)$$

$$= \$10\,500(0.6)$$

$$= \$6300$$

The after-tax annual cost of leasing is $6300. It is less expensive to lease the van than it is to buy it, so David should lease the van. It is worth noting that this example is a simplified version of real life, since we have ignored numerous tax rules relating to the eligibility of expenses for automobiles for illustration purposes. ■

REVIEW PROBLEM 7.3

Putco does subcontracting for an electronics firm that assembles printed circuit boards. Business has been good lately, and Putco is thinking of purchasing a new IC chip-placement machine. It has a first cost of $450 000 and is expected to save the company $125 000 per year in labour and operating costs compared with the manual system it has now. A similar system that also automates the circuit board loading and unloading process costs $550 000 and will save about $155 000 per year. The life of either system is expected to be four years. The salvage value of the $450 000 machine will be $180 000, and that of the $550 000 machine will be $200 000. Putco uses an after-tax MARR of 9 percent to make decisions about such projects. On the basis of an IRR comparison, which alternative (if either) should it choose? Putco pays taxes at a rate of 40 percent and the CCA rate for the equipment is 20 percent.

ANSWER

Putco has three mutually exclusive alternatives:

1. Do nothing.
2. Buy the chip-placement machine.
3. Buy a similar chip-placement machine with an automated loading and unloading process.

Following the procedure from Chapter 6, the projects are already ordered on the basis of first cost. We therefore begin with the first alternative: The before-tax (and thus the after-tax) IRR of the "do nothing" alternative is 0 percent.

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The before-tax IRR on the incremental investment to the second alternative can be found by solving for i in

$$-\$450\,000 + \$125\,000(P/A,i,4) + \$180\,000(P/F,i,4) = 0$$

By trial and error, we obtain an $\text{IRR}_{\text{before-tax}}$ of 15.92 percent. This gives an approximate $\text{IRR}_{\text{after-tax}}$ of $0.1592(1 - 0.40) = 0.0944$, or 9.44 percent. With an after-tax MARR of 9 percent, it would appear that this alternative is acceptable, though a detailed after-tax computation may be in order. We need to solve for i in:

$$(-\$450\,000)\text{CTF} + \$125\,000(P/A,i,4)(1 - t) + \$180\,000(P/F,i,4)\text{CSF} = 0$$

Doing so gives an $\text{IRR}_{\text{after-tax}}$ of 9.36 percent. Since this exceeds the required after-tax MARR of 9 percent, this alternative becomes the current best. We next find the $\text{IRR}_{\text{after-tax}}$ on the incremental investment required for the third alternative. The $\text{IRR}_{\text{before-tax}}$ is first found by solving for i in:

$$-(\$550\,000 - \$450\,000) + (\$155\,000 - \$125\,000)(P/A,i,4)$$
$$+(\$200\,000 - \$180\,000)(P/F,i,4) = 0$$

This gives an $\text{IRR}_{\text{before-tax}}$ of 13.66 percent, or an approximate $\text{IRR}_{\text{after-tax}}$ of 8.2 percent. This is close enough to the required after-tax MARR of 9 percent to warrant a detailed incremental $\text{IRR}_{\text{after-tax}}$ computation. ■

REVIEW PROBLEM 7.4

David Cosgrove (from Review Problem 7.2) is still thinking over whether to buy a van. Assuming he remains in business for the foreseeable future, he will need a vehicle for transportation indefinitely, whether he owns or leases it. In his original analysis, he assumed that the van would be replaced at the end of five years. Because appearances are important to David, he would not consider keeping a vehicle for longer than five years, but he now recognizes that the economic life of the van may be shorter than that. Assuming that the van depreciates in value by a constant proportion each year, determine how frequently David should replace it. The CCA rate is 30 percent and his tax rate is 40 percent.

ANSWER

The first step in the solution is to recognize that David is facing a cyclic replacement problem, since it is reasonable to assume that he will always replace each van with one similar to the previous one. We now need to assess the annual cost of replacing a van each year, every two years, and so on, up to replacement every five years. Before proceeding, however, we need to determine the depreciation rate to use so that we can determine the approximate value of the van when it is n years old for $n = 1, 2, 3$, and 4.

We have for the declining-balance method of depreciation:

$$d = 1 - \sqrt[n]{\frac{S}{P}} = 1 - \sqrt[5]{\frac{6000}{30\,000}} = 0.27522$$

Using the formula $\text{BV}_{\text{db}}(n) = P(1 - d)^n$, we find that the book value of the van at the end of each year is:

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End of Year	Book Value
0	$30 000
1	21 743
2	15 759
3	11 422
4	8 278
5	6 000

Note that these are book values, not the UCC balances. The book values are estimates of the market value, which is needed to judge when the asset should be replaced. A UCC balance is similar to a book value but is used for calculating the CCA only.

Now the annual worth computations can be done using the CTF values calculated in Review Problem 7.2:

AW(replace every year)

$$= \text{AW(capital recovery)} + \text{AW(operating)}$$

$$= \$30\,000(A/P,12\%,1)\text{CTF} - \$21\,743(A/F,12\%,1)\text{CSF} + (\$5800)(1-t)$$

$$= \$12\,463$$

AW(replace every two years)

$$= \$30\,000(A/P,12\%,2)\text{CTF} - \$15\,759(A/F,12\%,2)\text{CSF}$$
$$+ \$5800(1-t) + \$400(A/F,12\%,2)(1-t)$$
$$= \$11\,235$$

AW(replace every three years)

$$= \$30\,000(A/P,12\%,3)\text{CTF} - \$11\,422(A/F,12\%,3)\text{CSF}$$
$$+ \$5800(1-t) + [\$400(F/P,12\%,1) + \$800](A/F,12\%,3)(1-t)$$
$$= \$10\,397$$

AW(replace every four years)

$$= \$30\,000(A/P,12\%,4)\text{CTF} - \$8278(A/F,12\%,4)\text{CSF}$$
$$+ \$5800(1-t) + [\$400(F/P,12\%,2) + \$800(F/P,12\%,1)$$
$$+ \$1200](A/F,12\%,4)(1-t)$$
$$= \$9775$$

AW(replace every five years)

$$= \$30\,000(A/P,12\%,5)\text{CTF} - \$6000(A/F,12\%,5)\text{CSF}$$
$$+ \$5800(1-t) + [\$400(F/P,12\%,3) + \$800(F/P,12\%,2)$$
$$+ \$1200(F/P,12\%,1) + \$1600](A/F,12\%,5)(1-t)$$
$$= \$9303$$

On the basis of these calculations, it is best for David to replace the van at the end of every five years. Its economic life may be longer than five years, but as far as David is concerned, a five-year-old van has reached the end of its useful life and must be replaced. ■

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SUMMARY

Income taxes can have a significant effect on engineering economics decisions. In particular, taxes reduce the effective cost of an asset, the savings generated, and the value of the sale of an asset.

In this chapter, we provided a basic introduction to the Canadian capital cost allowance system and the use of undepreciated capital cost accounts. The CCA rate is a declining-balance rate that is mandated for use in calculating the depreciation expenses for capital assets. These depreciation expenses are then used in determining the amount of taxes owing for the year. Assets are designated as belonging to a particular CCA class. The book values for taxation purposes calculated for all the assets in each class are accumulated into a UCC account.

The future CCA claims that arise from the purchase of an asset are benefits that reduce the after-tax first cost. The CTF permits the quick calculation of the net effect of these benefits, while similarly, the CSF permits the calculation of the net effect of future loss of CCA claims for assets that are sold or scrapped.

It was noted that, for after-tax calculations, an after-tax MARR must be used. After-tax calculations were illustrated for present worth, annual worth, and IRR evaluations. An approximate IRR comparison method was also given.

The review problems at the end of the chapter illustrated how taxes affect present worth and annual worth comparisons, replacement analyses, and internal rate of return computations.

CLOSE-UP 7.3 Tax Rules in Other Countries

The principles of taking tax effects into account when making economic decisions are not dependent on the particular tax rules of different countries, and methods like the approximate after-tax rate of return calculations are applicable anywhere. However, for an accurate determination of a project's viability, the particular rules of the project's jurisdiction must be taken into account. Here is an overview of the tax rules of the United States, the United Kingdom, and Australia:

United States: The United States requires that assets be depreciated for tax purposes according to a particular mixture of declining-balance and straight-line methods called MACRS (modified accelerated cost recovery system). Like the Canadian system, different types of assets belong to different classes that determine how quickly the asset depreciates to a zero book value. Similar to the Canadian half-year rule, every asset is assumed to be purchased in the middle of the first year. Salvage value can either be taxable income if it is a larger amount than the book value, or a deductible expense if it is lower than book value.

United Kingdom: In the UK system, the values of all assets are added at the time of purchase to a pool similar to the UCC pool under the CCA system, except that there are no classes—everything is pooled together. Each year, 25 percent of the remaining value of the pool—called the written down value (WDV)—is considered to be an expense. There are only a few exceptions, notably buildings, which are allowed to depreciate at only 4 percent per year. When an asset is salvaged, a corresponding adjustment is made to the pool.

Australia: Australia has very simple rules. The taxpayer can choose both the life of the asset and the depreciation method. The depreciation method can either be straight-line or declining-balance, and if it is declining-balance, then the rate is 150 percent divided by the life of the asset. First year depreciation expense is pro-rated by the number of days the asset is in use.

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ENGINEERING ECONOMICS IN ACTION, PART 7B

The Work Report

"So what is this, anyhow?" Clem was looking at the report that Naomi had handed him. "A consulting report?"

"Sorry, chief, it is a bit thick." Naomi looked a little embarrassed. "You see, Terry has to do a work report for his university. It's part of the co-op program. He got interested in the 10-stage die problem and asked me if he could make that study his work report. I said okay, subject to its perhaps being confidential. I didn't expect it to be so thick, either. But he's got a good executive summary at the front."

"Hmm . . ." The room was quiet for a few minutes while Clem read the summary. He then leafed through the remaining parts of the report. "Have you read this through? It looks really quite good."

"I have. He has done a very professional job—er, at least what seems to me to be very professional." Naomi suddenly remembered that she hadn't yet gained her professional engineer's designation. She also hadn't been working at Canadian Widgets much longer than Terry. "I gathered most of the data for him, but he did an excellent job of analyzing it. As you can see from the summary, he set up the replacement problem as a set of mutually exclusive alternatives, involving upgrading the die now or later and even more than once. He did a nice job on the taxes, too."

"Tell me more about how he handled the taxes."

"He was really thorough. I had to hold his hand a bit to make sure he understood how the UCC accounts work, but once he had that, everything else seemed to fall into place. He reduced the purchase price by the benefits of future CCA claims. The installation cost and future savings were reduced by the taxation rate, and the salvage values were reduced for loss of future CCA claims."

"Did he understand about the capital tax factor and the capital salvage factor?"

"Yes, he did."

"Not bad. I think we've got a winner there, Naomi. Let's make sure we get him back for his next work term."

Naomi nodded. "What about his work report, Clem? Should we ask him to keep it confidential?"

Clem laughed. "Well, I think we should, and not just because there are trade secrets in the report. I don't want anyone else knowing what a gem we have in Terry!"

PROBLEMS

A. Key Concepts

7.1 Collingwood Caskets generally uses a before-tax MARR of 14 percent. Vincent wants to do a detailed calculation of the cash flows associated with a new planer for the assembly line. What would be an appropriate after-tax MARR for him to use if Collingwood Caskets pays

(a) 40 percent corporate taxes?

(b) 50 percent corporate taxes?

(c) 60 percent corporate taxes?

7.2 What is the approximate after-tax IRR on a two-year project for which the first cost is \$12 000, savings are \$5000 in the first year and \$10 000 in the second year, and taxes are at 40 percent?

7.3 Waterloo Industries pays 40 percent corporate income taxes and its after-tax MARR is 18 percent. A project has a before-tax IRR of 24 percent. Should the project be

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7.4 What is the exact after-tax IRR on a project for which the first cost is \$12 000, savings are \$5000 in the first year and \$10 000 in the second year, taxes are at 40 percent, and the CCA rate is 30 percent?

7.5 Identify each of the following according to their CCA class(es) and CCA rate(s):

(a) A soldering gun costing \$75

(b) A garage used to store spare parts

(c) A new computer

(d) A 100-tonne punch press

(e) A crop-dusting attachment for a small airplane

(f) An oscilloscope worth exactly \$600

7.6 Calculate the CTF and CSF for each of the following:

(a) Tax rate of 50 percent, CCA of 20 percent, and an after-tax MARR of 9 percent

(b) Tax rate of 35 percent, CCA of 30 percent, and an after-tax MARR of 12 percent

(c) Tax rate of 55 percent, CCA of 5 percent, and an after-tax MARR of 6 percent

7.7 A company's first year's operations can be summarized as follows:

Revenues: \$110 000

Expenses (except CCA): \$65 000

Its capital asset purchases in the first year totalled \$100 000. With a CCA rate of 20 percent and a tax rate of 55 percent, how much income tax did it pay?

7.8 A company's second year operations can be summarized as follows:

Revenues: \$110 000

Expenses (except CCA): \$65 000

Its capital asset purchases in the first year totalled \$100 000, with none in the second year. With a CCA rate of 20 percent and a tax rate of 55 percent, how much income tax did it pay?

7.9 The UCC balance for a firm's automobile fleet at the end of 2009 was \$10 000. There was one truck in service at this time. At the beginning of 2010, the firm purchased two trucks for a total of \$50 000. At the beginning of 2012, it purchased another truck for \$20 000. At the beginning of 2013, the truck owned in 2009 was sold for \$3000. The CCA rate for automobiles is 30 percent. What was the firm's UCC balance at the end of 2013?

7.10 Use a spreadsheet program to create a chart showing how the values of the CTF and the CSF change for after-tax MARRs of 0 percent to 30 percent. Assume a fixed tax rate of 50 percent and a CCA rate of 20 percent.

B. Applications

7.11 Enrique has just completed a detailed analysis of the IRR of a waste-water treatment plant for Montreal Meat Products. The 8.7 percent after-tax IRR he calculated compared favourably with a 5.2 percent after-tax MARR. For reporting to upper manage-

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Products pays 53 percent corporate taxes, what figures will Enrique report to upper management?

7.12 International Computing Corporation (ICC) is considering updating its automated inventory control system. The supplier has estimated the first cost as \$2 300 000 and the annual savings as \$880 000; after its 10-year life, it will have a salvage value of \$200 000. The tax rate for ICC is 45 percent and the company uses an after-tax MARR of 10 percent. What is the present worth of the new system? Should ICC make this investment?

7.13 Go to the Canada Revenue Agency website and search for the T2 Corporation—Income Tax Guide. Find the section in the guide dealing with CCA rates and identify each of the following according to its CCA class(es) and CCA rate(s).

(a) A heated, rigid-frame greenhouse worth \$57 000

(b) A small tractor with attachments for earth-moving and snow removal worth \$24 000

(c) New software for inventory control purposes costing \$70 000

(d) Advanced data network switching equipment that costs \$56 000

(e) Cash register and barcode scanning device used for point-of-sales data collection. Cost is \$12 000 for the cash register and \$200 for the scanning device.

7.14 What is the after-tax present worth of a chip placer if it costs \$55 000 and saves \$17 000 per year? After-tax interest is at 10 percent. Assume the device will be sold for a \$1000 salvage value at the end of its six-year life. The CCA rate is 20 percent and the corporate income tax rate is 54 percent.

7.15 Quebec Widgets is looking at a \$400 000 digital midget rigid widget gadget (CCA Class 8). The gadget is expected to save \$85 000 per year over its 10-year life, with no scrap value. The company's tax rate is 45 percent, and its after-tax MARR is 15 percent. On the basis of an approximate IRR, should it invest in this gadget?

7.16 Canada Widgets is looking at a \$400 000 digital midget rigid widget gadget (CCA Class 8). The gadget is expected to save \$85 000 per year over its 10-year life, with no scrap value. The company's tax rate is 45 percent and its after-tax MARR is 15 percent. On the basis of an exact IRR, should it invest in this gadget?

7.17 Go to the Canada Revenue Agency website and find the form Schedule 8 for the T2 Short Corporation Income Tax Return. This is a worksheet for calculating UCC balances. Use the sheet to make the following calculations (separately). In all cases, there are no adjustments (e.g., for GST rebates or for investment tax credits).

(a) The UCC balance at the end of the previous year is \$10 000. Assets purchased in Class 10 for the current year amount to \$30 000. Find the UCC at the end of the year.

(b) The UCC balance at the end of the previous year is \$10 000. Assets purchased in Class 10 for the current year amount to \$20 000. Dispositions were \$5000. Find the UCC at the end of the year.

(c) The UCC balance at the end of the previous year for Class 8 was \$20 000. This year, an asset worth \$20 000 was added to Class 8 and another worth \$15 000 was disposed of. What is the year-end UCC for this year?

7.18 Churchill Metal Products opened for business in 1999. Over the following years, its transactions for CCA Class 8 assets consisted of the following:

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Date	Item	Activity	Amount
March 11, 1999	Machine 1	Purchase	$ 50 000
April 24, 1999	Machine 2	Purchase	150 000
November 3, 2002	Machine 3	Purchase	250 000
November 22, 2002	Machine 1	Sale	10 000
May 20, 2006	Machine 4	Purchase	60 000
August 3, 2011	Machine 5	Purchase	345 000
September 12, 2012	Machine 3	Sale	45 000

What CCA amount did Churchill Metal Products claim for the 20 percent UCC account in 2013?

7.19 What is the total after-tax annual cost of a machine with a first cost of $45 000 and operating and maintenance costs of $0.22 per unit produced? It will be sold for $4500 at the end of five years. Production is 750 units per day, 250 days per year. The CCA rate is 30 percent, the after-tax MARR is 20 percent, and the corporate income tax rate is 40 percent.

7.20 Chrétien Brothers Salvage made several equipment purchases in the past decade. Its first asset was a tow truck bought in 2006 for $25 000. In 2008, a van was purchased for $14 000. A second tow truck was bought in 2011 for $28 000, and the first one was sold the following year for $5000. Using a 30 percent CCA rate (automobiles, trucks, and vans), what was the balance of its UCC account at the end of 2013?

7.21 Whitehorse Construction just bought a crane for $380 000. At a CCA rate of 20 percent, what is the present worth of the crane, taking into account the future benefits resulting from the CCA? Whitehorse has a tax rate of 35 percent and an after-tax MARR of 6 percent.

7.22 Hull Hulls is considering the purchase of a 30-tonne hoist. The first cost is expected to be $230 000. Net savings will be $35 000 per year over a 12-year life, and it will be salvaged for $30 000. If the company's after-tax MARR is 8 percent and it is taxed at 45 percent, what is the present worth of this project?

7.23 Kanata Konstruction is considering the purchase of a truck. Over its five-year life, it will provide net revenues of $15 000 per year at an initial cost of $65 000 and a salvage value of $20 000. KK pays 35 percent in taxes, the CCA rate for trucks is 30 percent, and the after-tax MARR is 12 percent. What is the annual cost or worth of this purchase?

7.24 A new binder will cost Revelstoke Printing $17 000, generate net savings of $3000 per year over a seven-year life, and be salvaged for $1000. Revelstoke's before-tax MARR is 10 percent, it is taxed at 40 percent, and the binder has a 20 percent CCA rate. What is the company's exact after-tax IRR on this investment? Should the investment be made?

7.25 A slitter for sheet sandpaper owned by Abbotsford Abrasives (AA) requires regular maintenance costing $7500 per year. Every five years it is overhauled at a cost of $25 000. The original capital cost was $200 000, and an additional $25 000 in non-capital expenses was incurred at the time of installation. The machine has an expected life of 20 years and a $15 000 salvage value, and it will not be overhauled at the end of its life. AA pays taxes at a rate of 45 percent and expects an after-tax rate of return of 10 percent on

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investments. Recalling that the CCA rate for production equipment is 20 percent, what is the after-tax annual cost of the slitter?

7.26 Roch bought a \$100 000 machine (Machine A) on November 12, 1981. As a CCA Class 8 asset, what was its book value, measured as its contribution to the UCC for that class, at the end of 1991? Roch purchased an identical \$100 000 machine (Machine B) on November 14, 1981. What was its book value at the end of 1991?

7.27 A chemical recovery system costs \$30 000 and saves \$5280 each year of its seven-year life. The salvage value is estimated at \$7500. The after-tax MARR is 9 percent and taxes are at 45 percent. What is the net after-tax annual benefit or cost of purchasing the chemical recovery system?

7.28 Salim is considering the purchase of a backhoe for his pipeline contracting firm. The machine will cost \$110 000, last six years with a salvage value of \$20 000, and reduce annual maintenance, insurance, and labour costs by \$30 000 per year. The after-tax MARR is 9 percent and Salim's corporate tax rate is 55 percent. What is the exact after-tax IRR for this investment? What is the approximate after-tax IRR? Should Salim buy the backhoe?

7.29 Refer to Problem 6.21 on page 231. Grazemont Dairy has a corporate tax rate of 40 percent and the filling machine for the dairy line has a CCA rate of 30 percent. The firm has an after-tax MARR of 10 percent. On the basis of the exact IRR method, determine which alternative Grazemont Dairy should choose.

C. More Challenging Problems

7.30 In 2011, the Sackville Furniture Company bought a new band saw for \$360 000. Aside from depreciation expenses, its yearly expenses totalled \$1 300 000 versus \$1 600 000 in income. How much tax (at 50 percent) would the company have paid in 2011 if it had been permitted to use each of the following depreciation schemes?

(a) Straight-line, with a life of 10 years and a zero salvage value

(b) Straight-line, with a life of five years and a zero salvage value

(c) Declining-balance, at 20 percent

(d) Declining-balance, at 40 percent

(e) Fully expensed that year

7.31 Rodney has discovered that, for the past three years, his company has been classifying as CCA Class 8 items costing between \$200 and \$500 that should be in CCA Class 12. If an estimated \$10 000 of assets per year were misclassified, what is the present worth today of the cost of this mistake? Assume that the mistake can only be corrected for assets bought in the future. Rodney's company pays taxes at 50 percent and its after-tax MARR is 9 percent.

7.32 CB Electronix needs to expand its capacity. It has two feasible alternatives under consideration. Both alternatives will have essentially infinite lives.

Alternative 1: Construct a new building of 20 000 square metres now. The first cost will be \$2 000 000 and annual maintenance costs will be \$10 000. In addition, the building will need to be painted every 15 years (starting in 15 years) at a cost of \$15 000.

Alternative 2: Construct a new building of 12 500 square metres now and an addition of 7500 square metres in 10 years. The first cost of the 12 500-square-metre building will

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be $1 250 000. The annual maintenance costs will be $5000 for the first 10 years (i.e., until the addition is built). The 7500-square-metre addition will have a first cost of $1 000 000. Annual maintenance costs of the renovated building (the original building and the addition) will be $11 000. The renovated building will cost $15 000 to repaint every 15 years (starting 15 years after the addition is done).

Given a CCA rate of 5 percent for the buildings, a corporate tax rate of 45 percent, and an after-tax MARR of 15 percent, carry out an annual-worth comparison of the two alternatives. Which is preferred?

The following Ridgely Custom Metal Products (RCMP) case is used for Problems 7.33 to 7.38. RCMP must purchase a new tube bender. There are three models:

Model	First Cost	Economic Life	Yearly Net Savings	Salvage Value
T	$100 000	5 years	$50 000	$20 000
A	150 000	5 years	60 000	30 000
X	200 000	3 years	75 000	100 000

RCMP's after-tax MARR is 11 percent and the corporate tax rate is 52 percent. A tube bender is a CCA Class 8 asset.

7.33 Using the present worth method and the least-cost multiple of the service lives, which tube bender should it buy?

7.34 RCMP realizes that it can forecast demand for its products for only three years in advance. The salvage value for model T after three years is $40 000 and for model A is $80 000. Using the present worth method and a three-year study period, which of the three alternatives is now best?

7.35 Using the annual worth method, which tube bender should Ridgely buy?

7.36 What is the approximate after-tax IRR for each of the tube benders?

7.37 What is the exact after-tax IRR for each of the tube benders?

7.38 Using the approximate after-tax IRR comparison method, which of the tube benders should Ridgely buy? (Reminder: You must look at the incremental investments.)

7.39 Refer to Problem 6.21 on page 231. Grazemont Dairy has a corporate tax rate of 40 percent and the filling machine for the dairy line has a CCA rate of 30 percent. The company has an after-tax MARR of 10 percent. Using an approximate IRR approach, determine which alternative Grazemont Dairy should choose.

7.40 A cash flow sequence has a receipt of $10 000 today, followed by a disbursement of $8000 at the end of this year and again next year, and then a receipt of $5500 three years from now. The MARR is 6 percent. Taxes are at 50 percent, and the disbursements are not depreciable assets and thus can be expensed in the year they occur.

(a) What is the ERR for this set of cash flows?

(b) What is the approximate ERR for this set of cash flows?

(c) Would a project with these cash flows be a good investment?

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MINI-CASE 7.1

Flat Taxes

As discussed in this chapter, personal income taxes in most developed countries are **progressive,** meaning that the rate of taxation increases at higher income levels. However, in several countries a **flat (or proportional) tax** is used. In its basic form, a flat tax requires that a fixed percentage of income (for individuals) or profit (for corporations) be paid as tax. It is simple and said to be fairer for everyone, as well as more lucrative for governments.

Following the fall of communism, Russia and most of the former communist Eastern European countries instituted flat tax regimes. These countries have since had strong economic growth, and many economists credit the flat tax as an important factor in this growth. Other countries that have flat tax include Hong Kong, Saudi Arabia, Nigeria, Uruguay, and the Bahamas.

For individuals, a flat tax is very easy to manage. For most workers, no tax return is required since deductions made by employers on their behalf complete their tax compliance. Also there is usually a minimum income before any tax is payable, so that low income earners are protected.

There are several important consequences of a flat tax on businesses. One is that in most implementations profit is taxed only once, as opposed to some countries in which it is taxed at the company level and then again at the taxpayer level when profits are distributed as dividends or capital gains. Another important consequence for most implementations of a flat tax is that all capital purchases for a company are expensed in the year of purchase. Flat taxes also reduce the administration costs for companies, individuals, and governments.

Discussion

The concept of flat taxes has generated heated debate in some developed countries. The simplicity and efficiency of flat taxes make them attractive alternatives to bloated tax bureaucracies, massively complex tax rules, and frustrating reporting requirements that are the norm. Also, there is evidence that flat taxes promote compliance and generate more tax revenue than progressive taxes. However, there are those who would be adversely affected by a change to a flat tax, and there is considerable resistance generated whenever a serious effort to institute a flat tax is made. This may be why the only major countries to move to a flat tax in recent years are ones such as Russia and the Eastern European countries that are newly instituting income taxes and consequently are not threatening entrenched interests.

Questions:

1. Which of the following groups would likely welcome a flat tax? Which would resist it?
   - **(a)** Accountants
   - **(b)** Small business owners
   - **(c)** Individuals with investments in the stock market
   - **(d)** Government tax department workers
   - **(e)** Low-wage earners
   - **(f)** Rich people

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(g) Capital equipment manufacturers

(h) Leasing companies

(i) Welfare recipients

(j) You

2. If a country changed from a tax regime in which corporate profits are taxed twice to a regime in which they are taxed only once, what would likely be the effect on the stock market?

3. In the long run, would the ability to expense capital equipment fully in the year of purchase dramatically affect a company's investment decisions? If so, do you think society is better off as a consequence of these effects, or worse off?

Appendix 7A Deriving the Capital Tax Factor

The change in tax laws of November 13, 1981, made the formula for the CTF a bit complex. To derive the CTF formula, it is easiest to look at the situation before the laws were changed.

Before November 13, 1981, the tax benefit that could be obtained for a depreciable asset with a CCA rate d and a first cost P, when the company was paying tax at rate t, was

Ptd for the first year

$Ptd(1-d)$ for the second year

$Ptd(1-d)^{N-1}$ for the Nth year

Taking the present worth of each of these benefits and summing gives:

$$\text{PW(benefits)} = Ptd\left(\frac{1}{(1+i)} + \frac{(1-d)}{(1+i)^2} + \cdots + \frac{(1-d)^{N-1}}{(1+i)^N} + \cdots\right)$$

$$= \frac{Ptd}{(1+i)}\left(1 + \frac{(1-d)^1}{(1+i)} + \frac{(1-d)^2}{(1+i)^2} + \cdots + \frac{(1-d)^N}{(1+i)^N} + \cdots\right)$$

Noting that for $q < 1$,

$$\lim_{n\to\infty}(1 + q + q^2 + \cdots + q^n) = \frac{1}{1-q}$$

And

$$\frac{1-d}{1+i} < 1$$

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Then:

$$\text{PW (benefit)} = \frac{Ptd}{(1+i)}\left[\frac{1}{1-\frac{(1-d)}{(1+i)}}\right]$$

$$= \frac{Ptd}{(1+i)}\left[\frac{1}{\frac{(1+i)}{(1+i)}-\frac{(1-d)}{(1+i)}}\right]$$

$$= \frac{Ptd}{(1+i)}\left(\frac{(1+i)}{(i+d)}\right)$$

$$= \frac{Ptd}{(i+d)}$$

If we subtract the present worth of the tax benefits from the first cost, it will give us the present worth of the asset, taking into account all tax benefits from depreciation forever.

$$\text{PW(asset)} = P - \frac{Ptd}{(i+d)}$$

$$= P\left(1-\frac{td}{(i+d)}\right)$$

The factor

$$\left(1-\frac{td}{(i+d)}\right)$$

is now called the capital salvage factor (CSF) and was the formula in use for acquisitions before November 13, 1981.

Now, however, only half of the first cost of an asset can be used in the CCA calculations for the first year. By recognizing that the net effect of current laws is to delay the tax benefits of half of the first cost by one year, the present worth of the benefits is then

$$\text{PW(benefits)} = 0.5\left(\frac{Ptd}{(i+d)}\right) + 0.5\left(\frac{Ptd}{(i+d)}\right)\left(\frac{1}{(1+i)}\right)$$

$$= 0.5\,\frac{Ptd}{(i+d)}\left(1+\frac{1}{(1+i)}\right)$$

$$= 0.5\,\frac{Ptd}{(i+d)}\left(\frac{(1+i)}{(1+i)}+\frac{1}{(1+i)}\right)$$

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$$= 0.5\ \frac{Ptd}{(i+d)}\left(\frac{(2+i)}{(1+i)}\right)$$

$$= P\ \frac{td(1+\frac{i}{2})}{(i+d)(1+i)}$$

And the present worth of the asset itself is

$$\text{PW(asset)} = P - P\ \frac{td(1+\frac{i}{2})}{(i+d)(1+i)}$$

$$= P\left[1 - \frac{td(1+\frac{i}{2})}{(i+d)(1+i)}\right]$$

Thus the CTF is

$$\text{CTF} = 1 - \frac{td(1+\frac{i}{2})}{(i+d)(1+i)}$$

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Replacement Decisions

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ENGINEERING ECONOMICS IN ACTION, PART 8A

You Need the Facts

"You know the 5-stage progressive die that we use for the Admiral Motors rocker arm contract?" Naomi was speaking to Terry, her co-op student, one Tuesday afternoon. "Clem asked me to look into replacing it with a 10-stage progressive die that would reduce the hand finishing substantially. It's mostly a matter of labour cost saving, but there is likely to be some quality improvement with the 10-stage die as well. I would like you to come up with a ballpark estimate of the cost of switching to the 10-stage progressive die."

Terry asked, "Don't you have the cost from the supplier?"

"Yes, but not really," said Naomi. "The supplier is Hamilton Tools. They've given us a price for the machine, but there are a lot of other costs involved in replacing one production process with another."

"You mean things like putting the machine in place?" Terry asked.

"Well, there's that," responded Naomi. "But there is also a lot more. For example, we will lose production during the changeover. That's going to cost us something."

"Is that part of the cost of the 10-stage die?"

"It's part of the first cost of switching to the 10-stage die," Naomi said. "If we decide to go ahead with the 10-stage die and incur these costs, we'll never recover them—they are sunk. We have already incurred those costs for the 5-stage die and it's only two years old. It still has lots of life in it. If the first costs of the 10-stage die are large, it's going to be hard to make a cost justification for switching to the 10-stage die at this time."

"Okay, how do I go about this?" Terry asked.

Naomi sat back and chewed on her yellow pencil for about 15 seconds. She leaned forward and began. "Let's start with order-of-magnitude estimates of what it's going to cost to get the 10-stage die in place. If it looks as if there is no way that the 10-stage die is going to be cost-effective now, we can just stop there."

"It sounds like a lot of fuzzy work," said Terry.

"Terry, I know you like to be working with mathematical models. I'm also sure that you can read the appropriate sections on replacement models in an engineering economics book. But none of those models is worth anything unless you have data to put in it. You need the models to know what information to look for. And once you have the information, you will make better decisions using the models. But you do need the facts."

8.1 Introduction

Survival of businesses in a competitive environment requires regular evaluation of the plant and equipment used in production. As these assets age, they may not provide adequate quality, or their costs may become excessive. When a plant or piece of equipment is evaluated, one of four mutually exclusive choices will be made.

1. An existing asset may be kept in its current use without major change.
2. An existing asset may be overhauled so as to improve its performance.
3. An existing asset may be removed from use without replacement by another asset.
4. An existing asset may be replaced with another asset.

This chapter is concerned with methods of making choices about possible replacement of long-lived assets. While the comparison methods developed in Chapters 5 and 6 for choosing between alternatives are often used for making these choices, the issues of replacement deserve a separate chapter for several reasons. First, the relevant costs for making replacement decisions are not always obvious, since there are costs associated with taking the replaced assets out of service that should be considered. This was ignored in the

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studies in Chapters 5 and 6. Second, the service lives of assets were provided to the reader in Chapters 5 and 6. As seen in this chapter, the principles of replacement allow the calculation of these service lives. Third, assumptions about how an asset might be replaced in the future can affect a decision now. Some of these assumptions are implicit in the methods analysts use to make the choices. It is therefore important to be aware of these assumptions when making replacement decisions.

The chapter starts with an example to introduce some of the basic concepts involved in replacement decisions. Following this is a discussion of the reasons why a long-lived asset may be replaced. We then develop the idea of the *economic life* of an asset—the service life that minimizes the average cost of using the asset. This is followed by a discussion of replacement with an asset that differs from the current asset, in which the built-in cost advantage of existing assets is revealed. Finally, we look at the case of replacement where there may be a series of replacements for a current asset, each of which might be different.

We considered the implications of taxes for replacement decisions in Chapter 7. We assume in this chapter that no future price changes due to inflation are expected. The effect of expected price changes on replacement decisions will be considered in Chapter 9.

8.2 A Replacement Example

We introduce some of the basic concepts involved in replacement decisions through an example.

EXAMPLE 8.1

Sergio likes hiring engineering students to work in his landscaping business during the summer because they are such hard workers and have a lot of common sense. The students are always complaining about maintenance problems with the lawnmowers, which are subject to a lot of use and wear out fairly quickly. His routine has been to replace the machines every five years. Clarissa, one of the engineering student workers, has suggested that replacing them more often might make sense, since so much time is lost when there is a breakdown, in addition to the actual repair cost.

"I've checked the records and have made some estimates that might help us figure out the best time to replace the machines," Clarissa reports. "Every time there is a breakdown, the average cost to fix the machine is $60. In addition to that, there is an average loss of two hours of time at $20 per hour. As far as the number of repairs required goes, the pattern seems to be zero repairs the first season we use a new lawnmower. However, in the second season, you can expect about one repair, two repairs in the third season, four repairs in the fourth, and eight in the fifth season. I can see why you only keep each mower five years!"

"Given that the cost of a new lawnmower has averaged about $600 and that they decline in value at 40 percent per year, and assuming an interest rate of 5 percent, I think we have enough information to determine how often the machines should be replaced," Clarissa concludes authoritatively.

How often should Sergio replace his lawnmowers? How much money will he save?

To keep things simple for now, let's assume that Sergio has to have lawns mowed every year for an indefinite number of years into the future. If he keeps each lawnmower for, say, three years rather than five years, he will end up buying lawnmowers more

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frequently, and his overall capital costs for owning the lawnmowers will increase. However, his repair costs should decrease at the same time since newer lawnmowers require fewer repairs. We want to find out which replacement period results in the lowest overall costs—this is the replacement period Sergio should adopt and is referred to as the *economic life* of the lawnmowers.

We could take any period of time as a study period to compare the various possible replacement patterns using a *present worth* approach. The least common multiple of the service lives method (see Chapter 4) suggests that we would need to use a $3 \times 4 \times 5 =$ 60-year period if we were considering service lives between one and five years. This is an awkward approach in this case, and even worse in situations where there are more possibilities to consider. It makes much more sense to use an *annual worth* approach. Furthermore, since we typically analyze the costs associated with owning and operating an asset, annual worth calculated in the context of a replacement study is commonly referred to as **equivalent annual cost (EAC)**. In the balance of the chapter, we will therefore use EAC rather than annual worth. However, we should not lose sight of the fact that EAC computations are nothing more than the annual worth approach with a different name adopted for use in replacement studies.

Returning to Sergio's replacement problem, if we calculate the EAC for the possibility of a one-year, two-year, three-year (and so on) replacement period, the pattern that has the lowest EAC would indicate which is best for Sergio. It would be the best because he would be spending the least, keeping both the cost of purchase and the cost of repairs in mind.

This can be done in a spreadsheet, as illustrated in Table 8.1. The first column, "Replacement Period," lists the possible replacement periods being considered. In this case, Sergio is looking at periods ranging from one to five years. The second column lists the salvage value of a lawnmower at the end of the replacement period, in this case estimated using the declining-balance method with a rate of 40 percent. This is used to compute the entries of the third column. "EAC Capital Costs" is the annualized cost of purchasing and salvaging each lawnmower, assuming replacement periods ranging from one to five years. Using the capital recovery formula this annualized cost is calculated as:

$$\text{EAC(capital costs)} = (P - S)(A/P, i, N) + Si$$

where

EAC(capital costs) = annualized capital costs for an N-year replacement period

P = purchase price

S = salvage value of the asset at the end of N years

Table 8.1 Total Equivalent Annual Cost Calculations for Lawnmower Replacement Example

Replacement Period (Years)	Salvage Value	EAC Capital Costs	Annual Repair Costs	EAC Repair Costs	EAC Total
1	\$360.00	\$270.00	\$ 0.00	\$ 0.00	\$270.00
2	216.00	217.32	100.00	48.78	266.10
3	129.60	179.21	200.00	96.75	275.96
4	77.76	151.17	400.00	167.11	318.27
5	46.66	130.14	800.00	281.64	411.79

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S can be calculated in turn as

$$BV_{db}(n) = P(1 - d)^n$$

For example, in the case of a three-year replacement period, the calculation is

$$\begin{aligned}\text{EAC(capital costs)} &= [600 - 600(1 - 0.40)^3](A/P,5\%,3) + [600(1 - 0.40)^3](0.05)\\ &= (600 - 129.60)(0.36721) + (129.60)(0.05)\\ &\cong 179.21\end{aligned}$$

The "average" annual cost of repairs (under the heading "EAC Repair Costs"), assuming for simplicity that the cash flows occur at the end of the year in each case, can be calculated as:

$$\begin{aligned}\text{EAC(repairs)} &= [(60 + 40)(P/F,5\%,2) + (60 + 40)(2)(P/F,5\%,3)](A/P,5\%,3)\\ &= [100(0.90703) + 200(0.86584)](0.36721)\\ &\cong 96.75\end{aligned}$$

The total EAC is then:

$$\text{EAC(total)} = \text{EAC(capital costs)} + \text{EAC(repairs)} = 179.22 + 96.75 \cong 275.96$$

Examining the EAC calculations in Table 8.1, it can be seen that the EAC is minimized when the replacement period is two years (and this is only slightly cheaper than replacing the lawnmowers every year). So this is saying that if Sergio keeps his lawnmowers for two years and then replaces them, his average annual costs over time will be minimized. We can also see how much money Clarissa's observation can save him by subtracting the expected yearly costs from the estimate of what he is currently paying. This shows that on average Sergio saves \$411.79 – \$266.10 = \$145.69 per lawnmower per year by replacing his lawnmowers on a two-year cycle over replacing them every five years. ■

The situation illustrated in Example 8.1 is the simplest case possible in replacement studies. We have assumed that the physical asset to be replaced is identical to the one replacing it, and such a sequence continues indefinitely into the future. By *asset*, we mean any machine or resource of value to an enterprise. An existing physical asset is called the **defender**, because it is currently performing the value-generating activity. The potential replacement is called the **challenger**. However, it is not always the case that the challenger and the defender are the same. It is generally more common that the defender is outmoded or less adequate than the challenger, and also that new challengers can be expected in the future.

This gives rise to several cases to consider. Situations like Sergio's lawnmower problem are relatively uncommon—we live in a technological age where it is unlikely that a replacement for an asset will be identical to the asset it is replacing. Even lawnmowers improve in price, capability, or quality in the space of a few years. A second case, then, is that of a defender that is different from the challenger, with the assumption that the replacement will continue in a sequence of identical replacements indefinitely into the future. Finally, there is the case of a defender different from the challenger, which is itself different from another replacing it further in the future. All three of these cases will be addressed in this chapter.

Before we look at these three cases in detail, let's look at why assets have to be replaced at all and how to incorporate various costs into the replacement decision.

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8.3 Reasons for Replacement or Retirement

If there is an ongoing need for the service an asset provides, at some point it will need replacement. **Replacement** becomes necessary if there is a cheaper way to get the service the asset provides, or if the service provided by the existing asset is no longer adequate.

An existing asset is **retired** if it is removed from use without being replaced. This can happen if the service that the asset provides is no longer needed. Changes in customer demand, changes in production methods, or changes in technology may result in an asset no longer being necessary. For example, the growth in the use of MP3 players for audio recordings has led manufacturers of compact discs to retire some production equipment since the service it provided is no longer needed.

There may be a cheaper way to get the service provided by the existing asset for several reasons. First, productive assets often deteriorate over time because of wearing out in use or simply because of the effect of time. As a familiar example, an automobile becomes less valuable with age (older cars, unless they are collectors' cars, are worth less than newer cars with the same mileage) or if it has high mileage (the kilometres driven reflect the wear on the vehicle). Similarly, production equipment may become less productive or more costly to operate over time. It is usually more expensive to maintain older assets. They need fixing more often, and parts may be harder to find and cost more.

Technological or organizational change can also bring about cheaper methods of providing service than the method used by an existing asset. For example, the technological changes associated with the use of computers have improved productivity. Organizational changes, both within a company and in markets outside the company, can lead to lower-cost methods of production. A form of organizational change that has become very popular is the specialist company. These companies take on parts of the production activities of other companies. Their specialization may enable them to have lower costs than the companies can attain themselves. See Close-Up 8.1.

The second major reason why a current asset may be replaced is inadequacy. An asset used in production can become inadequate because it has insufficient capacity to meet growing demand or because it no longer produces items of high enough quality. A company may have a choice between adding new capacity parallel to the existing capacity or replacing the existing asset with a higher capacity asset, perhaps one with more advanced technology. If higher quality is required, there may be a choice between upgrading an existing piece of

CLOSE-UP 8.1 Specialist Companies

Specialist companies concentrate on a limited range of very specialized products. They develop the expertise to manufacture these products at minimal cost. Larger firms often find it more economical to contract out production of low-volume components instead of manufacturing the components themselves.

In some industries, the use of specialist companies is so pervasive that the companies apparently manufacturing a product are simply assembling it; the actual manufacturing takes place at dozens or sometimes hundreds of supplier firms.

A good example of this is the automotive industry. In North America, auto makers support an extremely large network of specialist companies, linked by computer. A single specialist company might supply brake pads, for example, to all three major auto manufacturers. Producing brake pads in huge quantities, the specialist firm can refine its production process to extremes of efficiency and profitability.

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equipment or replacing it with equipment that will yield the higher quality. In either case, contracting out the work to a specialist is one possibility.

In summary, there are two main reasons for replacing an existing asset. First, an existing asset will be replaced if there is a cheaper way to get the service that the asset provides. This can occur because the asset ages or because of technological or organizational changes. Second, an existing asset will be replaced if the service it provides is inadequate in either quantity or quality.

8.4 Capital Costs and Other Costs

When a decision is made to acquire a new asset, it is essentially a decision to purchase the capacity to perform tasks or produce output. **Capacity** is the ability to produce, often measured in units of production per time period. Although production requires capacity, it is also important to understand that just acquiring the capacity entails costs that are incurred whether or not there is actual production. Furthermore, a large portion of the capacity cost is incurred early in the life of the capacity. There are two main reasons for this:

1. Part of the cost of acquiring capacity is the expense incurred over time because the assets required for that capacity gradually lose their value. This expense is often called the **capital cost** of the asset. It is incurred by the difference between what is paid for the assets required for a particular capacity and what the assets could be resold for some time after purchase. The largest portion of the capital costs typically occurs early in the life of the asset.
2. Installing a new piece of equipment or new plant sometimes involves substantial up-front costs, called **installation costs**. These are the costs of acquiring capacity, excluding the purchase cost, which may include disruption of production, training of workers, and perhaps a reorganization of other processes. Installation costs are not reversible once the capacity has been put in place.

For example, if Sergio bought a new lawnmower to accommodate new landscaping clients, rather than for replacement, he would be increasing the capacity of his lawn-mowing service. The capital cost of the lawnmower in the first year would be its associated loss in market value over that year. The installation cost would probably be negligible.

It is worth noting that, in general, the total cost of a new asset includes both the installation costs and the cost of purchasing the asset. When we compute the capital costs of an asset over a period of time, the first cost (usually denoted by P) includes the installation costs. However, when we compute a salvage value for the asset as it ages, we do *not* include the installation costs as part of the depreciable value of the asset, since these costs are expended upon installation and cannot be recovered at a later time.

The large influence of capital costs associated with acquiring new capacity means that, once the capacity has been installed, the *incremental* cost of continuing to use that capacity during its planned life is relatively low. This gives a defender a cost advantage during its planned life over a challenger.

In addition to the capital and installation costs, the purchase of an asset carries with it future **operating and maintenance costs**. Operating costs might include electricity, gasoline, or other consumables, and maintenance might include periodic servicing and repairs. Also, it is worth noting that a challenger may also give rise to changes in revenues as well as changes in costs that should not be neglected.

The different kinds of costs discussed in this section can be related to the more general ideas of fixed and variable costs. **Fixed costs** are those that remain the same,

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regardless of actual units of production. For example, capital costs are usually fixed—once an asset is purchased, the cost is incurred even if there is zero production. **Variable costs** are costs that change depending on the number of units produced. The costs of the raw materials used in production are certainly variable costs, and to a certain degree operating and maintenance costs are as well.

With this background, we now look at the three different replacement cases:

1. Defender and challenger are identical and repeat indefinitely.
2. Challenger repeats indefinitely, but is different from defender.
3. Challenger is different from defender, but does not repeat.

NET VALUE 8.1

Estimating Salvage Values and Scrap Values

An operating asset can have considerable value as long as it continues to perform the function for which it is intended. However, if it is replaced, its salvage value greatly depends on what is done with it. It is likely that the salvage value is different from whatever depreciation value is calculated for accounting or taxation purposes. To make a good replacement decision, it is desirable to have an accurate estimate of the actual salvage value of the asset.

The internet can be very helpful in estimating salvage values. A search for the asset by type, year, and model may reveal a similar asset in a used market. Or a more general search may reveal a broker for used assets of this nature who might be contacted to provide an estimate of salvage value based on the broker's experience with similar assets. In both of these cases, not only can a salvage value be determined, but also a channel for disposing of the asset is found. Even if the asset is scrapped, its value can be estimated from, for example, posted values for metal scrap available on the web.

8.5 Defender and Challenger Are Identical

All long-lived assets eventually require replacement. Consequently, the issue in replacement studies is not *whether* to replace an asset, but *when* to replace it. In this section we consider the case where there is an ongoing need for a service provided by an asset and where the asset technology is not changing rapidly. (This is the case for Sergio's landscaping example.)

Several assumptions are made.

1. The defender and challenger are assumed to be technologically identical. It is also assumed that this remains true for the company's entire planning horizon.
2. The lives of these identical assets are assumed to be short relative to the time horizon over which the assets are required.
3. Relative prices and interest rates are assumed to be constant over the company's time horizon.

These assumptions are quite restrictive. In fact, there are only a few cases where the assumptions strictly hold (cable used for electric power delivery is an example). Nonetheless, the idea of economic life of an asset is still useful to our understanding of replacement analysis.

Assumptions 1 and 2 imply that we may model the replacement decision as being repeated an indefinitely large number of times. The objective is then to determine a

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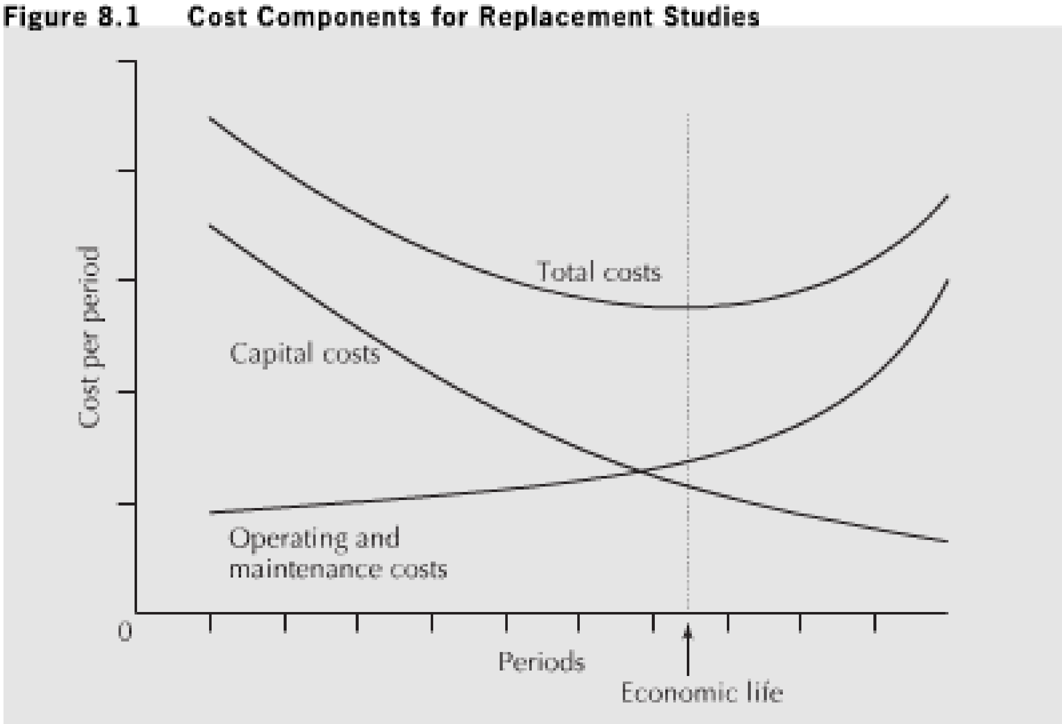
minimum-cost lifetime for the assets, a lifetime that will be the same for all the assets in the sequence of replacements over the company's time horizon.

We have seen that the relevant costs associated with acquiring a new asset are the capital costs, installation costs (which are often pooled with the capital costs), and operating and maintenance costs. It is usually true that operating and maintenance costs of assets—plant or equipment—rise with the age of the asset. Offsetting increases in operating and maintenance costs is the fall in capital costs per year that usually occurs as the asset life is extended and the capital costs are spread over a greater number of years. The rise in operating and maintenance costs per year, and the fall in capital costs per year as the life of an asset is extended, work in opposite directions. In the early years of an asset's life, the capital costs per year (although decreasing) usually, but not always, dominate total yearly costs. As the asset ages, increasing operating and maintenance costs usually overtake the declining annual capital costs. This means that there is a lifetime that will minimize the *average* cost (adjusting for the time value of money) per year of owning and using long-lived assets. This is referred to as the **economic life** of the asset.

These ideas are illustrated in Figure 8.1. Here we see the capital costs per period decrease as the number of periods the asset is kept increases because assets tend to depreciate in value by a smaller amount each period of use. On the other hand, the operating and maintenance costs per period increase because older assets tend to need more repairs and have other increasing costs with age. The economic life of an asset is found at the point where the rate of increase in operating and maintenance costs per period equals the rate of decrease in capital costs per period, or equivalently where the total cost per period is minimized.

Figure 8.1 Cost Components for Replacement Studies



EXAMPLE 8.2

The Jiffy Printer Company produces printers for home use. Jiffy is considering installing an automated plastic moulding system to produce parts for the printers. The moulder itself costs \$20 000 and the installation costs are estimated to be \$5000. Operating and maintenance costs are expected to be \$30 000 in the first year and to rise

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at the rate of 5 percent per year. Jiffy estimates depreciation with a declining-balance model using a rate of 40 percent, and uses a MARR of 15 percent for capital investments. Assuming that there will be an ongoing need for the moulder, and assuming that the technology does not change (i.e., no cheaper or better method will arise), how long should Jiffy keep a moulder before replacing it with a new model? In other words, what is the economic life of the automated moulding system?

Determining the economic life of an asset is most easily done with a spreadsheet. Table 8.2 shows the development of the equivalent annual costs for the automated plastic moulding system of Example 8.2.

In general, the EAC for an asset has two components:

$$\text{EAC} = \text{EAC(capital costs)} + \text{EAC(operating and maintenance)}$$

If

P = the current value of an asset = (for a new asset) purchase price + installation costs

S = the salvage value of an asset N years in the future

then

$$\text{EAC(capital costs)} = [P - (P/F, i, N)S]\,(A/P, i, N)$$

which in Close-Up 4.1 was shown to be equivalent to

$$\text{EAC(capital costs)} = (P - S)(A/P, i, N) + Si$$

In the first column of Table 8.2 is the life of the asset, in years. The second column shows the salvage value of the moulding system as it ages. The equipment costs \$20 000 originally, and as the system ages the value declines by 40 percent of current value each

Table 8.2 Computation of Total Equivalent Annual Costs of the Moulding System With a MARR = 15%

Life in Years	Salvage Value	EAC Capital Costs	EAC Operating and Maintenance Costs	EAC Total
0	\$20 000.00			
1	12 000.00	\$16 750.00	\$30 000.00	\$46 750.00
2	7200.00	12 029.07	30 697.67	42 726.74
3	4320.00	9705.36	31 382.29	41 087.65
4	2592.00	8237.55	32 052.47	40 290.02
5	1555.20	7227.23	32 706.94	39 934.17
6	933.12	6499.33	33 344.56	39 843.88
7	559.87	5958.42	33 964.28	39 922.70
8	335.92	5546.78	34 565.20	40 111.98
9	201.55	5227.34	35 146.55	40 373.89
10	120.93	4975.35	35 707.69	40 683.04

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year, giving the estimated salvage values listed in Table 8.2. For example, the salvage value at the end of the fourth year is

$$BV_{db}(4) = 20\,000(1 - 0.4)^4$$
$$\cong 2592$$

The next column gives the equivalent annual capital costs if the asset is kept for N years, $N = 1, \ldots, 10$. This captures the loss in value of the asset over the time it is kept in service. As an example of the computations, the equivalent annual capital cost of keeping the moulding system for four years is

$$\begin{aligned}\text{EAC(capital costs)} &= (P - S)(A/P,15\%,4) + Si \\ &= (20\,000 + 5000 - 2592)(0.35027) + 2592(0.15) \\ &\cong 8238\end{aligned}$$

Note that the installation costs have been included in the capital costs, as these are expenses incurred at the time the asset is originally put into service. Table 8.2 illustrates that the equivalent annual capital costs decline as the asset's life is extended. Next, the equivalent annual operating and maintenance costs are found by converting the stream of operating and maintenance costs (which are increasing by 5 percent per year) into a stream of equal-sized annual amounts. Continuing with our sample calculations, the EAC of operating and maintenance costs when the moulding system is kept for four years is

$$\begin{aligned}&\text{EAC(operating and maintenance costs)} \\ &= 30\,000\,[(P/F,15\%,1) + (1.05)(P/F,15\%,2) + (1.05)^2(P/F,15\%,3) \\ &\quad + (1.05)^3(P/F,15\%,4)]\,(A/P,15\%,4) \\ &\cong 32\,052\end{aligned}$$

Notice that the equivalent annual operating and maintenance costs increase as the life of the moulding system increases.

Finally, we obtain the total equivalent annual cost of the moulding system by adding the equivalent annual capital costs and the equivalent annual operating and maintenance costs. This is shown in the last column of Table 8.2. We see that at a six-year life the declining equivalent annual installation and capital costs offset the increasing operating and maintenance costs. In other words, the economic life of the moulder is six years, with a total EAC of $39 844. ■

While it is *usually* true that capital cost per year falls with increasing life, it is not always true. Capital costs per year can rise at some point in the life of an asset if the decline in value of the asset is not smooth or if the asset requires a major overhaul.

If there is a large drop in the value of the asset in some year during the asset's life, the cost of holding the asset over that year will be high. Consider the following example.

EXAMPLE 8.3

An asset costs $50 000 to buy and install and has a resale value of $40 000 after installation. It then declines in value by 20 percent per year until the fourth year, when its value drops from over $20 000 to $5000 because of a predictable wearing-out of a major component. Determine the equivalent annual capital cost of this asset for lives ranging from one to four years. The MARR is 15 percent.

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The computations are summarized in Table 8.3. The first column gives the life of the asset in years. The second gives the salvage value of the asset as it ages. The asset loses 20 percent of its previous year's value each year except in the fourth, when its value drops to \$5000. The last column summarizes the equivalent annual capital cost of the asset. Sample computations for the third and fourth years are:

EAC(capital costs, three-year life)

$$= (P - S)(A/P,15\%,3) + Si$$
$$= (40\,000 + 10\,000 - 20\,480)(0.43798) + 20\,480(0.15)$$
$$\cong 16\,001$$

EAC(capital costs, four-year life)

$$= (P - S)(A/P,15\%,4) + Si$$
$$= (40\,000 + 10\,000 - 5000)(0.35027) + 5000(0.15)$$
$$\cong 16\,512$$

Table 8.3 EAC of Capital Costs for Example 8.3

Life in Years	Salvage Value	EAC Capital Costs
0	\$40 000	
1	32 000	\$25 500
2	25 600	18 849
3	20 480	16 001
4	5000	16 512

The large drop in value in the fourth year means that there is a high cost of holding the asset in the fourth year. This is enough to raise the average capital cost per year. ■

In summary, when we replace one asset with another with an identical technology, it makes sense to speak of its economic life. This is the lifetime of an individual asset that will minimize the average cost per year of owning and using it. In the next section, we deal with the case where the challenger is different from the defender.

SPREADSHEET SAVVY

As already demonstrated in earlier Spreadsheet Savvy boxes, there are many useful features in spreadsheet software that make economic evaluations much easier to carry out. Spreadsheet software is also used to prepare and present results to others. Reports, whether formal or informal, communicate more clearly and persuasively when they are easy to read and formatted in a professional manner. Some of the basic formatting features of Excel are covered here.

The most basic formatting choices are font, font size, and effects such as **bold**, *italics*, or <u>underline</u>. In Excel 2010, these formatting choices can be found under the Home tab under Font. Simply select the cells to be formatted, choose the appropriate format, and Excel will apply it to the selected cells. Alternatively, by right-clicking on the selected cells, a pop-up box with a number of alternatives will appear, one of which is Format Cells. Selecting this will lead you to a range of formatting

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options for the selected cells, including font, alignment, border, fill, and number. The table below illustrates some common formatting choices from these alternatives.

	A	B	C	D
1				
2		Defender		
3		Life in Years	Salvage Value	Operating and Maintenance Costs
4		0	$49 000.00	
5		1	36 500.23	$17 000.97
6		2	19 875.19	21 320.23
7		3	15 656.78	26 806.56
8		4	6 742.10	33 774.75

Cells B2:D3 are formatted as "text" (Number tab). These cells also have their background colour set to grey (Fill tab). Cells B3:D3 are centred horizontally and have "wrap text" control selected (Number tab) so that if the text in the column is too long to appear on one line, it "wraps" and appears on two lines. "Defender" was entered into cell B2. Cells B2:D2 were selected and the option chosen was Centre Across Selection, thus centring "Defender" across the three selected columns.

Cells B4:B8 are formatted as numbers with zero decimal places (Number tab) and have been centred horizontally (Alignment tab). The formatting for cells C4:D8 is custom: They are right (indent) aligned with four spaces indented (Alignment tab). Custom formatting has also been applied (Number tab) so that two decimal places appear and a space is used as a thousands separator rather than a comma.

Custom formats can be applied by selecting the Custom formatting option (Number tab) and entering a format style. In this case, $### ###.00 was used for cells C4 and D5 and ### ###.00 for the remaining numeric cells. The $ places a leading dollar sign, and number signs are used to display as many or as few numeric characters as needed (up to 999 999). Two decimal places will always appear, regardless of the number of significant digits stored in the cell.

8.6 Challenger Is Different From Defender; Challenger Repeats Indefinitely

The decision rule that minimizes cost in the case where a defender is faced by a challenger that is expected to be followed by a sequence of identical challengers is as follows.

1. Determine the economic life of the challenger and its associated EAC.
2. Determine the remaining economic life of the defender and its associated EAC.
3. If the EAC of the defender is greater than the EAC of the challenger, replace the defender now. Otherwise, do not replace now.

In many cases, the computations in step 2 can be reduced somewhat. For assets that have been in use for several years, the yearly capital costs will typically be low compared to the yearly operating costs—the asset's salvage value won't change much from year to year but the operating costs will continue to increase. If this is true, as it often is for assets being replaced, the **one year principle** can be used. This principle states that if the capital costs

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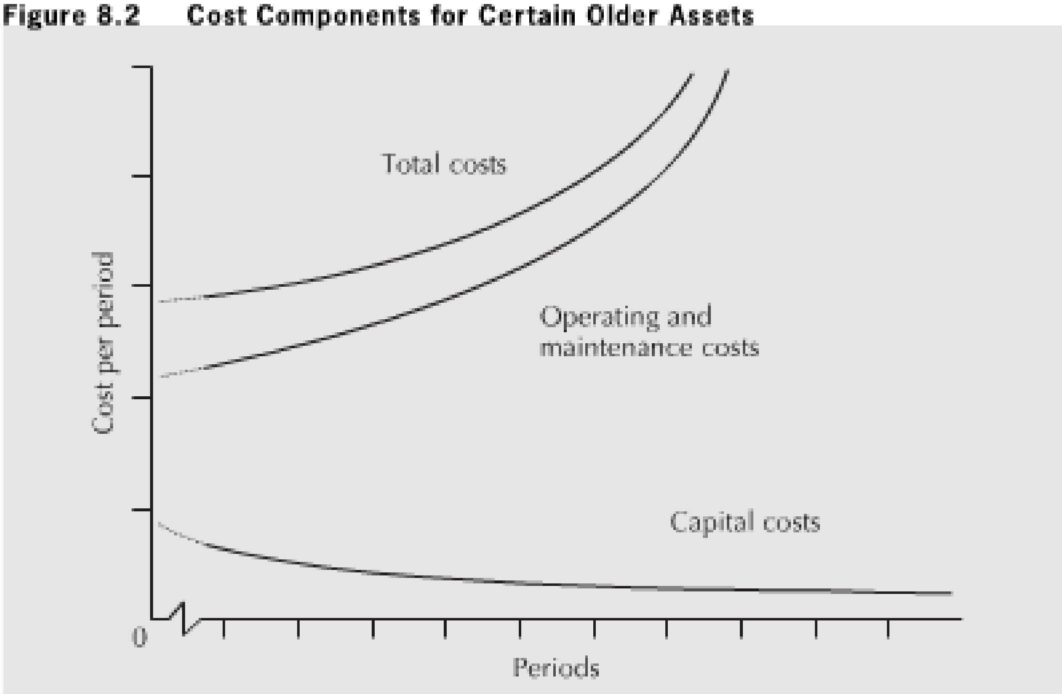
for the defender are small compared to the operating costs, and the yearly operating costs are monotonically increasing, the economic life of the defender is one year and its total EAC is the cost of using the defender for one more year.

The principle thus says that if the EAC of keeping the defender one more year exceeds the EAC of the challenger at its economic life, the defender should be replaced immediately. The advantage of the one year principle is that there is no need to find the service life for the defender that minimizes the EAC—it is known in advance that the EAC is minimized in a one-year period. The principle is particularly useful because for most assets the operating costs increase smoothly and monotonically as the asset is kept for longer and longer periods of time, while the capital costs decrease smoothly and monotonically. For a defender that has been in use for some time, the EAC (operating costs) will typically dominate the EAC (capital costs), and thus the total EAC will increase over any additional years that the asset is kept. This is illustrated in Figure 8.2, which can be compared to Figure 8.1 on page 286.

Figure 8.2 Cost Components for Certain Older Assets



For older assets that conform to this pattern of costs, it is only necessary to check whether the defender needs replacing due to costs over the next year, because in subsequent years the case for the defender will only get worse, not better. If there is an uneven yearly pattern of operating costs, the one year principle cannot be used, because the current year might give an unrealistic value due to the particular expenses in that year.

EXAMPLE 8.4

An asset is three years old. Yearly operating and maintenance costs are currently $5000 per year, increasing by 10 percent per year. The salvage value for the asset is currently $60 000 and is expected to be $50 000 one year from now. Can the one year principle be used?

The capital costs are not low (and thus the EAC(capital costs) for any given service life is not low) compared to the operating and maintenance costs. Even though costs have a regular pattern, the one year principle cannot be used. ■

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EXAMPLE 8.5

An asset is 10 years old. Yearly operating and maintenance costs are currently \$5000 per year, increasing by 10 percent per year. The salvage value of the asset is currently \$8000 and is expected to be \$7000 one year from now. Can the one year principle be used?

The capital costs are low compared to the operating and maintenance costs, and costs have a regular pattern. The one year principle can be used. ■

EXAMPLE 8.6

An asset is 10 years old. Operating and maintenance costs average \$5000 per year, increasing by 10 percent per year. However, most of the operating and maintenance costs consist of a periodic overhaul costing \$15 000 that occurs every three years. The salvage value of the asset is currently \$8000 and is expected to be \$7000 one year from now. Can the one year principle be used?

The capital costs are low compared to the operating and maintenance costs but the operating and maintenance costs do not have an even pattern from year to year. The one year principle cannot be used. ■

The one year principle can be used when it is clear that the key conditions—low capital costs and a regular year-to-year pattern of monotonically increasing operating and maintenance costs—are satisfied. Where a situation is ambiguous, it is always prudent to fully assess the EAC of the defender.

To fully explore the case of a defender being replaced by a challenger that repeats, as well as to explore some other ideas useful in replacement analysis, the next three subsections cover examples to illustrate the analysis steps. In the first, we examine the situation of replacing subcontracted capacity with in-house production. This is an example of replacing a service with an asset. In the second example, the issue of sunk costs is examined by considering the replacement of an existing productive asset with a different challenger. In the final example, we look at the situation of making replacement decisions when there are irregular cash flows.

8.6.1 Converting From Subcontracted to In-House Production

EXAMPLE 8.7

Currently, the Jiffy Printer Company of Example 8.2 pays a custom moulder \$0.25 per piece (excluding material costs) to produce parts for its printers. Demand is forecast to be 200 000 parts per year. Jiffy is considering installing the automated plastic moulding system described in Example 8.2 to produce the parts. Should it do so now?

In Jiffy's situation, the *defender* is the current technology: a subcontractor. The *challenger* is the automated plastic moulding system. In order to decide whether Jiffy is better off with the defender or the challenger, we need to compute the unit cost (cost per piece) of production with the automated moulder and compare it to the unit cost for the subcontracted parts. If the automated system is better, the challenger wins and should replace the defender.

From Example 8.2:

EAC(moulder) = 39 844

Dividing the EAC by the expected number of parts needed per year allows us to calculate the unit cost as 39 838/200 000 = 0.1992.

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When the unit cost of in-house production is compared with the \$0.25 unit cost of subcontracting the work, in-house production is cheaper, so Jiffy should replace the subcontracting with an in-house automated plastic moulding system. ■

This example has illustrated the basic idea behind a replacement analysis when we are considering the purchase of a new asset as a replacement for current technology. The cost of the replacement must take into account the capital costs (including installation) and the operating and maintenance costs over the life of the new asset.

In the next subsection, we see how some costs are no longer relevant in the decision to replace an *existing* asset.

8.6.2 The Irrelevance of Sunk Costs

Once an asset has been installed and has been operating for some time, the costs of installation and all other costs incurred up to that time are no longer relevant to any decision to replace the current asset. These costs are called **sunk costs**. Only those costs that will be incurred in keeping and operating the asset from this time on are relevant. This is best illustrated with an example.

EXAMPLE 8.8

Two years have passed since the Jiffy Printer Company from Example 8.7 installed an automated moulding system to produce parts for its printers. At the time of installation, it expected to be producing about 200 000 pieces per year, which justified the investment. However, its actual production has turned out to be only about 150 000 pieces per year. Its unit cost is \$39 844/150 000 = \$0.2656 rather than the \$0.1992 it had expected. It estimates the current market value of the moulder at \$7200. In this case, maintenance costs do not depend on the actual production rate. Should Jiffy sell the moulding system and go back to buying from the custom moulder at \$0.25 per piece?

In the context of a replacement problem, Jiffy is looking at replacing the existing system (the defender) with a different technology (the challenger). Since Jiffy already has the moulder and has already expended considerable capital on putting it into place, it may be better for Jiffy to keep the current moulder for some time longer. Let us calculate the cost to Jiffy of keeping the moulding system for one more year. This may not be the optimal length of time to continue to use the system, but if the cost is less than \$0.25 per piece it is cheaper than retiring or replacing it now.

The reason why the cost of keeping the moulder an additional year may be low is that the capital costs for the two-year-old system are now low compared with the costs of putting the capacity in place. The capital cost for the third year is simply the loss in value of the moulder over the third year. This is the difference between what Jiffy can get for the system now, at the end of the second year, and what it can get a year from now when the system will be three years old. Jiffy can get \$7200 for the system now. Using the declining-balance depreciation rate of 40 percent to calculate a salvage value, we can determine the capital cost associated with keeping the moulder over the third year.

Applying the capital recovery formula from Chapter 4, the EAC for capital costs is

$$\begin{aligned}\text{EAC(capital costs, third year)} &= (P - S)(A/P,15\%,1) + Si \\ &= [7200 - 0.6(7200)](1.15) + 0.6(7200)(0.15) \\ &\cong 3960\end{aligned}$$

Recall that the operating and maintenance costs started at \$30 000 and rose at 5 percent

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$$\text{EAC(operating and maintenance, third year)} = 30\,000(1.05)^2 \cong 33\,075$$

The total cost of keeping the moulder for the third year is the sum of the capital costs and the operating and maintenance costs:

$$\begin{aligned}\text{EAC(third year)} &= \text{EAC(capital costs, third year)} + \\ &\quad \text{EAC (operating and maintenance, third year)} \\ &= 3960 + 33\,075 \\ &\cong 37\,035\end{aligned}$$

Dividing the annual costs for the third year by 150 000 units gives us a unit cost of $0.247 for moulding in-house during the third year. Not only is this lower than the average cost over a six-year life of the system, it is also lower than what the subcontracted custom moulder charges. Similar computations would show that Jiffy could go two more years after the third year with in-house moulding. Only then would the increase in operating and maintenance costs cause the total unit cost to rise above $0.25.

Given the lower demand, we see that installing the automated moulding system was a mistake for Jiffy. The average lifetime costs for in-house moulding were greater than the cost of subcontracting, but once the system was installed, it was not optimal to go back to subcontracting immediately. This is because the capital cost associated with the purchase and installation of an asset (which becomes sunk after its installation) is disproportionately large as compared with the cost of using the asset once it is in place. ■

That a defender has a cost advantage over a challenger, or over contracting out during its planned life, is important. It means that if a defender is to be removed from service during its life for cost reasons, the average lifetime costs for the challenger or the costs of contracting out must be considerably lower than the average lifetime costs of the defender.

Just because well-functioning defenders are not often retired for cost reasons does not mean that they will not be retired at all. Changes in markets or technology may make the quantity or quality of output produced by a defender inadequate. This can lead to its retirement or replacement even when it is functioning well.

8.6.3 When Capital or Operating Costs Are Non-Monotonic

Sometimes operating costs do not increase smoothly and monotonically over time. The same can happen to capital costs. When the operating or capital costs are not smooth and monotonic, the one year principle does not apply. The reason why the principle does not apply is that there may be periodic or one-time costs that occur over the course of the next year (as in the case where periodic overhauls are required). These costs may make the cost of keeping the defender for one more year greater than the cost of installing and using the challenger over its economic life. However, there may be a life longer than one year over which the cost of using the defender is less than the cost of installing and using a challenger. Consider this example concerning the potential replacement of a generator.

EXAMPLE 8.9

The Colossal Construction Company uses a generator to produce power at remote sites. The existing generator is now three years old. It cost $11 000 when purchased. Its current salvage value of $2400 is expected to fall to $1400 next year and to $980 the year after, and to continue declining at 30 percent of current value per year. Its ordinary

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$500 per year. There is also a requirement to do an overhaul that will cost $1000 this year and every third year thereafter.

New fuel-efficient generators have been developed, and Colossal is thinking of replacing its existing generator. It is expected that the new generator technology will be the best available for the foreseeable future. The new generator sells for $9500. Installation costs are negligible. Other data for the new generator are summarized in Table 8.4.

Table 8.4 Salvage Values and Operating Costs for New Generator

End of Year	Salvage Value	Operating Cost
0	$9500	
1	8000	$1000
2	7000	1000
3	6000	1200
4	5000	1500
5	4000	2000
6	3000	2000
7	2000	2000
8	1000	3000

Should Colossal replace the existing generator with the new type? The MARR is 12 percent.

We first determine the economic life for the challenger. The calculations are shown in Table 8.5.

Sample calculations for the EAC of keeping the challenger for one, two, and three years are as follows:

$$\begin{aligned} \text{EAC(1 year)} &= (P - S)(A/P, 12\%, 1) + Si + 1000 \\ &= (9500 - 8000)(1.12) + 8000(0.12) + 1000 \\ &\cong 3640 \end{aligned}$$

Table 8.5 Economic Life of the New Generator

End of Year	Salvage Value	Operating Costs	EAC
1	$8000	$1000	$3640.00
2	7000	1000	3319.25
3	6000	1200	3236.50
4	5000	1500	**3233.07***
5	4000	2000	3290.81
6	3000	2000	3314.16
7	2000	2000	3318.68
8	1000	3000	3393.52

*Lowest equivalent annual cost.

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$$\begin{aligned}\text{EAC(2 years)} &= (P - S)(A/P,12\%,2) + Si + 1000\\ &= (9500 - 7000)(0.5917) + 7000(0.12) + 1000\\ &\cong 3319\end{aligned}$$

$$\begin{aligned}\text{EAC(3 years)} &= (P - S)(A/P,12\%,3) + Si + 1000 + 200(A/F,12\%,3)\\ &= (9500 - 6000)(0.41635) + 6000(0.12) + 1000\\ &\quad + 200(0.29635)\\ &\cong 3237\end{aligned}$$

As the number of years increases, this approach for calculating the EAC becomes more difficult, especially since in this case the operating costs are neither a standard annuity nor an arithmetic gradient. An alternative is to calculate the present worths of the operating costs for each year. The EAC of the operating costs can be found by applying the capital recovery factor to the sum of the present worths for the particular service period considered. This approach is particularly handy when using spreadsheets.

By either calculation, we see in Table 8.5 that the economic life of the generator is four years.

Next, to see if and when the defender should be replaced, we calculate the costs of keeping the defender for one more year. Using the capital recovery formula:

$$\begin{aligned}&\text{EAC (keep defender 1 more year)}\\ &\quad = \text{EAC(capital costs)} + \text{EAC(operating costs)}\\ &\quad = (2400 - 1400)(A/P,12\%,1) + 1400(0.12) + 2000\\ &\quad \cong 3288\end{aligned}$$

The equivalent annual cost of using the defender one more year is \$3288. This is more than the yearly cost of installing and using the challenger over its economic life. Since the operating costs are not smoothly increasing, we need to see if there is a longer life for the defender for which its costs are lower than for the challenger. This can be done with a spreadsheet, as shown in Table 8.6.

We see that, for an additional life of three years, the defender has a lower cost per year than the challenger, when the challenger is kept over its economic life. Therefore, the defender should not be replaced at this time. Next year a new evaluation should be performed. ■

Table 8.6 Equivalent Annual Cost of Additional Life for the Defender

Additional Life in Years	Salvage Value	Operating Costs	EAC
0	\$2400		
1	1400	\$2000	\$3288
2	980	1500	2722
3	686	2000	**2630**
4	480	3500	2872
5	336	3000	2924
6	235	3500	3013

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8.7 Challenger Is Different From Defender; Challenger Does Not Repeat

In this section, we no longer assume that challengers are alike. We recognize that future challengers will be available and we expect them to be better than the current challenger. We must then decide if the defender should be replaced by the current challenger. Furthermore, if it is to be replaced by the current challenger, *when* should the replacement occur? This problem is quite complex. The reason for the complexity is that, if we believe that challengers will be improving, we may be better off skipping the current challenger and waiting until the next improved challenger arrives. The difficulties are outlined in Example 8.10.

EXAMPLE 8.10

Rita is examining the possibility of replacing the kiln controllers at the Burnaby Insulators plant. She has information about the existing controllers and the best replacement on the market. She also has information about a new controller design that will be available in three years. Rita has a five-year time horizon for the problem. What replacement alternatives should Rita consider?

One way to determine the minimum cost over the five-year horizon is to determine the costs of *all* possible combinations of the defender and the two challengers. This is impossible, since the defender and challengers could replace one another at any time. However, it is reasonable to consider only the combinations of the period length of one year. Any period length could be used, but a year is a natural choice because investment decisions tend, in practice, to follow a yearly cycle. These combinations form a mutually exclusive set of investment opportunities (see Section 5.2 on page 162). If no time horizon were given in the problem, we would have had to assume one, to limit the number of possible alternatives.

The possible decisions that need to be evaluated in this case are shown in Table 8.7.

For example, the first row in Table 8.7 (Alternative 1) means to keep the defender for the whole five-year period. Alternative 2 is to keep the defender for four years, and then purchase the challenger four years from now and keep it for one year. Alternative 15 is to replace the defender now with the first challenger, keep it for three years, then replace it with the second challenger and keep the second challenger for the remaining two years.

To choose among these possible alternatives, we need information about the following for the defender and both challengers:

1. Costs of installing the challengers
2. Salvage values for different possible lives for all three kiln controllers
3. Operating and maintenance costs for all possible ages for all three

With this information, the minimum-cost solution is obtained by computing the costs for all possible decision alternatives. Since these are mutually exclusive projects, any of the comparison methods of Chapters 5 and 6 are appropriate, including present worth, annual worth, and IRR. The effects of sunk costs are already included in the enumeration of the various replacement possibilities, so looking at the benefits of keeping the defender is already automatically taken into account. ■

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Table 8.7 Possible Decisions for Burnaby Insulators

Decision Alternative	Defender Life in Years	First Challenger Life in Years	Second Challenger Life in Years
1	5	0	0
2	4	1	0
3	4	0	1
4	3	2	0
5	3	1	1
6	3	0	2
7	2	3	0
8	2	2	1
9	2	1	2
10	1	4	0
11	1	3	1
12	1	2	2
13	0	5	0
14	0	4	1
15	0	3	2

The difficulty with this approach is that the computational burden becomes great if the number of years in the time horizon is large. On the other hand, it is unlikely that information about a future challenger will be available under normal circumstances. In Example 8.10, Rita knew about a controller that wouldn't be available for three years. In real life, even if somehow Rita had inside information on the supplier research and marketing plans, it is unlikely that she would be confident enough of events three years away to use the information with complete assurance. Normally, if the information were available, the challenger itself would be available, too. Consequently, in many cases it is reasonable to assume that challengers in the planning future will be identical to the current challenger, and the decision procedure to use is the simpler one presented in the previous section.

REVIEW PROBLEMS

REVIEW PROBLEM 8.1

Kenwood Limousines runs a fleet of vans that ferry people from several outlying cities to a major international airport. New vans cost $45 000 each and depreciate at a declining-balance rate of 30 percent per year. Maintenance for each van is quite expensive, because they are in use 24 hours a day, seven days a week. Maintenance costs, which

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are about $3000 the first year, double each year the vehicle is in use. Given a MARR of 8 percent, what is the economic life of a van?

ANSWER

Table 8.8 shows the various components of this problem for replacement periods from one to five years. It can be seen that the replacement period with the minimum equivalent annual cost is two years. Therefore, the economic life is two years.

Table 8.8 Summary Computations for Review Problem 8.1

Year	Salvage Value	Maintenance Costs	Equivalent Annual Costs		
			Capital	Maintenance	Total
0	$45 000				
1	31 500	$3000	$17 100	$ 3000	$20 100
2	22 050	6000	14 634	4442	**19 076**
3	15 435	12 000	12 707	6770	19 477
4	10 805	24 000	11 189	10 594	21 783
5	7563	48 000	9981	16 970	26 951

As an example, the calculation for a three-year period is:

EAC(capital costs)

$$= (45\,000 - 15\,435)(A/P{,}8\%{,}3) + 15\,435(0.08)$$
$$= 29\,565(0.38803) + 15\,435(0.08)$$
$$\cong 12\,707$$

EAC(maintenance costs)

$$= [3000(F/P{,}8\%{,}2) + 6000(F/P{,}8\%{,}1) + 12\,000]\,(A/F{,}8\%{,}3)$$
$$= [3000(1.1664) + 6000(1.08) + 12\,000)](0.30804)$$
$$\cong 6770$$

$$\text{EAC(total)} = \text{EAC(capital costs)} + \text{EAC(maintenance costs)}$$
$$= 12\,707 + 6770 = 19\,477. \blacksquare$$

REVIEW PROBLEM 8.2

Canadian Widgets makes rocker arms for car engines. The manufacturing process consists of punching blanks from raw stock, forming the rocker arm in a 5-stage progressive die, and finishing in a sequence of operations using hand tools. A recently developed 10-stage die can eliminate many of the finishing operations for high-volume production.

The existing 5-stage die could be used for a different product, and in this case would have a salvage value of $20 000. Maintenance costs of the 5-stage die will total $3500 this year and are expected to increase by $3500 per year. The 10-stage die will cost $89 000 and will incur maintenance costs of $4000 this year, increasing by $2700 per year thereafter. Both dies depreciate at a declining-balance rate of 20 percent per year. The net yearly benefit of the automation of the finishing operations is expected to be $16 000 per year. The MARR is 10 percent. Should the 5-stage die be replaced?

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ANSWER

Since there is no information about subsequent challengers, it is reasonable to assume that the 10-stage die would be repeated. The EAC of using the 10-stage die for various periods is shown in Table 8.9.

A sample EAC computation for keeping the 10-stage die for two years is as follows:

EAC(capital costs, two-year life)

$$= (P - S)(A/P,10\%,2) + Si$$
$$= (89\,000 - 56\,960)(0.57619) + 56\,960(0.10)$$
$$\cong 24\,157$$

EAC(maintenance costs, two-year life)

$$= [4000(F/P,10\%,1) + 6700](A/F,10\%,2)$$
$$= [4000(1.1) + 6700](0.47619)$$
$$\cong 5286$$

Table 8.9 EAC Computations for the Challenger in Review Problem 8.2

Life in Years	Salvage Value	Maintenance Costs	Equivalent Annual Costs		
			Capital	Maintenance	Total
0	$89 000				
1	71 200	$ 4000	$26 700	$ 4000	$30 700
2	56 960	6700	24 157	5286	29 443
3	45 568	9400	22 021	6529	28 550
4	36 454	12 100	20 222	7729	27 951
5	29 164	14 800	18 701	8887	27 589
6	23 331	17 500	17 411	10 004	27 415
7	18 665	20 200	16 314	11 079	**27 393**
8	14 932	22 900	15 377	12 113	27 490

EAC(total, two-year life)

$$= 24\,157 + 5286$$
$$= 29\,443$$

Completing similar computations for other lifetimes shows that the economic life of the 10-stage die is seven years and the associated equivalent annual costs are $27 393.

The next step in the replacement analysis is to consider the annual cost of the 5-stage die (the defender) over the next year. This cost is to be compared with the economic life EAC of the 10-stage die—that is, $27 393. Note that the cost analysis of the defender should include the benefits generated by the 10-stage die as an operating cost for the 5-stage die, as this $16 000 is a cost of *not* changing to the 10-stage die.

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Since the capital costs are low and operating costs are monotonically increasing, the one year principle applies. The EAC of the capital and operating costs of keeping the defender one additional year are found as follows:

$$\text{Salvage value of 5-stage die after one year} = 20\,000(1 - 0.2) = \$16\,000$$

$$\begin{aligned}
&\text{EAC(capital costs, one additional year)}\\
&\quad = (P - S)(A/P,10\%,1) + Si\\
&\quad = (20\,000 - 16\,000)(1.10) + 16\,000(0.10)\\
&\quad \cong 6000
\end{aligned}$$

$$\begin{aligned}
&\text{EAC(maintenance and operating costs, one additional year)}\\
&\quad = 3500 + 16\,000\\
&\quad \cong 19\,500
\end{aligned}$$

$$\begin{aligned}
&\text{EAC(total, one additional year)}\\
&\quad = 19\,500 + 6000\\
&\quad \cong 25\,500
\end{aligned}$$

The 5-stage die should not be replaced this year because the EAC of keeping it one additional year ($25 500) is less than the optimal EAC of the 10-stage die ($27 393). The knowledge that the 5-stage die should not be replaced this year is usually sufficient for the immediate replacement decision. However, if a different challenger appears in the future, we would want to reassess the replacement decision.

It may also be desirable to estimate when in the future the defender might be replaced, even if it is not being replaced now. This can be done by calculating the equivalent annual cost of keeping the defender additional years until the time we can determine when it should be replaced. Table 8.10 summarizes those calculations for additional years of operating the 5-stage die.

Table 8.10 EAC Computations for Keeping the Defender Additional Years

Additional Life in Years	Salvage Value	Maintenance and Operating Costs	Equivalent Annual Costs		
			Capital	Operating	Total
0	$20 000				
1	16 000	$19 500	$6000	$19 500	$25 500
2	12 800	23 000	5429	21 167	26 595
3	10 240	26 500	4949	22 778	27 727
4	8192	30 000	4544	24 334	28 878
5	6554	33 500	4202	25 836	30 038
6	5243	37 000	3913	27 283	31 196
7	4194	40 500	3666	28 677	32 343
8	3355	44 000	3455	30 018	33 473

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As an example of the computations, the EAC of keeping the defender for two additional years is calculated as

Salvage value of 5-stage die after two years = 16 000(1 − 0.2) = 12 800

EAC(capital costs, two additional years)

$$= (P - S)(A/P,10\%,2) + Si$$
$$= (20\,000 - 12\,800)(0.57619) + 12\,800(0.10)$$
$$\cong 5429$$

EAC(maintenance and operating costs, two additional years)

$$= [19\,500(F/P,10\%,1) + (16\,000 + 7000)](A/F,10\%,2)$$
$$= [19\,500(1.1) + 23\,000](0.47619)$$
$$\cong 21\,167$$

EAC(total, two additional years)

$$= 5429 + 21\,167 = 26\,595$$

Further calculations in this manner will predict that the defender should be replaced at the end of the second year, given that the challenger remains the same during this time. This is because the EAC of keeping the defender for two years is less than the optimal EAC of the 10-stage die, but keeping the defender three years or more is more costly. ■

REVIEW PROBLEM 8.3

Avril bought a computer three years ago for $3000, which she can now sell on the open market for $300. The local Mr. Computer store will sell her a new HAL computer for $4000, including the new accounting package she wants. Her own computer will probably last another two years, and then would be worthless. The new computer would have a salvage value of $300 at the end of its economic life of five years. The net benefits to Avril of the new accounting package and other features of the new computer amount to $800 per year. An additional feature is that Mr. Computer will give Avril a $500 trade-in on her current computer. Interest is 15 percent. What should Avril do?

ANSWER

There are a couple of things to note about this problem. First, the cost of the new computer should be taken as $3800 rather than $4000. This is because, although the price was quoted as $4000, the dealer was willing to give Avril a $500 trade-in on a used computer that had a market value of only $300. This amounts to discounting the price of the new computer to $3800. Similarly, the used computer should be taken to be worth $300, and not $500. The $500 figure does not represent the market value of the used computer, but rather the value of the used computer combined with the discount on the new computer. One must sometimes be careful to extract from the available information the best estimates of the values and costs for the various components of a replacement study.

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First, we need to determine the EAC of the challenger over its economic life. We are told that the economic life is five years, and hence the EAC computations are as follows:

$$\begin{aligned}
\text{EAC(capital costs)} &= (3800 - 300)(A/P,15\%,5) + 300(0.15)\\
&= 3500(0.29832) + 45\\
&\cong 1089\\
\text{EAC(operating costs)} &= 0\\
\text{EAC(challenger, total)} &= 1089
\end{aligned}$$

Now we need to check the equivalent annual cost of keeping the existing computer one additional year. A salvage value for the computer for one year was not given. However, we can check to see if the EAC for the defender over two years is less than for the challenger. If it is, this is sufficient to retain the old computer.

$$\begin{aligned}
\text{EAC(capital costs)} &= (300 - 0)(A/P,15\%,2) + 0(0.15)\\
&= 300(0.61512) + 0\\
&\cong 185\\
\text{EAC(operating costs)} &= 800\\
\text{EAC(defender, total over 2 years)} &= 985
\end{aligned}$$

Avril should hang on to her current computer because its EAC over two years is less than the EAC of the challenger over its five-year economic life. ■

SUMMARY

This chapter is concerned with replacement and retirement decisions. Replacement can be required because there may be a cheaper way to provide the same service, or the nature of the service may have changed. Retirement can be required if there is no longer a need for the asset.

If an asset is replaced by a stream of identical assets, it is useful to determine the economic life of the asset, which is the replacement interval that provides the minimum annual cost. The asset should then be replaced at the end of its economic life.

If there is a challenger that is different from the defender, and future changes in technology are not known, one can determine the minimum EAC of the challenger and compare this with the cost of keeping the defender. If keeping the defender for any period of time is cheaper than the minimum EAC of the challenger, the defender should be kept. Often it is sufficient to assess the cost of keeping the defender for one more year.

Defenders that are still functioning well have a significant cost advantage over challengers or over obtaining the service performed by the defender from another source. This is because there are installation costs and because the capital cost per year of an asset diminishes over time.

Where future changes in technology are expected, decisions about when and whether to replace defenders are more complex. In this case, possible replacement decisions must be enumerated as a set of mutually exclusive alternatives and subjected to any of the standard comparison methods.

Figure 8.3 provides a summary of the overall procedure for assessing a replacement decision.

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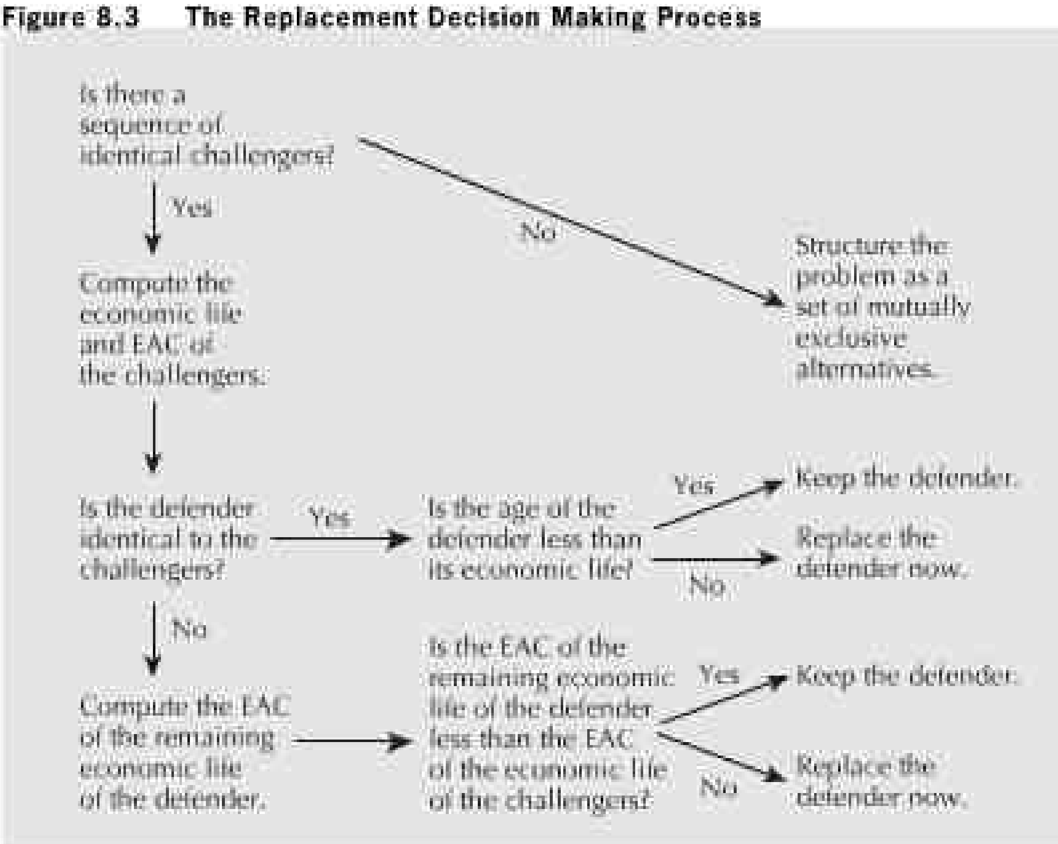
Figure 8.3 The Replacement Decision Making Process



ENGINEERING ECONOMICS IN ACTION, PART 8B

Decision Time

Naomi, Dave, and Clem were meeting in Clem's office. They had just finished a discussion of their steel-orderir policy. Clem turned to Naomi and said, "Okay. Let's look at the 10-stage progressive die. Where does that stand?

Naomi said, "It looks possible. Did you get a chance to read Terry's report?"

"Yes, I did," Clem answered. "Was it his idea to use the 5-stage die for small runs so that we don't have take a big hit from scrapping it?"

"Actually, it was," Naomi said.

"The kid may be a little intense," Clem said, "but he does good work. So where does that leave us?"

"Well, as I said, it looks possible that the 10-stage die will pay off," Naomi responded. "We have to decic what the correct time horizon is for making the analysis. Then we need more precise estimates of the costs ar salvage value for the 10-stage die."

Clem turned in his chair and asked, "What do you think, Dave?"

Dave straightened himself in his chair and said, "I really don't know. How much experience has Hamilt Tools had at making dies this complicated?"

Naomi answered, "Not much. If we took them up on their proposal, we'd be their second or third customer."

"What do you have in mind, Dave?" Clem asked.

"Well, if it's only the second or third time they've done something like this, I think we can expect som improvements over the next couple of years. So maybe we ought to wait," he replied.

"That makes sense," Clem responded. "I'd like you two to work on this. Give Tan Wang at Hamilton Tools a call. He know if anything is in the works. Get him to give you an estimate of what to expect. Then I want you to consider some po sibilities. You know: 'Replace now.' 'Wait one year.' 'Wait two years.' And so on. Don't make it too complicated. Then evalu ate the different possibilities. I want a recommendation for next week's meeting. It's getting to be decision time."

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PROBLEMS

A. Key Concepts

8.1 Last year, Clairbrook Canning Co. bought a fancy colour printer, which cost $20 000, for special printing jobs. Fast changes in colour printing technology have resulted in almost identical printers being available today for about one-quarter of the cost. Should CCC consider selling its printer and buying one of the new ones?

8.2 Maryhill Mines has a pelletizer that it is considering for replacement. Every three years it is overhauled at considerable cost. It is due for an overhaul this year. Evelyn, the company's mining engineer, has calculated that the sum of the operating and capital costs for this year for the pelletizer are significantly more than the EAC for a new pelletizer over its service life. Should the existing pelletizer be replaced?

8.3 Which of the following is a capital cost?

(a) A new printer

(b) Paper for a new printer

(c) Cabling to link data sensor nodes for a production management system

(d) Transportation costs to move a new kiln from the manufacturer to a cement plant

(e) Power to run cooling fans for a new snack food fryer

(f) The cost of a building extension that was constructed to allow the placement of a new forge for a steel mill

(g) Replacement cutting blades for a chipper

(h) Software necessary to run a new chip-placing machine

(i) Software updates to other equipment to allow it to interface with a new chip-placing machine

8.4 Freeport Brothers have recently purchased a process management system. Cabling installed in the plant connects data collection nodes to a central server. The costs of this system included the following:

Five data collection nodes	$4500 each
New server	$6000
60-metre cable	$11.40 per metre
Cabling hardware	$188
Node software	$1190 per node
Server software	$1950
10 hours of hardware installer time	$20 per hour
25 hours of software installer time	$60 per hour

If Freeport Brothers wanted to calculate a replacement interval for such a process management system, what would be the capital cost for the first year at a depreciation rate of 30 percent?

8.5 Determine the economic life for each of the items listed on the next page. Salvage values can be estimated by the declining-balance method using an annual rate of 20 percent.

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	Purchase	Installation	Operating
Item 1	\$10 000	\$2000	\$300 first year, increasing by \$300 per year
Item 2	\$20 000	\$2000	\$200 first year, increasing by \$200 per year
Item 3	\$30 000	\$3000	\$2000 first year, increasing by \$2000 per year

8.6 A new bottle-capping machine costs \$45 000, including \$5000 for installation. The machine is expected to have a useful life of eight years with no salvage value at that time (assume straight-line depreciation). Operating and maintenance costs are expected to be \$3000 for the first year, increasing by \$1000 each year thereafter. Interest is 12 percent.

(a) Construct a spreadsheet that has the following headings: Year, Salvage Value, Maintenance Costs, EAC(Capital Costs), EAC(Operating Costs), and EAC(Total Costs). Compute the EAC(Total Costs) if the bottle capper is kept for n years, $n = 1, \ldots, 8$.

(b) Construct a chart showing the EAC(Capital Costs), EAC(Operating Costs), and EAC(Total Costs) if the bottle capper were to be kept for n years, $n = 1, \ldots, 8$.

(c) What is the economic life of the bottle capper?

8.7 A water pump to be used by the city's maintenance department costs \$10 000 new. A running-in period, costing \$1000 immediately, is required for a new pump. Operating and maintenance costs average \$500 the first year, increasing by \$300 per year thereafter. The salvage value of the pump at any time can be estimated by the declining-balance rate of 20 percent. Interest is at 10 percent. Using a spreadsheet, calculate the EAC for replacing the pump after one year, two years, etc. How often should the pump be replaced?

8.8 The water pump from Problem 8.7 is being considered to replace an existing one. The current one has a salvage value of \$1000 and will retain this salvage value indefinitely.

(a) Operating costs are currently \$2500 per year and rise by \$400 per year. Should the current pump be replaced? When?

(b) Operating costs are currently \$3500 per year and rise by \$200 per year. Should the current pump be replaced? When?

8.9 An asset has operating and maintenance costs of \$3000 per year, increasing by 5 percent per year. The asset is currently worth \$350 000. Can the one year principle be used?

8.10 An asset has operating and maintenance costs of \$30 000 per year, decreasing by 5 percent per year. The asset is currently worth \$20 000. Can the one year principle be used?

8.11 An asset has operating and maintenance costs that average \$22 000 per year. If a main bearing fails—which can happen at any time—that particular year's cost will exceed

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costs are increasing regularly at about 3 percent per year, and the asset is currently worth \$66 000. Can the one year principle be used?

8.12 An asset has maintenance costs that average \$4000 per year and negligible operating costs. The asset is in an inaccessible location and consequently only actually receives maintenance once every four years. The asset has zero salvage or scrap value and the maintenance costs are rising at about the same rate as inflation. Can the one year principle be used?

B. Applications

8.13 Gerry likes driving small cars and buys nearly identical ones whenever the old one needs replacing. Typically, he trades in his old car for a new one costing about \$15 000. A new car warranty covers all repair costs above standard maintenance (standard maintenance costs are constant over the life of the car) for the first two years. After that, his records show an average repair expense (over standard maintenance) of \$2500 in the third year (at the end of the year), increasing by 50 percent per year thereafter. If a 30 percent declining-balance depreciation rate is used to estimate salvage values, and interest is 8 percent, how often should Gerry get a new car?

8.14 Gerry (see Problem 8.13) has observed that the cars he buys are somewhat more reliable now than in the past. A better estimate of the repair costs is \$1500 in the third year, increasing by 50 percent per year thereafter, with all other information in Problem 8.13 being the same. Now how often should Gerry get a new car?

8.15 For each of the following cases, determine whether the one year principle would apply.

(a) A defender has been in use for seven years and has negligible salvage value. Operating costs are \$400 per year for electricity. Once every five years it is overhauled at a cost of \$1000.

(b) A defender has been in use for seven years and has negligible salvage value. Operating costs are \$400 per year for electricity. Once a year it is overhauled at a cost of \$1000.

(c) A defender has been in use for two years and has negligible salvage value. Operating costs are \$400 per year for electricity. Once a year it is overhauled at a cost of \$1000.

(d) A defender has been in use for seven years and has current salvage value of \$4000. Its value one year from now is estimated to be \$4000. Operating costs are \$400 per year for electricity. Once a year it is overhauled at a cost of \$1000.

(e) A defender has been in use for seven years and has current salvage value of \$4000. Its value one year from now is estimated to be \$2000. Operating costs are \$400 per year for electricity. Once a year it is overhauled at a cost of \$1000.

8.16 A roller conveyor system used to transport cardboard boxes along an order-filling line costs \$100 000 plus \$20 000 to install. It is estimated to depreciate at a declining-balance rate of 25 percent per year over its 15-year useful life. Annual maintenance costs are estimated to be \$6000 for the first year, increasing by 20 percent every year thereafter. In addition, every third year, the rollers must be replaced at a cost of \$7000. Interest is at 10 percent.

(a) Construct a spreadsheet that has the following headings: Year, Salvage Value, Maintenance Costs, EAC(Capital Costs), EAC(Maintenance Costs), and EAC(Total Costs). Compute the EAC(Total Costs) if the conveyor were to be kept for n years, $n = 1, \ldots, 15$.

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(b) Construct a chart showing the EAC(Capital Costs), EAC(Maintenance Costs), and EAC(Total Costs) if the conveyor were to be kept for n years, $n = 1, \ldots, 15$.

(c) What is the economic life of the roller conveyor system?

8.17 Brockville Brackets (BB) has a three-year-old robot that welds small brackets onto car-frame assemblies. At the time the robot was purchased, it cost $300 000 and an additional $50 000 was spent on installation. BB acquired the robot as part of an eight-year contract to produce the car-frame assemblies. The useful life of the robot is 12 years, and its value is estimated to decline by 20 percent of current value per year, as shown in the first table below. Operating and maintenance costs estimated when the robot was purchased are also shown in the table.

BB has found that the operating and maintenance costs for the robot have been higher than anticipated. At the end of the third year, new estimates of the operating and maintenance costs are shown in the second table on the next page.

BB has determined that the reason the operating and maintenance costs were in error was that the robot was positioned too close to existing equipment for the mechanics to repair it easily and quickly. BB is considering moving the robot farther away from some adjacent equipment so that mechanics can get easier access for repairs. To move the robot will cause BB to lose valuable production time, which is estimated to have a cost of $25 000. However, once complete, the move will lower maintenance costs to what had originally been expected for the remainder of the contract (e.g., $40 000 for the fourth year, increasing by 10 percent per year thereafter). Moving the robot will not affect its salvage value.

If BB uses a MARR of 15 percent, should it move the robot? If so, when? Remember that the contract exists only for a further five years.

Defender, When New		
Life (Years)	Salvage Value	Operating and Maintenance Costs
0	$300 000	
1	240 000	$40 000
2	192 000	40 000
3	153 600	40 000
4	122 880	40 000
5	98 304	44 000
6	78 643	48 400
7	62 915	53 240
8	50 332	58 564
9	40 265	64 420
10	32 212	70 862
11	25 770	77 949
12	20 616	85 744

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Costs for Three-Year-Old Defender		
Additional Life (Years)	Salvage Value	Operating and Maintenance Costs
0	$153 600	
1	122 880	$50 000
2	98 304	55 000
3	78 643	60 500
4	62 915	66 550
5	50 332	73 205

8.18 Consider Brockville Brackets from Problem 8.17 but assume that it has a contract to produce the car assemblies for an indefinite period. If it does not move the robot, the operating and maintenance costs will be higher than expected. If it moves the robot (at a cost of $25 000), the operating and maintenance costs are expected to be what were originally expected for the robot. Furthermore, BB expects to be able to obtain new versions of the existing robot for an indefinite period in the future; each is expected to have an installation cost of $50 000.

(a) Construct a spreadsheet table showing the EAC(total costs) if BB keeps the current robot in its current position for n more years, $n = 1, \ldots, 9$.

(b) Construct a spreadsheet table showing the EAC(total costs) if BB moves the current robot and then keeps it for n more years, $n = 1, \ldots, 9$.

(c) Construct a spreadsheet table showing the EAC(total costs) if BB is to buy a new robot and keep it for n years, $n = 1, \ldots, 9$.

(d) On the basis of your answers for parts (a) through (c), what do you advise BB to do?

8.19 Nico has a 20-year-old oil-fired hot air furnace in his house. He is considering replacing it with a new high-efficiency natural gas furnace. The oil-fired furnace has a scrap value of $500, which it will retain indefinitely. A maintenance contract costs $300 per year, plus parts. Nico estimates that parts will cost $200 this year, increasing by $100 per year in subsequent years. The new gas furnace will cost $4500 to buy and $500 to install. It will save $500 per year in energy costs. The maintenance costs for the gas furnace are covered under guarantee for the first five years. The market value of the gas furnace can be estimated from straight-line depreciation with a salvage value of $500 after 10 years. Using a MARR of 10 percent, should the oil furnace be replaced?

8.20 Jack and Jill live in the suburbs. Jack is a self-employed house painter who works out of their house. Jill works in the city, to which she regularly commutes by car. The car is a four-year-old import. Jill could commute by bus. They are considering selling the car and getting by with the van Jack uses for work.

The car cost $12 000 new. It dropped about 20 percent in value in the first year, and after that it fell by about 15 percent per year. The car is now worth about $5900. They expect it to continue to decline in value by about 15 percent of current value every year. Operating and other costs are about $2670 per year. They expect this to rise by about 7.5 percent per year. A commuter pass costs $112 per month and is not expected to increase in cost.

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Jack and Jill have a MARR of 10 percent, which is what Jack earns on his business investments. Their time horizon is two years because Jill expects to quit work at that time.

(a) Will commuting by bus save money?

(b) Can you advise Jack and Jill about retiring the car?

8.21 Ener-G purchases new turbines at a cost of $100 000. Each has a 15-year useful life and must be overhauled periodically at a cost of $10 000. The salvage value of a turbine declines by 15 percent of current value each year, and operating and maintenance costs (including the cost of the overhauls) of a typical turbine are as shown in the table below (the costs for the fifth and tenth years include a $10 000 overhaul, but an overhaul is not done in the fifteenth year since this is the end of the turbine's useful life).

Defender, When New, Overhaul Every Five Years		
Life (Years)	**Salvage Value**	**Operating and Maintenance Costs**
0	$100 000	
1	85 000	$15 000
2	72 250	20 000
3	61 413	25 000
4	52 201	30 000
5	44 371	45 000
6	37 715	20 000
7	32 058	25 000
8	27 249	30 000
9	23 162	35 000
10	19 687	50 000
11	16 734	25 000
12	14 224	30 000
13	12 091	35 000
14	10 277	40 000
15	8735	45 000

(a) Construct a spreadsheet that gives, for each year, the EAC(operating and maintenance costs), EAC(capital costs), and EAC(total costs) for the turbines. Interest is 15 percent. How long should Ener-G keep each turbine before replacing it, given a five-year overhaul schedule? What are the associated equivalent annual costs?

(b) If Ener-G were to overhaul its turbines every six years (at the same cost), the salvage value and operating and maintenance costs would be as shown in the table on the next page. Should Ener-G switch to a six-year overhaul cycle?

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Defender, When New, Overhaul Every Six Years		
Life (Years)	Salvage Value	Operating and Maintenance Costs
0	$100 000	
1	85 000	$15 000
2	72 250	20 000
3	61 413	25 000
4	52 201	30 000
5	44 371	35 000
6	37 715	50 000
7	32 058	20 000
8	27 249	25 000
9	23 162	30 000
10	19 687	35 000
11	16 734	40 000
12	14 224	55 000
13	12 091	25 000
14	10 277	30 000
15	8735	35 000

8.22 The BBBB Machine Company makes a group of metal parts on a turret lathe for a local manufacturer. The current lathe is now six years old. It has a planned further life of three years. The contract with the manufacturer has three more years to run as well. A new, improved lathe has become available. The challenger will have lower operating costs than the defender.

The defender can now be sold for $1200 in the used-equipment market. The challenger will cost $25 000 including installation. Its salvage value after installation, but before use, will be $20 000. Further data for the defender and the challenger are shown in the tables that follow.

Defender		
Additional Life in Years	Salvage Value	Operating Cost
0	$1200	
1	600	$20 000
2	300	20 500
3	150	21 012.50

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Challenger		
Life in Years	Salvage Value	Operating Cost
0	$20 000	
1	14 000	$13 875
2	9800	14 360.63
3	6860	14 863.25

BBBB is not sure if the contract it has with the customer will be renewed. Therefore, BBBB wants to make the decision about replacing the defender with the challenger using a three-year study period. BBBB uses a 12 percent MARR for this type of investment.

(a) What is the present worth of costs over the next three years for the defender?

(b) What is the present worth of costs over the next three years for the challenger?

(c) Now suppose that BBBB did not have a good estimate of the salvage value of the challenger at the end of three years. What minimum salvage value for the challenger at the end of three years would make the present worth of costs for the challenger equal to that of the defender?

8.23 Suppose, in the situation described in Problem 8.22, BBBB believed that the contract with the manufacturer would be renewed. BBBB also believed that all challengers after the current challenger would be identical to the current challenger. Further data concerning these challengers are given on the next page. Recall that a new challenger costs $25 000 installed.

BBBB was also advised that machines identical to the defender would be available indefinitely. New units of the defender would cost $17 500, including installation. Further data concerning new defenders are shown in the table on the next page. The MARR is 12 percent.

(a) Find the economic life of the challenger. What is the equivalent annual cost over that life?

(b) Should the defender be replaced with the challenger or with a new defender?

(c) When should this be done?

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Challenger		
Life in Years	**Salvage Value**	**Operating Cost**
0	\$20 000.00	
1	14 000.00	\$13 875.00
2	9800.00	14 369.63
3	6860.00	14 863.25
4	4802.00	15 383.46
5	3361.40	15 921.88
6	2352.98	16 479.15
7	1647.09	17 055.92
8	1152.96	17 652.87
9	807.07	18 270.73
10	564.95	18 910.20
11	395.47	19 572.06
12	276.83	20 257.08

Defender When New		
Life in Years	**Salvage Value**	**Operating Cost**
0	\$15 000.00	
1	9846.45	\$17 250.00
2	6463.51	17 681.25
3	4242.84	18 123.28
4	2785.13	18 576.36
5	1828.24	19 040.77
6	1200.11	19 516.79
7	600.00	20 004.71
8	300.00	20 504.83
9	150.00	21 017.45
10	150.00	21 542.89
11	150.00	22 081.46
12	150.00	22 633.49
13	150.00	23 199.33

8.24 An existing piece of equipment has the following pattern of salvage values and operating and maintenance costs:

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Defender					
Additional Life (Years)	Salvage Value	Maintenance Costs	EAC Capital Costs	EAC Operating and Maintenance Costs	EAC Total
0	$10 000				
1	8000	$2000	$3500	$2000	$5500
2	6400	2500	3174	2233	5407
3	5120	3000	2905	2454	5359
4	4096	3500	2682	2663	5345
5	3277	4000	2497	2861	5359
6	2621	4500	2343	3049	5391
7	2097	5000	2214	3225	5439
8	1678	5500	2106	3391	5497
9	1342	6000	2016	3546	5562

A replacement asset is being considered. Its relevant costs over the next nine years are shown below.

There is a need for the asset (either the defender or the challenger) for the next nine years.

(a) What replacement alternatives are there?

(b) What replacement timing do you recommend?

Challenger					
Additional Life (Years)	Salvage Value	Maintenance Costs	EAC Capital Costs	EAC Operating and Maintenance Costs	EAC Total
0	$12 000				
1	9600	$1500	$4200	$1500	$5700
2	7680	1900	3809	1686	5495
3	6144	2300	3486	1863	5349
4	4915	2700	3219	2031	5249
5	3932	3100	2997	2189	5186
6	3146	3500	2811	2339	5150
7	2517	3900	2657	2480	5137
8	2013	4300	2528	2613	5140
9	1611	4700	2419	2737	5156

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8.25 Chatham Automotive purchased new electric forklifts to move steel automobile parts two years ago. These cost \$75 000 each, including the charging stand. In practice, it was found that they did not hold a charge as long as claimed by the manufacturer, so operating costs are very high. This also results in their currently having a salvage value of about \$10 000.

Chatham is considering replacing them with propane models. The new ones cost \$58 000. After one year, they have a salvage value of \$40 000, and thereafter decline in value at a declining-balance depreciation rate of 20 percent, as does the electric model from this time on. The MARR is 8 percent. Operating costs for the electric model are \$20 000 over the first year, rising by 12 percent per year. Operating costs for the propane model will initially be \$10 000 over the first year, rising by 12 percent per year. Should Chatham Automotive replace the forklifts now?

8.26 Suppose that Chatham Automotive (Problem 8.25) can get a \$14 000 trade-in value for its current electric model when it purchases a new propane model. Should it replace the electric forklifts now?

8.27 A joint former cost \$60 000 to purchase and \$100 000 to install seven years ago. The market value now is \$33 000, and this will decline by 12 percent of current value each year for the next three years. Operating and maintenance costs are estimated to be \$34 000 this year, and are expected to increase by \$500 per year.

(a) How much should the EAC of a new joint former be over its economic life to justify replacing the old one sometime in the next three years? The MARR is 10 percent.

(b) The EAC for a new joint former turns out to be \$10 300 for a 10-year life. Should the old joint former be replaced within the next three years? If so, when?

(c) Is it necessary to consider replacing the old joint former more than three years from now, given that a new one has an EAC of \$10 300?

8.28 Northwest Aerocomposite manufactures fibreglass and carbon fibre fairings. Its largest water-jet cutter will have to be replaced some time before the end of four years. The old cutter is currently worth \$49 000. Other cost data for the current and replacement cutters can be found in the tables that follow. The MARR is 15 percent. What is the economic life of the new cutter, and what is the equivalent annual cost for that life? When should the new cutter replace the old?

Challenger		
Life in Years	Salvage Value	Operating and Maintenance Costs
0	\$90 000	
1	72 000	\$12 000
2	57 600	14 400
3	46 080	17 280
4	36 864	20 736
5	29 491	24 883
6	23 593	29 860
7	18 874	35 832
8	15 099	42 998

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Defender		
Life in Years	Salvage Value	Operating and Maintenance Costs
0	$49 000	
1	36 500	$17 000
2	19 875	21 320
3	15 656	26 806
4	6742	33 774

8.29 Northwest Aerocomposite in Problem 8.28 found out that its old water-jet cutter may be overhauled at a cost of $14 000 now. The cost information for the old cutter after an overhaul is shown in the table below.

Defender With an Overhaul		
Life (Years)	Salvage Value	Operating and Maintenance Costs
0	$55 000	
1	40 970	$16 500
2	22 310	20 690
3	17 574	26 013
4	7568	32 775

Should Northwest overhaul the old cutter? If an overhaul takes place, when should the new cutter replace the old? Assume that the cost information for the replacement cutter is as given in Problem 8.28.

8.30 The water pump from Problem 8.7 has an option to be overhauled once. It costs $1000 to overhaul a three-year-old pump and $2000 to overhaul a five-year-old pump. The major advantage of an overhaul is that it reduces the operating and maintenance costs to $500, which will increase again by $300 per year thereafter. Should the pump be overhauled? If so, should it be overhauled in three years or five years?

C. More Challenging Problems

8.31 If the operating costs for an asset are $\$500 \times 2^n$ and the capital costs are $\$10\ 000 \times (0.8)^n$, where n is the life in years, what is the economic life of the asset?

8.32 A certain machine costs $25 000 to purchase and install. It has salvage values and operating costs as shown in the table on the next page. The salvage value of $20 000 listed at time 0 reflects the loss of the installation costs at the time of installation. The MARR is 12 percent.

(a) What is the economic life of the machine?

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Costs and Salvage Values for Various Lives		
Life in Years	Salvage Value	Operating Cost
0	$20 000.00	
1	16 000.00	$ 3000.00
2	12 800.00	3225.00
3	10 240.00	3466.88
4	8192.00	3726.89
5	6553.60	4006.41
6	5242.88	4306.89
7	4194.30	4629.90
8	3355.44	4977.15
9	2684.35	5350.43
10	2147.48	5751.72
11	1717.99	6183.09
12	1374.39	6646.83
13	1099.51	7145.34
14	879.61	7681.24
15	703.69	8257.33
16	562.95	8876.63
17	450.36	9542.38
18	360.29	10 258.06

Now assume that the MARR is 5 percent.

(c) What is the economic life of the machine?

(d) What is the equivalent annual cost over that life?

(e) Explain the effect of decreasing the MARR.

8.33 You own several copiers that are currently valued at $10 000 all together. Annual operating and maintenance costs for all copiers are estimated at $9000 next year, increasing by 10 percent each year thereafter. Salvage values decrease at a rate of 20 percent per year.

You are considering replacing your existing copiers with new ones that have a suggested retail price of $25 000. Operating and maintenance costs for the new equipment will be $6000 over the first year, increasing by 10 percent each year thereafter. The salvage value of the new equipment is well approximated by a 20 percent drop from the suggested retail price per year. Furthermore, you can get a trade-in allowance of $12 000 for your equipment if you purchase the new equipment at its suggested retail price. Your MARR is 8 percent. Should you replace your existing equipment now?

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8.34 The Brunswick Table Top Company makes tops for tables and desks. The company now owns a seven-year-old planer that is experiencing increasing operating costs. The defender has a maximum additional life of five years. The company is considering replacing the defender with a new planer.

The new planer would cost \$30 000 installed. Its value after installation, but before use, would be about \$25 000. The company has been told that there will be a new-model planer available in two years. The new model is expected to have the same first costs as the current challenger, but is expected to have lower operating costs. Data concerning the defender and the two challengers are shown in the tables that follow. Brunswick Table has a 10-year planning period and uses a MARR of 10 percent.

Defender		
Additional Life in Years	Salvage Value	Operating Cost
0	\$4000	
1	3000	\$20 000
2	2000	25 000
3	1000	30 000
4	500	35 000
5	500	40 000

First Challenger		
Life in Years	Salvage Value	Operating Cost
0	\$25 000	
1	20 000	\$16 800
2	16 000	17 640
3	12 800	18 522
4	10 240	19 448
5	8192	20 421
6	6554	21 442
7	5243	22 514
8	4194	23 639
9	3355	24 821
10	2684	26 062

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Second Challenger		
Life in Years	Salvage Value	Operating Cost
0	\$25 000	
1	20 000	\$12 000
2	16 000	12 600
3	12 800	13 230
4	10 240	13 892
5	8192	14 586
6	6554	15 315
7	5243	16 081
8	4194	16 885
9	3355	17 729
10	2684	18 616

(a) What are the combinations of planers that Brunswick can use to cover requirements for the next 10 years? For example, Brunswick may keep the defender one more year, then install the first challenger and keep it for nine years. Notice that the first challenger will not be installed after the second year when the second challenger becomes available. You may ignore combinations that involve installing the first challenger after the second becomes available. Recall also that the maximum additional life for the defender is five years.

(b) What is the best combination?

8.35 You estimate that your two-year-old car is now worth \$12 000 and that it will decline in value by 25 percent of its current value each year of its eight-year remaining useful life. You also estimate that its operating and maintenance costs will be \$2100, increasing by 20 percent per year thereafter. Your MARR is 12 percent.

(a) Construct a spreadsheet showing (1) additional life in years, (2) salvage value, (3) operating and maintenance costs, (4) EAC(operating and maintenance costs), (5) EAC(capital costs), and (6) EAC(total costs). What additional life minimizes the EAC(total costs)?

(b) Now you are considering the possibility of painting the car in three years' time for \$2000. Painting the car will increase its salvage value. By how much will the salvage value have to increase before painting the car is economically justified? Modify the spreadsheet you developed for part (a) to show this salvage value and the EAC(total costs) for each additional year of life. Will painting the car extend its economic life?

8.36 A long-standing principle of computer innovations is that computers double in power for the same price, or, equivalently, halve in cost for the same power, every 18 months. Auckland Data Services (ADS) owns a single computer that is at the end of its third year of service. ADS will continue to buy computers of the same power as its current one. Its

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current computer would cost $80 000 to buy today, excluding installation. Given that a new model is released every 18 months, what replacement policy should ADS adopt for computers over the next three years? Other facts to be considered are:

1. Installation cost is 15 percent of purchase price.
2. Salvage values are computed at a declining-balance depreciation rate of 50 percent.
3. Annual maintenance cost is estimated as 10 percent of accumulated depreciation or as 15 percent of accumulated depreciation per 18-month period.
4. ADS uses a MARR of 12 percent.

8.37 Tiny Bay Freight Company (TBFC) wants to begin business with one delivery truck. After two years of operation, the company plans to increase the number of trucks to two, and after four years, plans to increase the number to three. TBFC currently has no trucks. The company is considering purchasing one type of truck that costs $30 000. The operating and maintenance costs are estimated to be $7200 per year. The resale value of the truck will decline each year by 40 percent of the current value. The company will consider replacing a truck every two years. That is, the company may keep a truck for two years, four years, six years, and so on. TBFC's MARR is 12 percent.

(a) What are the possible combinations for purchasing and replacing trucks over the next five years so that TBFC will meet its expansion goals and will have three trucks in hand at the end of five years?

(b) Which purchase/replacement combination is the best?

Problems 8.38 through 8.41 are concerned with the economic life of assets where there is a sequence of identical assets. The problems explore the sensitivity of the economic life to four parameters: the MARR, the level of operating cost, the rate of increase in operating cost, and the level of first cost. In each problem there is a pair of assets. The assets differ in only a single parameter. The problem asks you to determine the effect of this difference on the economic life and to explain the result. All assets decline in value by 20 percent of current value each year. Installation costs are zero for all assets. Further data concerning the four pairs of assets are given in the table that follows.

Asset Number	First Cost	Initial Operating Cost	Rate of Operating Cost Increase	MARR
A1	$125 000	$30 000	12.5%/year	5%
B1	125 000	30 000	12.5%/year	25%
A2	100 000	30 000	$2000/year	15%
B2	100 000	40 000	$2000/year	15%
A3	100 000	30 000	5%/year	15%
B3	100 000	30 000	12.5%/year	15%
A4	75 000	30 000	5%/year	15%
B4	150 000	30 000	5%/year	15%

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8.38 Consider Assets A1 and B1. They differ only in the MARR.

(a) Determine the economic lives for Assets A1 and B1.

(b) Create a diagram showing the EAC(capital), the EAC(operating), and the EAC(total) for Assets A1 and B1.

(c) Explain the difference in economic life between A1 and B1.

8.39 Consider Assets A2 and B2. They differ only in the level of initial operating cost.

(a) Determine the economic lives for Assets A2 and B2.

(b) Create a diagram showing the EAC(capital), the EAC(operating), and the EAC(total) for Assets A2 and B2.

(c) Explain the difference in economic life between A2 and B2.

8.40 Consider Assets A3 and B3. They differ only in the rate of increase of operating cost.

(a) Determine the economic lives for Assets A3 and B3.

(b) Create a diagram showing the EAC(capital), the EAC(operating), and the EAC(total) for Assets A3 and B3.

(c) Explain the difference in economic life between A3 and B3.

8.41 Consider Assets A4 and B4. They differ only in the level of first cost.

(a) Determine the economic lives for Assets A4 and B4.

(b) Create a diagram showing the EAC(capital), the EAC(operating), and the EAC(total) for Assets A4 and B4.

(c) Explain the difference in economic life between A4 and B4.

8.42 This problem concerns the economic life of assets where there is a sequence of identical assets. In this case there is an opportunity to overhaul equipment. Two issues are explored. The first concerns the optimal life of equipment. The second concerns the decision of whether to replace equipment that is past its economic life. Consider a piece of equipment that costs $40 000 to buy and install. The equipment has a maximum life of 15 years. Overhaul is required in the fourth, eighth, and twelfth years. The company uses a MARR of 20 percent. Further information is given in the table below.

(a) Show that the economic life for this equipment is seven years.

(b) Suppose that the equipment is overhauled in the eighth year rather than replaced. Show that keeping the equipment for three more years (after the eighth year), until it next comes up for overhaul, has lower cost than replacing the equipment immediately.

Hint for part (b): The comparison must be done fairly and carefully. Assume that under either plan the replacement is kept for its optimal life of seven years. It is easier to compare the plans if they cover the same number of years. One way to do this is to consider an 11-year period as shown on the next page.

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Year	Salvage Value	Operating Cost	Overhaul Cost
0	$15 000		
1	12 000	$ 2000	
2	9600	2200	
3	7680	2420	
4	7500	2662	$ 2500
5	6000	2000	
6	4800	2200	
7	3840	2420	
8	4500	2662	32 500
9	3600	2000	
10	2880	2800	
11	2304	3920	
12	2000	5488	17 500
13	1200	4000	
14	720	8000	
15	432	16 000	

Year	Plan A	Plan B
0		
1	Defender	Replacement #1
2	Defender	Replacement #1
3	Defender	Replacement #1
4	Replacement #1	Replacement #1
5	Replacement #1	Replacement #1
6	Replacement #1	Replacement #1
7	Replacement #1	Replacement #1
8	Replacement #1	Replacement #2
9	Replacement #1	Replacement #2
10	Replacement #1	Replacement #2
11	Replacement #2	Replacement #2

First, show that the present worth of costs over the 11 years is lower under plan A than under plan B. Second, point out that the equipment that is in place at the end of the eleventh year is newer under plan A than under plan B.

(c) Why is it necessary to take into account the age of the equipment at the end of the

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8.43 Northfield Metal Works is a household appliance parts manufacturer that has just won a contract with a major appliance company to supply replacement parts to service shops. The contract is for five years. Northfield is considering using three existing manual punch presses or a new automatic press for part of the work. The new press would cost \$225 000 installed. Northfield is using a five-year time horizon for the project. The MARR is 25 percent for projects of this type. Further data concerning the two options are shown in the tables that follow.

Automatic Punch Press		
Life in Years	**Salvage Value**	**Operating Cost**
0	\$125 000	
1	100 000	\$25 000
2	80 000	23 750
3	64 000	22 563
4	51 200	21 434
5	40 960	20 363

Hand-Fed Press		
Additional Life in Years	**Salvage Value**	**Operating Cost**
0	\$10 000	
1	9000	\$25 000
2	8000	25 000
3	7000	25 000
4	6000	25 000
5	5000	25 000

Note that the hand-fed press values are for each of the three presses. Costs must be multiplied by three to get the costs for three presses. Northfield is not sure of the salvage values for the new press. What salvage value at the end of five years would make the two options equal?

8.44 **(a)** Referring to Figure 8.1 on page 286, why is the economic life different from the intersection of the reducing capital costs line and the increasing operating and maintenance costs line? Under what circumstances would the economic life correspond with the intersection of the lines?

(b) Referring to Figure 8.2 on page 291, the point at which total costs are lowest is not shown on the graph, but rather would have appeared on a section of the graph to the left of the part illustrated. As seen in Figure 8.1, the asset should have been replaced when total costs were lowest. Even if this wasn't done, every year of additional life the total costs of an asset in Figure 8.2 are increasing. However, as pointed out in the text, the situation illustrated in Figure 8.2 is very common, justifying the one year rule for such assets. How can it be that asset costs commonly have the structure seen in Figure 8.2?

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MINI-CASE 8.1

Lighting the Way

In March 2011, Sears Canada announced that it was banning the sale of inefficient incandescent and halogen lighting in all of its full-line and Sears Home stores in Canada (www.marketnews.ca/content/index/page?pid=9187, accessed September 28, 2011). It also announced that by August of the same year, it would replace more than 130 000 incandescent spotlights in its stores with LED (light-emitting diode) bulbs. It was estimated that this would save more than 16 million kWh (kilowatt hours) of electricity per year and reduce Sears's carbon footprint by 3611 tonnes annually.

"Sears Canada constantly strives to be a leader in sustainability by minimizing its environmental impact across all areas of its business, while helping Canadians choose products that save them money, reduce their eco footprint and create healthier homes," said Dr. James Gray-Donald, sustainability leader and associate vice-president of Sears Canada. "Replacing inefficient lighting products with LED and CFL options is a major move to save customers energy and money, while empowering them to take sustainable steps at home."

Discussion

We are all familiar with the routine of replacing a burned-out light bulb. For over a century, it has been a simple matter of finding a bulb of the same size and wattage and screwing it into place. However, the assumption that one could replace an old light bulb with an identical one has been amended in recent years. Now there are many different choices of technologies, each of which has different properties regarding life span, environmental impact, energy usage, appearance, and starting time.

For example, incandescent light bulbs are the traditional mainstay. They are cheap and give a strong light but are energy-wasteful and don't last very long. CFL (compact fluorescent) bulbs are longer lasting and more energy efficient, but contain toxic mercury and are slow to reach maximum brightness. LED bulbs are very long lasting (in terms of years of use) and can be designed to shine any desired colour, but require DC power and do not work well with dimmers.

Along with the new technologies has come a change in the very principle of replacing a light bulb. In the past, a light bulb would either function or not. One would only consider replacing it if it burned out. But it is now considered reasonable (and often admirable) to replace a perfectly functioning light bulb with another one that uses a different technology.

Questions

1. A typical incandescent light bulb will last about 1000 hours. Would it likely have been necessary for Sears to replace working incandescent bulbs with LEDs, or could they have simply replaced them as they burned out and still have met their August deadline? Under what circumstances would it make economic sense to replace the incandescent bulbs as soon as possible?
2. Clearly Sears Canada gains brand value by visibly being environmentally conscious. Do you think the real driver here is gaining favourable publicity? To guide you in your answer, a standard incandescent bulb produces about 15 lumens per watt, while a comparable LED produces 80 to 140 lumens per watt, and the current price of electricity is about \$0.65 per kWh.

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3. Sears will be able to buttress its environmental credentials and perhaps save money, but it seems peculiar that it would constrain its customers' choices, too. If customers really wanted to buy an incandescent bulb, they could possibly switch to a different retailer to get it and Sears could lose business. Which of the following possible reasons for this make sense to you and why?
   - **(a)** Incandescent bulbs are in short supply because they are no longer being manufactured.
   - **(b)** Profit margins are higher on the more expensive CFL and LED bulbs.
   - **(c)** Customers don't buy incandescent bulbs anyhow.
   - **(d)** Sears is afraid of being sued for contributing to climate change.
   - **(e)** Sears expects incandescent bulbs to be made illegal anyhow, so it might as well be at the front of the trend.
   - **(f)** Shelf space is expensive, and with so many competing technologies something has to be left out.
   - **(g)** Incandescent bulbs are simply not fashionable, and Sears is all about fashion.

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CHAPTER 9

Inflation

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ENGINEERING ECONOMICS IN ACTION, PART 9A

The Inflated Expert

Terry left Canadian Widgets to go back for his final term of school. Naomi and Terry had worked through several projects over Terry's last few work terms, and Naomi had been increasingly taking part in projects involving sister companies of Canadian Widgets; all were owned by Global Conglomerate Inc., often referred to as "head office."

"There's a guy from head office to see you, Naomi." It was Carole announcing the expected visitor, Bill Astad. Bill was one of the company's troubleshooters. His current interest concerned a sister company, Mexifab, a maquiladora on the Mexican border with Texas. (A maquiladora is an assembly plant that manufactures finished goods in northern Mexico under special tariff and tax rules.) After a few minutes of socializing, Bill explained the concern.

"It's the variability in the Mexican inflation rate that causes the problems. Mexico gets a new president every six years, and usually, about the time the president changes, the economy goes out of whack. And we can't price everything in dollars or euros. We do some of that, but we are located in Mexico and so we have to use Mexican pesos for a lot of our transactions.

"I understand from Anna Kulkowski that you know something about how to treat problems like that," Bill continued.

Naomi smiled to herself. She had written a memo a few weeks earlier pointing out how Canadian Widgets had been missing some good projects by failing to take advantage of the current very low inflation rates, and suddenly she was the expert!

"Well," she said, "I might be able to help. What you can do is this."

9.1 Introduction

Prices of goods and services bought and sold by individuals and firms change over time. Some prices, like those of agricultural commodities, may change several times a day. Other prices, like those for sugar and paper, change infrequently. While prices for some consumer goods and services occasionally decrease (as with high-tech products), on average it is more typical for prices to increase over time.

Inflation is the increase over time in average prices of goods and services. It can also be described as a decrease in the purchasing power of money over time. While most developed countries have experienced inflation in most years since World War II, there have been short periods when average prices in some countries have fallen. A decrease over time in average prices is called **deflation**. It can also be viewed as an increase in the purchasing power of money over time.

Because of inflation or deflation, prices are likely to change over the lives of most engineering projects. These changes will affect cash flows associated with the projects. Engineers may have to take predicted price changes into account during project evaluation to prevent the changes from distorting decisions.

In this chapter, we shall discuss how to incorporate an expectation of inflation into project evaluation. We focus on inflation because it has been the dominant pattern of price changes since the beginning of the twentieth century. The chapter begins with a discussion of how inflation is measured. We then show how to convert cash flows that occur at different points in time into dollars with the same purchasing power. We then consider how inflation affects the MARR, the internal rate of return, and the present worth of a project.

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9.2 Measuring the Inflation Rate

The **inflation rate** is the rate of increase in average prices of goods and services over a specified time period, usually a year. If prices of all goods and services moved up and down together, determining the inflation rate would be trivial. If all prices increased by 2 percent over a year, it would be clear that the average inflation rate would also be 2 percent. But prices do not move in perfect synchronization. In any period, some prices will increase, others will fall, and some will remain about the same. For example, candy bars are about 10 times as costly now as they were in the 1960s, but some electronics are about the same price or cheaper.

Because prices do not move in perfect synchronization, a variety of methods have been developed to measure the inflation rate. Most countries' governments track movement of average prices for a number of different collections of goods and services and calculate inflation rates from the changes in prices in these collections over time.

One set of prices typically tracked consists of goods and services bought by consumers. This set forms the basis of the **consumer price index (CPI)**. The CPI for a given period relates the average price of a fixed "basket" of these goods in the given period to the average price of the same basket in a *base period*. For example, Figure 9.1 shows the CPI for Canada for the period 1920 to 2010. The CPI for this chart has the year 2002 as the base year. The base year index is set at 100.

NET VALUE 9.1

Statistics Canada

A prime source of Canadian statistics, including the CPI and inflation rates, is Statistics Canada. Figures are readily available from the Statistics Canada website at www.statcan.gc.ca. Four main categories for Canadian statistics are economy, land, people, and state. Each of these categories includes information that can be useful in engineering economics. For example, the economy category includes the latest economic indicators such as gross domestic product (GDP) and personal spending on consumer goods and services; and manufacturing and construction figures such as the new housing price index, energy supply and demand, and the number of manufacturing shipments. The land category includes information on the environment (air pollution, expenditures on environmental protection by industry, etc.), which may be useful in estimating the impact of environmental factors in engineering projects. In the people category, statistics on population, labour, and employment can be found. Lastly, in the state category, statistics specific to the public sector (e.g., employment, assets and liabilities, and revenue and expenditures) can be obtained.

The index for any other year indicates the number of dollars needed in that year to buy the fixed basket of goods that cost $100 in 2002. Figure 9.1 shows that a basket of goods that cost $100 in 2002 (the base year) would have cost approximately $78 in 1988, and slightly more than $116 in 2010. More information about the CPI can be found on the Statistics Canada website at www.statcan.gc.ca (see also Net Value 9.1).

An inflation rate can be estimated directly from the CPI by expressing the changes in the CPI as a year-by-year percentage change. This is probably the most commonly used estimate of a national inflation rate. Figure 9.2 shows the national inflation rate for the period from 1920 to 2010 as derived from the CPI quantities in Figure 9.1.

It is important to note that, although the CPI is a commonly accepted inflation index, many different indexes are used to measure inflation. The value of an index depends on

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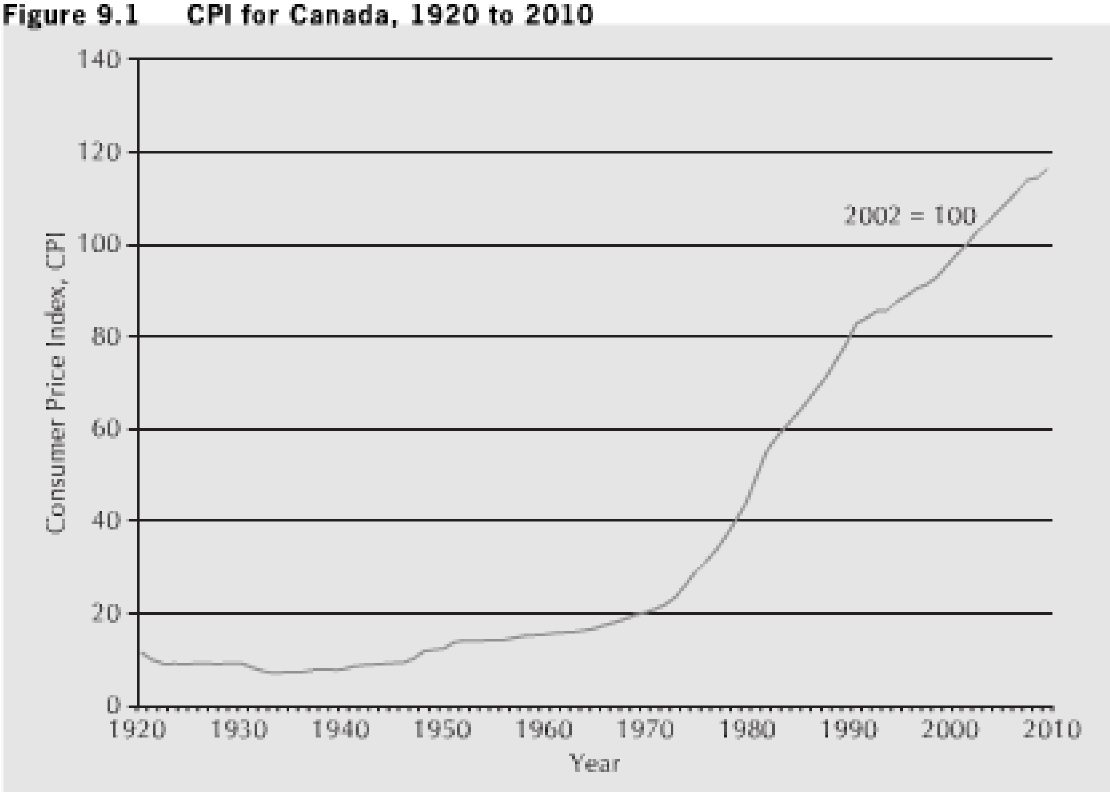
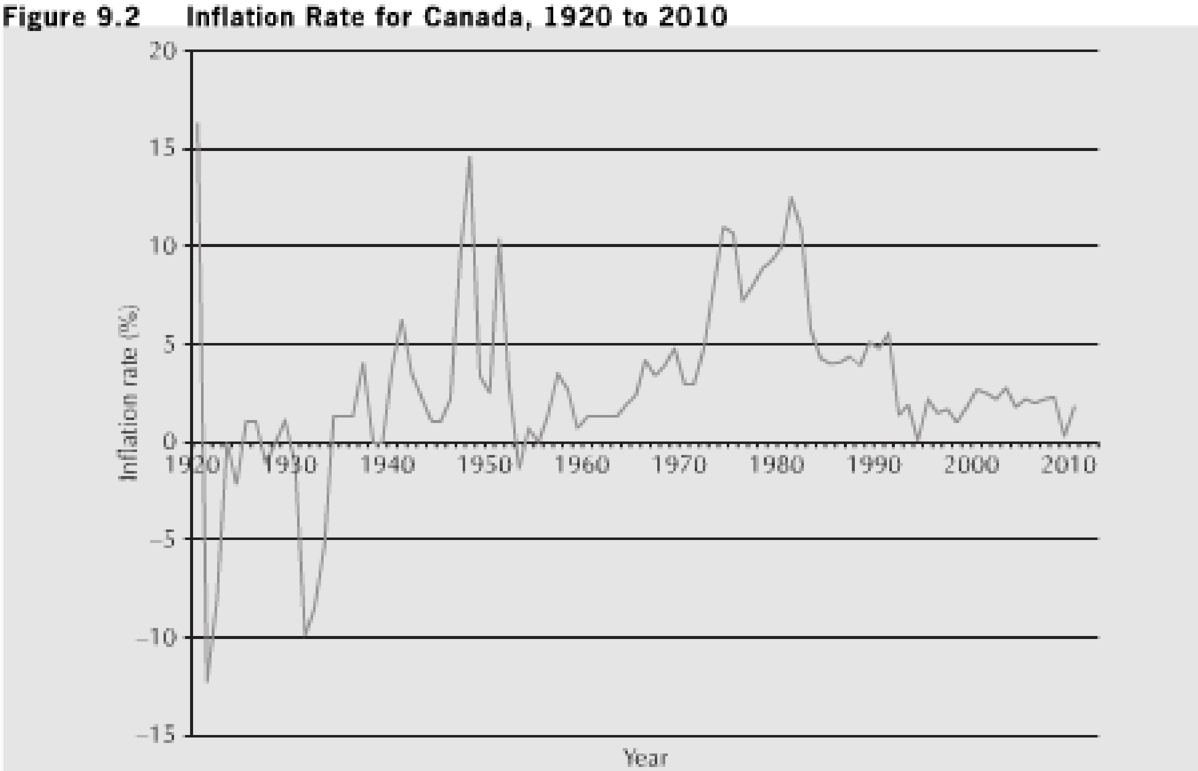
Figure 9.1 CPI for Canada, 1920 to 2010



the method used to compute the index and the set of goods and services for which the index measures price changes. To judge whether an index is appropriate for a particular purpose, the analyst should know how the goods and services for which he or she is estimating inflation compare with the set of goods and services used to compute the index. For this reason, we provide Appendix 9A, in which we illustrate the computation of one popularly used index.

Figure 9.2 Inflation Rate for Canada, 1920 to 2010



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CPI values and inflation rates vary considerably over time, as seen in Figures 9.1 and 9.2, and can be even more extreme. Low expected rates of inflation may be safely ignored, given the typical imprecision of predicted future cash flows. However, when expected inflation is high, it is necessary to include inflation in detailed economic calculations to avoid rejecting good projects.

Throughout the rest of this chapter, we assume that an analyst is able to obtain estimates for expected inflation rates over the life of a project and that project cash flows will change at the same rate as average prices. Consequently, the cash flows for a project can be assumed to increase at approximately the rate of inflation per year.

9.3 Economic Evaluation With Inflation

When prices change, the amount of goods a dollar will buy changes too. If prices fall, more goods may be bought for a given number of dollars, and the value of a dollar has risen. If prices rise, fewer goods may be bought for a given number of dollars, and the value of a dollar has fallen.

In project evaluation, we cannot make comparisons of dollar values across time without taking the price changes into account. We want dollars, not for themselves, but for what we can get for them. Workers are not directly interested in the money wages they will earn in a job. They are interested in how many hours of work it will take to cover expenses for their families, or how long it will take them to accumulate enough to make down payments on houses. Similarly, investors want to know if making an investment now will enable them to buy more real goods in the future, and by how much the amount they can buy in the future will increase. To know if an investment will lead to an increase in the amount they can buy in the future, they must take into account expected price changes.

We can take price changes into account in an approximate way by measuring the cash flows associated with a project in monetary units of constant purchasing power called **real dollars** (sometimes called **constant dollars**). This is in contrast to **current dollars** (sometimes called **actual dollars** or **nominal dollars**), which are expressed in the monetary units at the time the cash flows occur.

For example, if a photocopier will cost \$2200 one year from now, the \$2200 represents *current* dollars since that is the amount that would be paid at that time. If inflation is expected to be 10 percent over the year, the \$2200 is equivalent to \$2000 in real dollars. Of course, depending on the currency, one could also use the term "real euros" or "real pounds," for example.

Real dollars always need to be associated with a particular date (usually a year), called the **base year**. The base year need not be the present; it could be any time. People speak of "2000 dollars" or "1985 dollars" to indicate that real dollars are being used as well as indicating the base year associated with them. Provided that cash flows occurring at different times are converted into real dollars with the same base year, they can be compared fairly in terms of buying power.

9.3.1 Converting Between Real and Current Dollars

Converting current dollars in year N into real dollars in year N relative to a base year 0 is straightforward, provided that the value of a global price index like the CPI at year N relative to the base year is available. Let

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C_N = current dollars in year N

$R_{0,N}$ = real dollars equivalent to C_N relative to year 0, the base year

$I_{0,N}$ = the value of a global price index (like the CPI) at year N, relative to year 0

Then the conversion from current to real dollars is

$$R_{0,N} = \frac{C_N}{I_{0,N}/100} \tag{9.1}$$

Note that in Equation (9.1), $I_{0,N}$ is divided by 100 to convert it into a fraction because of the convention that a price index is set at 100 for the base year.

Transforming current dollar values into real dollars gives only an approximate offset to the effect of inflation. The reason is that there may be no readily available price index that accurately matches the "basket" of goods and services being evaluated. Despite the fact that available price indexes are approximate, they do provide a reasonable means of converting current cash flows to real cash flows relative to a base year.

An alternative means of converting current dollars to real dollars is available if we have an estimate for the average yearly inflation between now (year 0) and year N. Let

C_N = current dollars in year N

$R_{0,N}$ = real dollars equivalent to C_N relative to year 0, the base year

f = the inflation rate per year, assumed to be constant from year 0 to year N

Then the conversion from current dollars in year N to real dollars in year N relative to the base year 0 is

$$R_{0,N} = \frac{C_N}{(1+f)^N}$$

When the base year is omitted from the notation for real dollars, it is understood that the current year (year 0) is the base year, as in

$$R_N = \frac{C_N}{(1+f)^N} \tag{9.2}$$

Equation (9.2) can also conveniently be written in terms of the present worth compound interest factor

$$R_N = C_N(P/F,f,N) \tag{9.3}$$

EXAMPLE 9.1

Elliot Weisgerber's income rose from \$40 000 per year in 2010 to \$42 000 in 2013. At the same time the CPI (base year 2000) rose from 113.5 in 2010 to 122.3 in 2013. Was Elliot worse off or better off in 2013 compared with 2010?

We can convert Elliot's current dollar income in 2010 and 2013 into real dollars. This will tell us if his total purchasing power increased or decreased over the period from 2010 to 2013. Since the base year for the CPI is 2000, we will compare his 2010 and 2013 incomes in terms of real 2000 dollars.

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His real incomes in 2010 and 2013 in terms of 2000 dollars, using Equation (9.1), were

$$R_{00,10} = 40\,000/1.135 = 35\,242$$

$$R_{00,13} = 42\,000/1.223 = 34\,342$$

Even though Elliot's current dollar income rose between 2010 and 2013, his purchasing power fell, since the real dollar value of his income, according to the CPI, fell about 3 percent. ■

EXAMPLE 9.2

The cost of replacing a storage tank one year from now is expected to be €2 000 000. If inflation is assumed to be 5 percent per year, what is the cost of replacing the storage tank in real (today's) euros?

First, note that the €2 000 000 is expressed in current euros one year from today. The cost of replacing the tank in real (today's) euros can be found by letting

C_1 = 2 000 000 = the current cost one year from the base year (today)

R_1 = the real euro cost of the storage tank in one year

f = the inflation rate per year

Then, with Equation (9.2)

$$R_1 = \frac{C_1}{1+f} = \frac{2\,000\,000}{1.05} = €1\,904\,762$$

Alternatively, Equation (9.3) gives

$$R_1 = C_1(P/F,5\%,1) = 2\,000\,000\,(0.9524) = 1\,904\,762$$

The €2 000 000 current cost is equivalent to €1 904 762 real (today's) euros at the end of one year. ■

EXAMPLE 9.3

The cost of replacing a storage tank in 15 years is expected to be €2 000 000. If inflation is assumed to be 5 percent per year, what is the cost of replacing the storage tank 15 years from now in real (today's) euros?

The cost of the tank 15 years from now in real euros can be found by letting

C_{15} = 2 000 000 = the current cost 15 years from the base year (today)

R_{15} = the real euro cost of the storage tank in 15 years

f = the inflation rate per year

Then, with the use of Equation (9.2), we have

$$R_{15} = \frac{C_{15}}{(1+f)^{15}} = \frac{2\,000\,000}{(1.05)^{15}} = 962\,040$$

Alternatively, Equation (9.3) gives

$$R_{15} = C_{15}(P/F,5\%,15) = 2\,000\,000\,(0.48102) = 962\,040$$

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In 15 years, the storage tank will cost €962 040 in real (today's) euros. Note that this €962 040 is money to be paid 15 years from now. What this means is that the new storage tank can be replaced at a cost that would have the same purchasing power as about €962 040 today. ■

Now that we have the ability to convert from current to real dollars using an index or an inflation rate, we turn to the question of how inflation affects project evaluation.

SPREADSHEET SAVVY

Preparation of supporting documents for an engineering report usually entails printing portions of one or more worksheets or charts for inclusion in an appendix or in the main body of the report. There are many customizations that can be made to a printed Excel spreadsheet to identify the file it belongs to, its page number in sequence, or simply the date the printout was produced. This Spreadsheet Savvy provides some ideas on what some of these options are.

Most of these features can be located on the Page Layout tab of the ribbon. The most basic of these options is to set the size of the paper (e.g., legal versus letter), the orientation of the page (e.g., landscape versus portrait), and the page margins (e.g., wide, normal, or other settings, including custom). The Page Setup dialogue box (click on the small arrow to the bottom right of the Page Layout portion of the ribbon) allows you to set these features, as well as a number of other characteristics of the printed page. One handy option is to add a header or footer to the page (select the Header/Footer tab in the Page Setup dialogue box). Under Custom Header/Footer, you can insert one or more of text, page number, date, time, file path, or name and sheet name. These can be placed on the left or right or centred on the page.

Selected worksheet areas can be scaled to fit the page width or height or scaled to a set percentage of its original size by choosing the Scale to Fit option in the Page Layout tab. These choices are not directly available for chart objects, but scale options might be available under print options, depending on the printer used. Scaling to fit the page is useful when you want to print an area of a worksheet that is just a bit too large to fit onto a page. This option will automatically scale the printed area just enough so that either all the rows or all the columns appear. In addition to setting these scale options, worksheet gridlines and row and column headers can be shown or suppressed in the printed output by selecting the appropriate Sheet Options area on the Page Layout tab.

If you are working with a large worksheet and have data that runs over several pages, the option to print the same header on each page can be helpful. This way, the reader does not lose track of what each column means. To set the print header to appear on each printed page, select Print Titles on the Page Layout tab of the ribbon (under Page Setup). This will prompt you to enter the cell range containing the title to be repeated.

Another useful feature for a large worksheet is to be able to force a page break at a natural location in the data rather than having Excel insert a page break at an inconvenient place. This is done by selecting the row *below the one you want the page break* and then clicking on the Breaks option under the Page Setup section of Page Layout. Page breaks can also be removed one at a time or all at once.

9.4 The Effect of Correctly Anticipated Inflation

The main observation made in this section is that engineers must be aware of potential changes in price levels over the life of a project. We shall see that when future inflation is expected over the life of a project, the MARR needs to be increased. Engineers need to recognize this effect of inflation on the MARR to avoid rejecting good projects.

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9.4.1 The Effect of Inflation on the MARR

If we expect inflation, the number of current dollars that will be returned in the future does not tell us the value, in terms of purchasing power, of the future cash flow. The purchasing power of the earnings from an investment depends on the *real* dollar value of those earnings.

The **current interest rate** is the stated or observed interest rate based on current dollars. If we wish to earn interest at the current interest rate, i, on a one-year investment, and we invest \$$M$, the investment will yield \$$M(1 + i)$ at the end of the year. If the inflation rate over the next year is f, the real value of our cash flow is \$$M(1 + i)/(1 + f)$. We can use this to define the *real* interest rate. The **real interest rate**, i', is the interest rate that would yield the same number of real dollars in the absence of inflation as the current interest rate yields in the presence of inflation.

$$M(1 + i') = M\left(\frac{1 + i}{1 + f}\right)$$

$$i' = \frac{1 + i}{1 + f} - 1 \tag{9.4}$$

We may see terms like *real rate of return* or *real discount rate*. These are just special cases of the real interest rate.

The definition of the real interest rate can be turned around by asking the following question: If an investor wants a real rate of return, i', over the next year, and the inflation rate is expected to be f, what current interest rate, i, must be realized to get a real rate of return of i'?

The answer can be obtained with some manipulation of the definition of the real interest rate in Equation (9.4):

$$i = (1 + i')(1 + f) - 1 \text{ or, equivalently, } i = i' + f + i'f \tag{9.5}$$

Therefore, an investor who desires a real rate of return i' and who expects inflation at a rate of f will require a current interest rate $i = i' + f + i'f$. This has implications for the current MARR used in economic analyses. The **current MARR** is the minimum acceptable rate of return when cash flows are expressed in current dollars. If investors expect inflation, they require higher current rates of return on their investments than if inflation were not expected. The current MARR then will be the real MARR plus an upward adjustment that reflects the effect of inflation. The **real MARR** is the minimum acceptable rate of return when cash flows are expressed in real, or constant, dollars.

If we denote the current MARR by MARR_C and the real MARR by MARR_R, we have from Equation (9.5)

$$\text{MARR}_\text{C} = \text{MARR}_\text{R} + f + \text{MARR}_\text{R} \times f \tag{9.6}$$

Note that if MARR_R and f are small, the term $\text{MARR}_\text{R} \times f$ may be ignored and $\text{MARR}_\text{C} = \text{MARR}_\text{R} + f$ can be used as a "back of the envelope" approximation.

The real MARR can also be expressed as a function of the current MARR and the expected inflation rate:

$$\text{MARR}_\text{R} = \frac{1 + \text{MARR}_\text{C}}{1 + f} - 1 \tag{9.7}$$

Figure 9.3 shows the Canadian experience with inflation, the current prime interest rate, and the real interest rate for the 1961–2010 period. From 1961 to 1971, when

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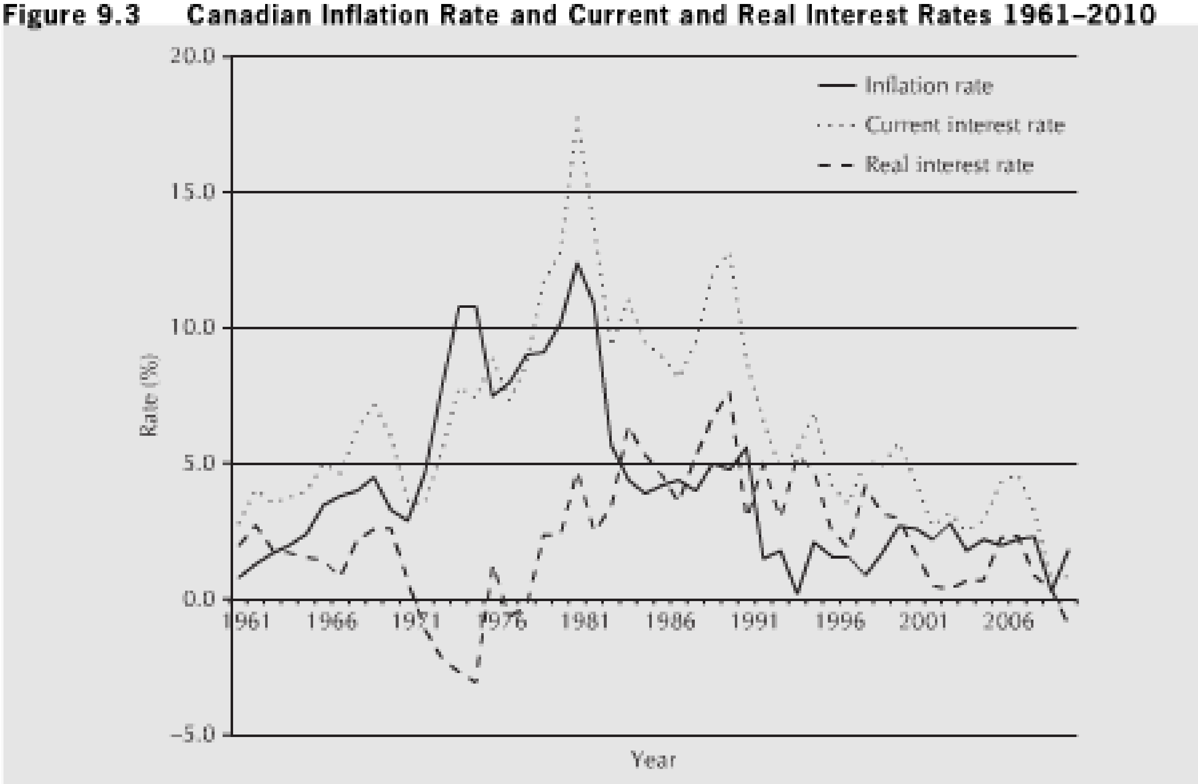
Figure 9.3 Canadian Inflation Rate and Current and Real Interest Rates 1961–2010



inflation was moderate and stable, the real interest rate was also stable, except for one blip in 1967. In the 1970s, conditions were very different when inflation exploded. This was due partly to large jumps in energy prices. Real interest rates were negative for the period 1972 to 1975 and 1977 to 1978. In the 1980s and early 1990s, real interest rates were quite high. The rest of the 1990s and early 2000s experienced lower inflation rates and real interest rates.

The high inflation rates of the 1970s were very unusual. Inflation in the range of 2 percent to 4 percent per year is more typical of developed countries like Canada. Averages of real interest rates and current inflation rates over subperiods are shown in Table 9.1.

Table 9.1 Average Canadian Real and Current Interest Rates

Period	Average Real Interest Rate (%)	Average Current Interest Rate (%)
1961–1971	1.82	2.75
1972–1981	0.08	8.47
1982–1991	4.84	5.29
1992–2003	2.95	1.81

EXAMPLE 9.4

Security Trust is paying 12 percent on one-year guaranteed investment certificates (GICs). The inflation rate is expected to be 5 percent over the next year. What is the real rate of interest? For a $5000 GIC, what will be the real dollar value of the amount received at the end of the year?

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The real interest rate is

$$i' = \frac{1+i}{1+f} - 1 = \frac{1.12}{1.05} - 1 = 0.067, \text{ or } 6.7\%$$

A \$5000 GIC will return \$5600 at the end of the year. The real value of the \$5600 in *today's* dollars is \$5600/1.05 = \$5333. This is the same as if there were no inflation and the investment earned 6.7 percent interest. ■

EXAMPLE 9.5

Susan got a \$1000 present from her aunt on her 16th birthday. She has noticed that Security Trust offers 6.5 percent on one-year guaranteed investment certificates (GICs). Her mother's business newspaper indicates that analysts are predicting an inflation rate of about 3.5 percent for the coming year. Susan's real MARR for such investments is 4 percent. If the analysts are correct, what is Susan's current MARR? Should she invest?

If the analysts are correct, Susan's current MARR is

$$\begin{aligned} \text{MARR}_C &= \text{MARR}_R + f + \text{MARR}_R \times f \\ &= 0.04 + 0.035 + (0.04)(0.035) \\ &= 0.0764 \end{aligned}$$

Susan's current MARR is about 7.64 percent. Since the current interest rate on the GIC is only 6.5 percent, she should not invest in the GIC. ■

9.4.2 The Effect of Inflation on the IRR

The effect of expected inflation on the current internal rate of return of a project is similar to the effect of inflation on the current MARR. Suppose that we are considering a T-year investment. The **current internal rate of return** on the project, IRR_C, is the rate of return of the project on the basis of current dollar cash flows. It can be found by solving for i^* in

$$\sum_{t=0}^{T} \frac{C_t}{(1_C + i^*)^t} = 0$$

where

C_t = the current cash flow in period t (receipts – disbursements)
T = the number of time periods
i^* = the actual internal rate of return

Suppose further that a yearly inflation rate of f is expected over the T-year life of the project. In terms of real dollars (with a base year of the time of the first cost), the current cash flow in period t can be written as $C_t = R_t(1+f)^t$ where R_t refers to the *real* dollar amount equivalent to the cash flow C_t. The expression that gives the current internal rate of return can be rewritten as

$$\sum_{t=0}^{T} \frac{R_t(1+f)^t}{(1+i^*)^t} = 0 \qquad (9.8)$$

In contrast, the **real internal rate of return** for the project, IRR_R, is the rate of return obtained on the real dollar cash flows associated with the project. It is the solution for i' in

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$$\sum_{t=0}^{T} \frac{R_t}{(1+i')^t} = 0 \tag{9.9}$$

What is the relationship between IRR_R and IRR_C? We have, from Equations (9.4) and (9.5),

$$\frac{1}{1+i'} = \frac{1+f}{1+i} \quad \text{or} \quad i = i' + f + i'f$$

and thus, analogous to Equation (9.5),

$$IRR_C = IRR_R + f + IRR_R \times f \tag{9.10}$$

Or, analogous to Equation (9.4), the real IRR can be expressed in terms of the current IRR and the inflation rate:

$$IRR_R = \frac{1 + IRR_C}{1+f} - 1 \tag{9.11}$$

In summary, the effect of inflation on the IRR is that the current IRR will be the real IRR plus an upward adjustment that reflects the effect of inflation.

EXAMPLE 9.6

Consider a two-year project that has a \$10 000 000 first cost and that is expected to bring about savings of \$15 000 000 at the end of the two years. If inflation is expected to be 5 percent per year and the real MARR is 13 percent, should the project be undertaken? Base your answer on an IRR analysis.

From the information given, $C_0 = -10\,000\,000$, $C_2 = 15\,000\,000$, and $f = 0.05$. The current IRR can be found by solving for i in

$$C_0 + \frac{C_2}{(1+i)^2} = 0$$

$$10\,000\,000 = 15\,000\,000/(1+i)^2$$

which leads to a current IRR of 22.475 percent.

The real IRR is then

$$\begin{aligned} IRR_R &= \frac{1 + IRR_C}{1+f} - 1 \\ &= \frac{1 + 0.22475}{1 + 0.05} - 1 \\ &= 0.1664 \text{ or } 16.64\% \end{aligned}$$

Since the real IRR exceeds the real MARR, the project should be undertaken. ■

In conclusion, the impact of inflation on the current MARR and the current IRR is that both have an adjustment for expected inflation implicitly included in them. The main implication of this observation is that, since both the current MARR and the current IRR increase in the same fashion, any project that was acceptable without inflation remains acceptable when inflation is expected. Any project that was unacceptable remains unacceptable.

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9.5 Project Evaluation Methods With Inflation

The engineer typically starts a project evaluation with an observed (current) MARR and projections of cash flows. As we have seen, the current MARR has two parts: the real rate of return on investment that investors require to put money into the company, plus an adjustment for the expected rate of inflation. The engineer usually observes only the sum and not the individual parts.

As for the projected cash flows, these are typically based on current prices. Because the projected cash flows are based on prices of the period in which evaluations are being carried out, they are in *real* dollars. They do not incorporate the effect of inflation. In this case, the challenge for the engineer is to correctly analyze the project when he or she has a *current* MARR (which incorporates inflation implicitly) and *real* cash flows (which do not take inflation into account).

Though it is common to do so, the engineer or analyst does not always start out with a *current* MARR and *real* cash flows. The cash flows may already have inflation implicitly factored in (in which case the cash flows are said to be current amounts). To carry out a project evaluation properly, the analyst must know whether inflation has been accounted for already in the MARR and the cash flows or whether it needs to be dealt with explicitly.

As a brief example, consider a one-year project that requires an investment of \$1000 today and yields \$1200 in one year. The current MARR is 25 percent. Whether the project is considered acceptable will depend on whether the \$1200 in one year is understood to be the current cash flow in one year or if it is the real value of the cash flow received in one year.

If the \$1200 is taken to be the current cash flow, the current internal rate of return, IRR_C, is found by solving for i^* in

$$-1000 + \frac{1200}{(1 + i^*)} = 0$$

$$i^* = IRR_C = 20\%$$

Hence, the project would not be considered economical. However, if the \$1200 is taken to be the real value of the cash flow in one year, and inflation is expected to be 5 percent over the year, then the current internal rate of return is found by solving for i^* in:

$$-1000 + \frac{1200\,(1 + 0.05)}{(1 + i^*)} = 0$$

$$i^* = IRR_C = 26\%$$

Hence, the project *would* be considered acceptable. As seen in this example, the economic viability of the project may depend on whether the \$1200 in one year has inflation implicitly factored in (i.e., is taken to be the current amount). This is why it is important to know what type of cash flows you are dealing with.

If the engineer has an estimate of inflation, there are two equivalent ways to carry out a project evaluation properly. The first is to work with current values for cash flows and current interest rates. The second is to work with real values for cash flows and real interest rates. *The two methods should not be mixed.*

These two methods of dealing with expected inflation, as well as two incorrect methods, are shown in Table 9.2.

The engineer must have a forecast of the inflation rate over the life of the project in order to adjust the MARR or cash flows for inflation. The best source of such forecasts may be the estimates of experts. Financial publications regularly report such predictions for relatively short periods of up to one year. Because there is evidence that even the short-term estimates

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Table 9.2 Methods of Incorporating Inflation Into Project Evaluation

1. Real MARR and Real Cash Flows
The real MARR does not include the effect of expected inflation. Cash flows are determined by today's prices. **Correct**
2. Current MARR and Current Cash Flows
The current MARR includes the effect of anticipated inflation. Cash flows include increases due to inflation. **Correct**
3. Current MARR and Real Cash Flows
The current MARR includes the effect of anticipated inflation. Cash flows are determined by today's prices. **Incorrect:** Biased against investments
4. Real MARR and Current Cash Flows
The real MARR does not include the effect of expected inflation. Cash flows include increases due to inflation. **Incorrect:** Biased in favour of investments

good practice to determine a range of possible inflation values for both long- and short-term projects. The engineer should test for sensitivity of the decision to values in the range. The subject of sensitivity analysis is addressed more fully in Chapter 10. Close-Up 9.1 discusses atypical patterns of price changes that may be specific to certain industries.

CLOSE-UP 9.1 Relative Price Changes

Engineers usually expect prices associated with a project to move with the general inflation rate. However, there are situations in which it makes sense to expect prices associated with a project to move differently from the average. This can happen when there are atypical forces affecting either the supply of or the demand for the goods.

For example, reductions in the availability of logs in North America caused a decrease in the supply of wood for construction, furniture, and pulp and paper in the 1980s. Average wood prices more than doubled between 1986 and 1995. This was about twice the increase in the CPI over that period. Since then, average wood prices have been decreasing while the CPI continues to increase. Another example is the price of computers. Product development and increases in productivity have led to increases in the supply of computers. This, in turn, has led to reductions in the relative price of computing power.

Changes in the relative prices of the goods sold by a specific industry will generally not have a noticeable effect on a MARR because investors are concerned with the overall purchasing power of the dollars they receive from an investment. Changes in the relative prices of the goods of one industry will not have much effect on investors' abilities to buy what they want.

Because the relative price changes will not affect the MARR, the analyst must incorporate expected relative price changes directly into the expected cash flows associated with a project. If the rate of relative price change is expected to be constant over the life of the project, this can be done using a geometric gradient to present worth conversion factor.

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EXAMPLE 9.7

Jagdeep can put his money into an investment that will pay him \$1000 a year for the next four years and \$10 000 at the end of the fifth year. Inflation is expected to be 5 percent over the next five years. Jagdeep's real MARR is 8 percent. What is the present worth of this investment?

The present worth may be obtained with real dollar cash flows and a real MARR or with current dollar cash flows and a current MARR.

The first solution approach will be to use real dollar and MARR_R. The real dollar cash flows in terms of *today's* dollars are

$$R_1, R_2, R_3, R_4, R_5 = \frac{C_1}{(1+f)}, \frac{C_2}{(1+f)^2}, \frac{C_3}{(1+f)^3}, \frac{C_4}{(1+f)^4}, \frac{C_5}{(1+f)^5}$$

$$= \frac{1000}{(1.05)}, \frac{1000}{(1.05)^2}, \frac{1000}{(1.05)^3}, \frac{1000}{(1.05)^4}, \frac{10\ 000}{(1.05)^5}$$

The present worth of the real cash flows, discounted by $\text{MARR}_\text{R} = 8$ percent, is

$$\text{PW} = \frac{1000}{(1.05)(1.08)} + \frac{1000}{(1.05)^2(1.08)^2} + \frac{1000}{(1.05)^3(1.08)^3} + \frac{1000}{(1.05)^4(1.08)^4} + \frac{10\ 000}{(1.05)^5(1.08)^5}$$

$$\cong 8282$$

The present worth of Jagdeep's investment is about \$8282.

Alternatively, the present worth can be found in terms of current dollars and MARR_C:

$$\text{PW} = \frac{1000}{(1+\text{MARR}_\text{C})} + \frac{1000}{(1+\text{MARR}_\text{C})^2} + \frac{1000}{(1+\text{MARR}_\text{C})^3} + \frac{1000}{(1+\text{MARR}_\text{C})^4} + \frac{10\ 000}{(1+\text{MARR}_\text{C})^5}$$

where

$$\text{MARR}_\text{C} = \text{MARR}_\text{R} + f + \text{MARR}_\text{R} \times f$$

Note that this is the sum of a four-period annuity with equal payments of \$1000 for four years and a single payment of \$10 000 in period 5. With this observation, the present worth computation can be simplified by the use of compound interest formulas:

$$\text{PW} = 1000(P/A,\text{MARR}_\text{C},4) + 10\ 000(P/F,\text{MARR}_\text{C},5)$$

With a real MARR of 8 percent and an inflation rate of 5 percent, the current MARR is then

$$\begin{aligned}\text{MARR}_\text{C} &= \text{MARR}_\text{R} + f + \text{MARR}_\text{R} \times f \\ &= 0.08 + 0.05 + (0.08)(0.05) \\ &= 0.134\end{aligned}$$

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and the present worth of Jagdeep's investment is

$$\begin{aligned} PW &= 1000(P/A,13.4\%,4) + 10\ 000(P/F,13.4\%,5) \\ &\cong 8282 \end{aligned}$$

The present worth of Jagdeep's investment is about \$8282, as was obtained through the use of the real MARR and a conversion from current to real dollars. ■

Though there are two distinct means of correctly adjusting for inflation in project analysis, the norm for engineering analysis is to make comparisons with the current MARR. One reason this is done has to do with how a MARR is chosen. As discussed in Chapter 4, the MARR is based on, among other things, the cost of capital. Since lenders and investors recognize the need to have a return on their investments higher than the expected inflation rate, they will lend to or invest in companies only at a rate that exceeds the inflation rate. In other words, the cost of capital already has inflation included. A MARR based on this cost of capital already includes, to some extent, inflation.

Consequently, if inflation is fairly static (even if it is high), a *current* dollar MARR is sensible. On the other hand, if changes in inflation are foreseen, or if sensitivity analysis specifically for inflation is desired, it may be wise to set a *real* dollar MARR and recognize an inflation rate explicitly in the analysis.

EXAMPLE 9.8

Lethbridge Communications is considering an investment in plastic moulding equipment for its product casings. The project involves \$150 000 in first costs and is expected to generate net savings (in current dollars) of \$65 000 per year over its three-year life. The company forecasts an inflation rate of 15 percent over the next year, and then inflation of 10 percent per year thereafter. Its real dollar MARR is 5 percent. Should this project be accepted on the basis of an IRR analysis?

In this problem, the inflation rate is not constant over the life of the project, so it is easiest to consider the cash flows for each year separately and to work in real dollars. First, as shown in Table 9.3, the current cash flows are converted into real cash flows.

Table 9.3 Converting From Current to Real Dollars for Lethbridge Communications

Year	Current Dollars	Real Dollars	
0	−\$150 000	−\$150 000	
1	65 000	56 522	$= 65\ 000(P/F,15\%,1)$ $= 65\ 000(0.86957)$
2	65 000	51 384	$= 65\ 000(P/F,15\%,1)(P/F,10\%,1)$ $= 65\ 000(0.86957)(0.90909)$
3	65 000	46 713	$= 65\ 000(P/F,15\%,1)(P/F,10\%,2)$ $= 65\ 000(0.86957)(0.82645)$

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Then, the real IRR can be found by solving for i' in

$$56\,522(P/F,i',1) + 51\,384(P/F,i',2) + 46\,713(P/F,i',3) = 150\,000$$

At $i' = 1\%$, LHS (left-hand side) = 151 673

At $i' = 2\%$, LHS = 148 821

The real IRR is between 1 percent and 2 percent. This is less than the real dollar MARR of 5 percent, so the project should not be undertaken. ■

EXAMPLE 9.9

Glasgow Resources has been offered a contract to sell land to the government at the end of 20 years. The contract states that Glasgow will get \$500 000 after 20 years from today, with no costs or benefits in the intervening years. A financial analyst for the firm believes that the inflation rate will be 4 percent for the next two years, rise to 15 percent for the succeeding 10 years, and then go down to 10 percent, where it will stay forever. Glasgow's real dollar MARR is 10 percent. What is the present worth of the contract?

In this case, it is easiest to proceed by calculating the current dollar MARR for each of the different inflation periods:

$$\text{MARR}_C\text{, years 13 to 20} = 0.10 + 0.10 + (0.10)(0.10) = 0.21 \text{ or } 21\%$$

$$\text{MARR}_C\text{, years 3 to 12} = 0.10 + 0.15 + (0.10)(0.15) = 0.265 \text{ or } 26.5\%$$

$$\text{MARR}_C\text{, years 0 to 2} = 0.10 + 0.04 + (0.10)(0.04) = 0.144 \text{ or } 14.4\%$$

With the individual MARRs, the present worth of the \$500 000 for each of years 12, 2, and 0 can be found:

$$\text{PW(year 12)} = 500\,000(P/F,21\%,8) = 500\,000 \times 1/(1.21)^8 = 108\,815$$

$$\text{PW(year 2)} = 108\,815\,(P/F,26.5\%,10) = 108\,815 \times 1/(1.265)^{10} = 10\,370$$

$$\text{PW(year 0)} = 10\,370\,(P/F,14.4\%,2) = 10\,370 \times 1/(1.144)^2 = 7924$$

The present worth of the contract is approximately \$7924. ■

EXAMPLE 9.10

Bildmet is an extruder of aluminum shapes used in construction. It is experiencing a high scrap rate of 5 percent. The manager, Greta Kehl, estimates that reprocessing scrap costs about \$0.30 per kilogram. The high scrap rate is due partly to operator error. Ms. Kehl believes that a short training course for the operator would reduce the scrap rate to about 4 percent. The course would cost about \$1100. Bildmet is now working with a before-tax actual MARR of 22 percent. Past experience suggests that operators quit their jobs after about five years; the correct time horizon for the retraining project is therefore five years. The data pertaining to the training course are summarized in Table 9.4. Should Bildmet retrain its operator?

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Table 9.4 Training Course Data

Output (kilograms/year)	125 000
Scrap (kilograms/year)	6250
Reprocessing cost ($/kilogram)	0.30
Scrap cost ($/year)	1875
Savings due to training ($/year)	375
First cost of training ($)	1100
Inflation rate (%/year)	5
Current MARR (%/year)	22

First, note that the current MARR $i = 22$ percent incorporates an estimate by investors of inflation of $f = 5$ percent per year over the next five years. If this estimate of future inflation is correct, Ms. Kehl needs to make an adjustment to take inflation into account. Either the projected annual saving from reduced scrap needs to be increased by the 5 percent rate of inflation, or she needs to reduce the MARR to its real value. We will illustrate the first approach with current cash flows and the current MARR.

Increasing savings to take inflation into account leads to projected (current) savings as shown in Table 9.5.

For example, using Equation (9.2), the expected saving in year 3 is $\$375(1 + f)^3 = \$434.11$. The present worth of the savings in year 3 is $\$434.11/(1 + i)^3 = \$239.07$. Note that this assumes that the savings begin in year 1.

The present worth of the savings over the five-year time frame, when discounted at the current MARR of 22 percent, is $1222. This makes the project viable since its cost is $1100.

We note that the same result could have been reached by working with the real MARR and the constant cost savings of $375 per year. MARR_R is given by

$$\text{MARR}_\text{R} = 1 + \frac{\text{MARR}_\text{C}}{1 + f} - 1 = \frac{1.22}{1.05} - 1 = 0.1619$$

Table 9.5 Savings Due to the Training Course

Year	Current Savings	Present Worth
1	$393.75	$322.75
2	413.44	277.77
3	434.11	239.07
4	455.81	205.75
5	478.61	177.08

The present worth of the real stream of returns, when these are discounted by the real MARR, is given by

$$\text{PW} = 375(P/A,16.19\%,5) \cong 1222$$

which is the same result as the one obtained with the current MARR and current cash flows. ■

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REVIEW PROBLEMS

REVIEW PROBLEM 9.1

Athabaska Engineering was paid $100 000 to manage a construction project in 1990. How much would the same job have cost in 2010 if the average annual inflation rate between 1990 and 2010 was 5 percent?

ANSWER

The compound amount factor can be used to calculate the value of 100 000 1990 dollars in 2010 dollars, using the inflation rate as an interest rate:

$$\begin{aligned}
\text{2010 dollars} &= 100\,000(F/P,5\%,20) \\
&= 100\,000(2.6533) \\
&= 265\,330
\end{aligned}$$

The same job would have cost about $265 330 in 2010 dollars. ■

REVIEW PROBLEM 9.2

A computerized course drop-and-add program is being developed for a local community college. It will cost $300 000 to develop and is expected to save $50 000 per year in administrative costs over its 10-year life. If inflation is expected to be 4 percent per year for the next 10 years and a real MARR of 5 percent is required, should the project be adopted?

ANSWER

First, assuming that $50 000 in administrative costs are current dollars, we can calculate the current IRR for the project. The current IRR is the solution for i in

$$300\,000 = 50\,000(P/A,i,10)$$

$$(P/A,i,10) = 6$$

$$\text{For } i = 11\%, (P/A,i,10) = 5.8892$$

$$\text{For } i = 10\%, (P/A,i,10) = 6.1445$$

The current IRR of 10.55 percent is found by interpolating between these two points. We then convert the current IRR into a real IRR to determine if the project is viable:

$$\text{IRR}_R = \frac{1 + \text{IRR}_C}{1 + f} - 1 = \frac{1.1055}{1.04} - 1 = 0.06298 \text{ or } 6.3\%$$

Since the real IRR of 6.3 percent exceeds the real MARR of 5 percent, the project should be undertaken. ■

REVIEW PROBLEM 9.3

Robert is considering purchasing a bond with a face value of $5000 and a coupon rate of 8 percent, due in 10 years. Inflation is expected to be 5 percent over the next 10 years. Robert's real MARR is 10 percent, compounded semiannually. What is the present worth of this bond to Robert?

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ANSWER

This problem can be done with either real interest and real cash flows or current interest and current cash flows. It is somewhat easier to work with current cash flows, so we must first convert the real interest rate given to a current interest rate.

Robert's annual real MARR is $(1 + 0.10/2)^2 - 1 = 0.1025$. (Recall that the 10 percent is a nominal rate, compounded semiannually.)

If annual inflation is 5 percent, Robert's current *annual* MARR is

$$\begin{aligned} MARR_C &= MARR_R + f + MARR_R \times f \\ &= 0.1025 + 0.05 + (0.1025)(0.05) \\ &= 0.15763 \text{ or } 15.763\% \end{aligned}$$

The present worth of the \$5000 Robert will get in 10 years is then

$$\begin{aligned} PW &= 5000(P/F, MARR_C, 10) \\ &= 5000(0.23138) \cong 1157 \end{aligned}$$

Next, the bond pays an annuity of \$5000 × 0.08/2 = \$200 every six months. To convert the annuity payments to their present worth, we need a current six-month MARR. This can be obtained with a six-month inflation rate and Robert's six-month real MARR of 10 percent/2 = 5 percent. With f = 5 percent per annum, the inflation rate per six-month period can be calculated with

$$\begin{aligned} f_{12} &= (1 + f_6)^2 - 1 \\ f_6 &= (1 + f_{12})^{1/2} - 1 \\ &= (1 + 0.05)^{1/2} - 1 = 0.0247 \text{ or } 2.47\% \end{aligned}$$

The current MARR per six-month period is then given by

$$\begin{aligned} MARR_C &= MARR_R + f + MARR_R \times f = 0.05 + 0.0247 + (0.05)(0.0247) \\ &= 0.07593 \text{ or } 7.593\% \end{aligned}$$

The present worth of the dividend payments is

$$\begin{aligned} PW(\text{dividends}) &= 200(P/A, 7.59\%, 20) \\ &= 200(10.125) \\ &= 2025 \end{aligned}$$

Finally,

$$\begin{aligned} PW(\text{bond}) &= 1157 + 2025 \\ &= 3182 \end{aligned}$$

The present worth of the bond is \$3182. ■

REVIEW PROBLEM 9.4

Trimfit, a manufacturer of automobile interior trim, is considering the addition of a new product to its line. Data concerning the project are given below. Should Trimfit accept the project?

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New Product Line Information	
First cost ($)	11 500 000
Planned output (units/year)	275 000
Current MARR	20%
Range of possible inflation rates	0% to 4%
Study period	10 years

Current-Year Prices ($/unit)	
Raw materials	16.00
Labour	6.25
Product sales price	32.00

ANSWER

First, we note that the expected net revenue per unit (not counting amortization of first costs) is $9.75 = $32 − $16 − $6.25. The project is potentially viable.

In doing the project evaluation, we can proceed with either current or real dollars. Since we do not know what the inflation rate will be, the easiest way to account for inflation is to keep all prices in real dollars and adjust the current MARR to a real MARR by using values for the inflation rate within the potential range given. The project can then be evaluated with one of the standard methods. Since many of the figures are given in terms of annual amounts, an annual worth analysis will be carried out. Inflation rates of 0 percent, 1 percent, and 4 percent will be used. The results are shown in Table 9.6.

In Table 9.6, the annual worth of the project depends on the inflation rate assumed. Since the current MARR of 20 percent implicitly includes anticipated inflation, different

Table 9.6 Annual Worth Computations for Trimfit

Annual Worth Comparisons for Various Inflation Rates					
Inflation Rate per Year	Real MARR	Fixed Cost per Year ($)	Variable Cost per Year ($)	Revenue per Year ($)	Annual Worth (Profit) per Year ($)
0%	20.00%	2 743 012	6 118 750	8 800 000	− 61 762
1%	18.81%	2 633 122	6 118 750	8 800 000	48 128
4%	15.38%	2 325 083	6 118 750	8 800 000	356 167

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trial inflation rates imply different values for the real MARR. For example, at 1 percent inflation, the real MARR implied is

$$\text{MARR}_\text{R} = \frac{1 + \text{MARR}_\text{C}}{1 + f} - 1 = \frac{1.20}{1.01} - 1 = 0.1881 \text{ or } 18.81\%$$

The fixed cost per year is obtained by finding the annual amount over 10 years equivalent to the first cost when the appropriate real MARR is used. For example, with 1 percent inflation, the fixed cost per year is

$$A = P(A/P,\text{MARR}_\text{R},10) = 11\ 500\ 000 \left(\frac{0.1881\ (1.1881)^{10}}{(1.1881)^{10}} - 1 \right)$$
$$= 2\ 633\ 122$$

Next, the variable cost per year is the sum of the raw material cost and the labour cost per unit multiplied by the total expected output per year—that is, \$22.25 × 275 000 = \$6 118 750. Revenue per year is the sales price multiplied by the expected output: \$32 × 275 000 = \$8 800 000. Notice that the variable cost and the revenue are the same for all three values of the inflation rate. This is because they are given in real dollars.

Finally, the annual worth of the project is determined by the revenue per year less the fixed and variable costs per year. The annual worth is negative for zero inflation, but is positive for both 1 percent and 4 percent inflation rates. Since periods of at least 10 years in which there has been zero inflation have been rare in the twentieth and twenty-first centuries, it is probably safe to assume that there will be some inflation over the life of the project. Therefore, the project appears to be acceptable, since its annual worth will be positive if inflation is at least 1 percent. ■

SUMMARY

In this chapter, the concept of inflation was introduced and we considered the impact that inflation has on project evaluation. We began by discussing methods of measuring inflation. The main result here was that there are many possible measures, all of which are only approximate.

The concept of current cash flows and interest rates and real cash flows and interest rates was introduced. Current dollars are in currency at the time of payment or receipt, while real dollars are constant over time and are expressed with respect to a base year. Compound amount factors can be used to convert single payments between real and current dollars.

Most of the chapter was concerned with the effect of correctly anticipated inflation on project evaluation and on how to incorporate inflation into project evaluation correctly. We showed that, where engineers have no reason to believe project prices will behave differently from average prices, project decisions are the same with or without correctly anticipated inflation. Finally, we pointed out that predicting inflation is very difficult. This implies that engineers should work with ranges of values for possible future inflation rates. The engineer should test for sensitivity of decisions to possible inflation rates.

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ENGINEERING ECONOMICS IN ACTION, PART 9B

Exploiting Volatility

Bill Astad of head office had been asking Naomi about how to deal with the variable inflation rates experie by a sister company in Mexico. "Okay, Naomi, let's see if I have this straight. For long-term projects of, sa years or more, it makes sense to use a single inflation figure—the average rate. I can just add that to the MARR to get a current MARR. Boy, it's easy to get confused between the real and the current. But I do unders the principle."

"And the short-term projects?" Naomi prompted.

"For the short-term ones, it makes more sense to break them up into time periods. For each period, sel 'best guess' inflation rate and do a stepwise calculation from period to period. So the inflation rate in the m of the presidential cycle would be relatively low, while near the changeover time it would be a higher estima course, the actual values used would depend on the political and economic situation at the time the decisi made. I understand that one, too, but it is complicated."

"I agree," said Naomi. "I guess we're lucky things are more predictable here."

"We are," Bill replied. "On the other hand, if we can make good decisions in spite of a volatile econo Mexico, Mexifab may have an advantage over its competitors. Thanks for your help, Naomi."

PROBLEMS

A. Key Concepts

9.1 Which of the following are real and which are current?

- **(a)** Allyson has been promised a \$10 000 inheritance when her uncle Bill dies.
- **(b)** Bette's auto insurance will pay the cost of a new windshield if her current one breaks.
- **(c)** Cory's meal allowance while he is in university is \$2000 per term.
- **(d)** Dieter's company promises that its prices will always be the same as they were in 1975.
- **(e)** Engworth will construct a house for Zolda, and Zolda will pay Engworth \$150 000 when the house is finished.
- **(f)** Fran's current salary is \$3000 per month.
- **(g)** Greta's retirement plan will pay her \$1500 per month, adjusted for the cost of living.

9.2 Find the real amounts (with today as the base year) corresponding to the current amounts shown below for a 4 percent inflation rate.

- **(a)** \$400 three years from now
- **(b)** €400 three years ago
- **(c)** \$10 next year
- **(d)** \$350 983 ten years from now
- **(e)** £1 one thousand years ago
- **(f)** \$1 000 000 000 three hundred years from now

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9.3 Find the present worth today in real value corresponding to the current values shown below for a 4 percent inflation rate and a 4 percent interest rate.

(a) \$400 three years from now

(b) €400 three years ago

(c) \$10 next year

(d) \$350 983 ten years from now

(e) £1 one thousand years ago

(f) \$1 000 000 000 three hundred years from now

9.4 An investment pays \$10 000 in five years.

(a) If inflation is 10 percent per year, what is the real value of the \$10 000 in today's dollars?

(b) If inflation is 10 percent and the real MARR is 10 percent, what is the present worth?

(c) What current dollar MARR is equivalent to a 10 percent real MARR when inflation is 10 percent?

(d) Compute the present worth using the current dollar MARR from part (c).

9.5 An annuity pays \$1000 per year for 10 years. Inflation is 6 percent per year.

(a) If the real MARR is 8 percent, what is the current dollar MARR?

(b) Using the current dollar MARR from part (a), calculate the present worth of the annuity.

9.6 An annuity pays \$1000 per year for 12 years. Inflation is 6 percent per year. The annuity costs \$7500 now.

(a) What is the current dollar internal rate of return?

(b) What is the real internal rate of return?

9.7 A bond pays \$10 000 per year for the next 10 years. The bond costs \$90 000 now. Inflation is expected to be 5 percent over the next 10 years.

(a) What is the current dollar internal rate of return?

(b) What is the real internal rate of return?

9.8 Inflation is expected to average about 4 percent over the next 50 years. How much would we expect to pay 50 years from now for each of the following?

(a) \$1.59 hamburger

(b) \$15 000 automobile

(c) \$180 000 house

9.9 The average person now has assets totalling \$38 000. If the average real wealth per person remains the same and if inflation averages 5 percent in the future, when will the average person become a millionaire?

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B. Applications

9.10 How much is the present worth of $10 000 ten years from now under each of the following patterns of inflation, if interest is at 5 percent? On the basis of your answers, is it generally reasonable to use an average inflation rate in economic calculations?

(a) Inflation is 4 percent.

(b) Inflation is 0 percent for five years, and then 8 percent for five years.

(c) Inflation is 8 percent for five years, and then 0 percent for five years.

(d) Inflation is 6 percent for five years and then 2 percent for five years.

(e) Inflation is 0 percent for nine years and then 40 percent for one year.

9.11 The current dollar MARR for Jungle Products Ltd. of Parador is 300 percent. The inflation rate in Parador is 250 percent. What is the company's real MARR?

9.12 Krystyna has a long-term consulting contract with an insurance company that guarantees her $25 000 per year for five years. She believes inflation will be 3 percent this year and 5 percent next year, and then will stay at 10 percent indefinitely. Krystyna's real MARR is 12 percent. What is the present worth of this contract?

9.13 I have a bond that will pay me $2000 every year for the next 30 years. My first payment will be a year from today. I expect inflation to average 3 percent over the next 30 years. My real MARR is 10 percent. What is the present worth of this bond?

9.14 Ken will receive a $15 000 annual payment from a family trust. This will continue until Ken is 30; he is now 20. Inflation averages 4 percent and Ken's real MARR is 8 percent. If the first payment is a year from now and a total of 10 payments are to be made, what is the present worth of his remaining income from the trust?

9.15 Inflation in Russistan currently averages 40 percent per month. It is expected to diminish to 20 percent per month following the presidential elections 12 months from now. The Russistan Oil Company (ROC) has just signed an agreement with the Global Petroleum Group for the sale of future shipments. The ROC will receive 500 million rubles per month over the next two years, and also 500 million rubles per month indexed to inflation (i.e., real rubles). If the ROC has a real MARR of 1.5 percent per month, what is the total present worth of this contract?

9.16 The widget industry maintains a price index for a standard collection of widgets. The base year was 2002 until 2012, when the index was recomputed with 2012 as the base year. The following data concerning prices for the years 2010 to 2013 are available:

Year	Price Index 2002 Base	Price Index 2012 Base
2010	125	N/A
2011	127	N/A
2012	130	100
2013	N/A	110

What was the percentage increase in prices of widgets between 2010 and 2013?

9.17 A group of farmers in Inverness is considering building an irrigation system from a water supply in some nearby mountains. They want to build a concrete reservoir with a steel pipe system. The first cost would be $200 000 with (current) annual maintenance costs of $2000. They expect the irrigation system will bring them $22 000 per year in

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additional (current) revenues due to better crop production. Their real dollar MARR is 4 percent and they anticipate inflation to be 3 percent per year. Assume that the reservoir will have a 20-year life.

(a) Using the current cash flows, find the current IRR on this project.

(b) What is the current MARR?

(c) Should they invest?

9.18 Refer to Problem 9.17.

(a) Convert the current cash flows into real cash flows.

(b) Find the present worth of the project using the real MARR.

(c) Should they invest?

9.19 Bosco Consulting is considering a potential contract with the Upper Sobonian government to advise it on exploration for oil in Upper Sobonia. Bosco would make an investment of 1 500 000 Sobonian zerts to set up a Sobonian office in 2015. The Upper Sobonian government would pay Bosco 300 000 zerts in 2016. In the years 2017 to 2022, the current zerts value of the payments would increase at the rate of inflation in Upper Sobonia. The following data are available concerning the project:

Investment in Upper Sobonia	
Expected Sobonian inflation rate (2015–2022)	15%/year
Expected inflation rate (2015–2022)	3%/year
Value of Sobonian zerts in 2015	$0.25
Expected decline in value of zerts (2015–2022)	10%/year
First cost in 2015 (zerts)	1 500 000
Cash flows in 2016–2022 (real 2016 zerts)	300 000
Bosco's current dollar MARR	22%

(a) Construct a table with the following items:

Real (2015) zert cash flows
Current zert cash flows
Current dollar cash flows
Real dollar cash flows

(b) What is the present worth in 2015 dollars of this project?

9.20 Johnson Products now buys a certain part for its chain saws. The managers are considering the production of the part in-house. They can install a production system that would have a life of five years with no salvage value. They believe that over the next five years the real price of purchased parts will remain fixed. They expect the real price of labour and other inputs to production to rise over the next five years. Further information about the situation is in the table below.

(a) Assume inflation is 2 percent per year in the first year of operation. What will be the current dollar cost of labour for in-house production in the second year?

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Annual cost of purchase ($/year)	750 000
Expected real change in cost of purchase	0%
Expected real change in labour cost	4%
Expected real change in other operating costs	2%
Labour cost/unit (first year of operation) ($)	10.5
Other operating cost/unit (first year of operation) ($)	9
In-house first cost ($)	200 000
Use rate (units/year)	25 000
Current dollar MARR	20%
Study period (years)	5

(b) Assume inflation is 2 percent per year in the first two years of operation. What will be the current dollar cost of other operating inputs for in-house production in the third year?

(c) Assume that inflation averages 2 percent per year over the five-year life of the project. What is the present worth of costs for purchase and for in-house production?

9.21 Metcan Ltd.'s smelter produces its own electric power. The plant's power capacity exceeds its current requirements. Metcan has been offered a contract to sell excess power to a nearby utility company. Metcan would supply the utility company with 17 500 megawatt-hours per year (MWh/a) for 10 years. The contract would specify a price of $22.75 per megawatt-hour for the first year of supply, which would rise by 1 percent per year after this. This is independent of the current rate of inflation over the 10 years.

Metcan would incur a first cost to connect its plant to the utility system. There would also be operating costs attributable to the contract. Metcan believes these costs would track the current inflation rate. The terms of the contract and Metcan's costs are shown in the tables below.

Metcan Sale of Power	
Output price in 2014 ($/MWh)	22.75
Price adjustment (2015–2023)	1% per year
Power to be supplied (MWh/a)	17 500
Contract length	10 years
Metcan's Costs	
First cost in 2013 ($)	175 000
Operating cost in 2008 ($)	332 500
Current dollar MARR before tax	20%

(a) Find the present worth of the contract under the assumption that there is no inflation over the life of the contract.

(b) Find the present worth of the contract under four assumptions: inflation is (i) 1 percent per year, (ii) 2 percent per year, (iii) 3 percent per year, and (iv) 4 percent per year.

(c) Should Metcan accept the contract?

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9.22 Free Wheels has a plant that assembles bicycles. The plant now has a small cafeteria for the workers, but the kitchen equipment is in need of substantial overhaul. Free Wheels has been offered a contract by Besteats to supply food to the workers. The particulars of the situation are shown in the table. Should Free Wheels continue with the in-house food service or contract the service to Besteats?

Food Service: In-House Versus Contract	
Food service labour (hours/year)	6000
Wage rate (real, time 1, \$/hour)	7.5
Overhead cost (real, time 1, \$/year)	18 000
Kitchen equipment first cost (current, time 0, \$)	25 000
Contract cost, years 1 to 3 (current \$)	55 000
Contract cost, years 4 to 6 (current \$)	63 700
Current dollar MARR	22%
Expected annual inflation rate	5%
Study period (years)	6

C. More Challenging Problems

9.23 Go to the Statistics Canada website (www.statcan.gc.ca).

(a) What is the current base year for the CPI? What was the trend over the last two years?

(b) Summarize, if the information is given, what the commodities in the CPI basket are, the relative importance of the commodities in the CPI basket, how the CPI basket is updated, and how prices are collected for the CPI.

(c) Which of the subcategories (e.g., food, transportation, etc.) appears to be contributing the most to the overall CPI index?

(d) Are there regions of the country with a different CPI than other regions? Why?

9.24 Go to the Statistics Canada website (www.statcan.gc.ca).

(a) Find or calculate the most recent inflation rate. What has been the trend in the inflation rate over the last two years?

(b) How does the current inflation rate compare with the interest rates offered at banks and other financial institutions for savings accounts? Can you estimate the real interest rate available for your savings?

(c) How does inflation in Canada compare with inflation elsewhere? Find a country with particularly low inflation (or high deflation) and a country with particularly high inflation.

9.25 Bildkit, a building products company, is considering an agreement with a distributor in the foreign country of Maloria to supply kits for constructing houses in Maloria. Sales would start next year. The expected receipts from the sale of the kits next year is 30 000 000 Malorian yen. The number of units sold is expected to grow by 10 percent per year over the life of the contract. The actual yen price is expected to grow at the rate

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There will be a first cost for Bildkit. As well, there will be operating costs over the life of the contract. Operating cost per unit will be constant in real dollars over the life of the contract. Since the number of units sold will rise by 10 percent per year, real operating costs will rise by 10 percent per year. Actual operating costs per unit will rise at the rate of inflation in Bildkit's country.

The value of the Malorian yen is expected to increase over the life of the contract. Data concerning the proposed contract are shown in the table below.

Bildkit in Maloria			
Receipts in first year (current yen)	30 000 000	First cost now (current $)	200 000
Growth of receipts (real yen)	10%/year	Operating cost in first year of operation (current $)	350 000
Malorian inflation rate	1%/year	Inflation rate in Bildkit's country	3%
Value of yen year 0 ($)	0.015	Current dollar MARR	22%
Rate of increase in value of yen	2%	Study period	8 years

(a) What is the present worth of receipts in dollars?

(b) What is the present worth of the cash outflows in dollars?

9.26 Leftway Information Systems is considering a contract with the Ibernian government to supply consulting services over a five-year period. The following real Ibernian pound cash flows are expected:

Cash Flows in Year 2010 Ibernian Pounds	
First cost	1 800 000
Net revenue 2014 to 2018	550 000

Further information is in the table below:

Expected Ibernian inflation rate	10%
Value of Ibernian pound in 2013 ($)	1.25
Expected annual rate of decline in the value of the Ibernian pound	5%
Expected inflation rate in Leftway's country	2.50%
Leftway's real MARR	15%

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(a) What is the real Ibernian pound internal rate of return on this project? (*Hint:* Leftway's country can be ignored in answering this question.)

(b) What is the current pound internal rate of return? (*Hint:* Leftway's country can be ignored in answering this question.)

(c) Use the internal rate of return in dollars to decide if Leftway should accept the proposed contract.

9.27 Sonar warning devices are being purchased by the St. James department store chain to help trucks back up at store loading docks. The total cost of purchase and installation is $220 000. There are two types of saving from the system. Faster turnaround time at the congested loading docks will save $50 000 per year in today's dollars. Reduced damage to the loading docks will save $30 000 per year in today's dollars. St. James has an observed current dollar MARR of 18 percent. The sonar system has a life of four years. Its scrap value in today's dollars is $20 000. The inflation rate is expected to be 6 percent per year over the next four years.

(a) What is St. James's real MARR?

(b) What is the real internal rate of return? (This is most easily done with a spreadsheet.)

(c) Compute the current internal rate of return using Equation (9.10).

(d) Compute the current internal rate of return from the current dollar cash flows. (This is most easily done with a spreadsheet.)

(e) What is the present worth of the system?

9.28 Lifewear, a manufacturer of women's sports clothes, is considering adding a line of skirts and jackets. The production would take place in a part of its factory that is now not being used. The first output would be available in time for the 2015 fall season. The following information is available:

New Product Line Information	
First cost in 2014 ($)	15 500 000
Planned output (units/year)	325 000
Observed, current dollar MARR before tax	0.25
Study period	6 years
Year 2014 Prices ($/unit)	
Materials	12
Labour	7.75
Output	35

(a) What is the real internal rate of return?

(b) What inflation rate will make the real MARR equal to the real internal rate of return?

(c) Calculate the present worth of the project under three possible future inflation rates. Assume that the inflation rate will be 1 percent, 2 percent, or 3 percent per year.

(d) Decide if Lifewear should add this new line of skirts and jackets. Explain your answer.

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9.29 Century Foods, a producer of frozen meat products, is considering a new plant near Essen, Germany, for its sausage rolls and frozen meat pies. The company has estimates of production cost and selling prices in the first year. It expects the real value of operating costs per unit to fall because of improved operating methods. It also expects competitive pressures to cause the real value of product prices to fall. The following data are available:

Century Food Plant Data	
Output price in 2015 (€/box)	22
Operating cost in 2015 (€/box)	15.5
Planned output rate (boxes/year)	275 000
Fall in real output price	1.5% per year
Fall in real operating cost per box	1.0% per year
First cost in 2014 (€)	7 500 000
Study period	10 years
Current euro MARR before tax	20%

(a) Assume that there is zero inflation. What is the present worth, in 2014, of the project?

(b) Assume that there is zero inflation. What is the internal rate of return? (This is most easily done with a spreadsheet.)

(c) At what inflation rate would the current euro internal rate of return equal 20 percent?

(d) Should Century Foods build the new plant? Explain your answer.

9.30 Clarkwood is a wood products manufacturer. Its managers are considering a modification to the production line that would enable an increase in output. One of Clarkwood's concerns is that the price of wood is rising more rapidly than inflation. The managers expect that because of this the operating cost per unit will rise at a rate 4 percent higher than the rate of inflation. That is, if the rate of inflation is f, Clarkwood's operating cost will rise at the rate $f_c = 1.04(1 + f) - 1$. However, competitive pressures from plastics will prevent the prices of Clarkwood's products from rising more than 1 percent above the inflation rate. The particulars of the project are shown in the table below.

Clarkwood's Project	
Output price in 2014 ($/unit)	30
Price increase	2% above inflation
Operating cost in 2014 ($/unit)	24
Operating cost increase	4% above inflation
Expected output due to project (units/year)	50 000
First cost in 2013 ($)	900 000
Observed current dollar MARR	0.25
Time horizon (years)	10

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(a) Find the present worth of the project under the assumption of zero inflation.

(b) Find the present worth of the project under these assumptions: the expected inflation is (i) 1 percent per year, and (ii) 2 percent per year.

(c) Should Clarkwood accept the project?

9.31 Smooth-Top is a manufacturer of desktops. It is considering an increase of capacity. Consulting engineers have submitted two routes to accomplish this: (1) install a new production line that would produce wooden desktops finished with hardwood veneer and (2) install a new production line that would produce wooden desktops finished with simulated wood made from hard plastic.

Smooth-Top is concerned about the price of hardwood veneer. It believes the price of veneer will rise over the next 10 years. However, it believes the price of veneer-finished desktops will rise by less than the rate at which the price of veneer rises. Information about the two potential projects is in the following table.

(a) Compute the present worth of each option under the assumption that the real price of hardwood-finished desktops and real cost of hardwood veneer do not change (rather than as stated in the table). Assume zero inflation.

Smooth-Top Desktop Project	
Plastic-finish real price and real cost change	0%
Veneer-finish expected real price change	1%
Veneer-finish expected real cost change	5%
Wood cost/unit ($)	12.5
Plastic cost/unit ($)	9
Wood price/unit ($)	32
Plastic price/unit ($)	26
Wood first cost ($)	2 050 000
Plastic first cost ($)	2 700 000
Wood output rate (units/year)	30 000
Plastic output rate (units/year)	45 000
Study period	10 years
Current dollar MARR	25%

(b) Compute the present worth of each option under the assumption that the real price of hardwood-finished desktops and the real value of hardwood veneer desktop operating costs increase as indicated in the table. Assume that inflation is expected to be 2 percent over the study period.

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9.32 Belmont Grocers has a distribution centre in Winnipeg. The manual materials-handling system at the centre has deteriorated to the point that it must be either replaced or substantially refurbished. Replacement with an automated system would cost about \$240 000. Refurbishing the manual system would cost about \$50 000. In either case, capital expenditures would take place this year. Operating either the new system or the refurbished system would begin next year. It is expected that either the new system or the refurbished system will operate for 10 years with no further capital expenditures. Belmont is concerned that labour costs in Winnipeg may rise in real terms over the next 10 years. The range of increases in real terms that appears possible is from 4 percent to 7 percent per year. Inflation rates between 2 percent and 4 percent are expected over the next 10 years. Complete data on the two alternatives are given in the table that follows.

(a) Find the total costs per unit for each of the two alternatives under the assumption of zero inflation and no increase in costs for the manual system.

(b) Make a recommendation about which alternative to adopt. Base the recommendation on the present worth of costs for the two systems under various assumptions concerning inflation and the rate of change in the real operating cost of the manual system. Explain your recommendation.

Materials Handling Data	
Automated expected real operating cost change	0%
Manual expected real operating cost change	4% to 7%
Manual operating cost/unit (first year of operation) (\$)	10.5
Automated operating cost/unit (first year of operation) (\$)	9
Manual first cost (\$)	50 000
Automated first cost (\$)	240 000
Output rate (units/year)	15 000
Current dollar MARR	20%
Study period	10 years
Possible inflation rates	2% to 4%

9.33 The United Gum Workers have a cost-of-living clause in their contract with Mont-Gum-Ery Foods. The contract is for two years. The contract states that, if the inflation rate in the first year exceeds 1 percent, wages in the second year will increase by the inflation rate of the first year. Does this clause increase or decrease risk? Explain.

9.34 In 10 years, Mid-Atlantic Corp. will be investing \$200 000 either in Columbo or in Avalon. The exchange rate between the Columboan dollar and the Avalonian pound is fixed at \$2 = £1. Dollars and pounds can be exchanged at no cost at any time.

If the \$200 000 is invested in Columbo, each dollar invested will return \$0.30 per year for each of the following five years. If the \$200 000 is converted to pounds and invested in Avalon, each pound invested will return £0.24 per year for the following seven years.

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Columbo is subject to ongoing average inflation of 4 percent, while inflation in Avalon averages 2 percent. If the real MARR for Mid-Atlantic is 10 percent, which investment is preferred? How much money should Mid-Atlantic set aside now (invested at the MARR) to ensure that it has enough money to make the investment in 10 years?

MINI-CASE 9.1

Economic Comparison of High Pressure and Conventional Pipelines: Associated Engineering

Associated Engineering conducted an evaluation of sources of water supply for a municipality. One of the considerations was the choice of high-pressure or conventional pipelines for transmitting treated water to the municipality from a distant water source.

Conventional pipelines, most often made of concrete, have a limited maximum tensile strength, which for analysis purposes was taken to be 200 pounds per square inch (psi). High-pressure pipe, made of steel, can withstand up to 60 000 psi, although the pipe examined by Associated Engineering had a strength of 42 000 psi.

The major advantage of the steel pipe is that fewer pumping stations are needed than with the concrete pipe. The distance to be pumped is 85 kilometres; this requires either one pumping station for high-pressure pipe or six pumping stations for concrete pipe.

Each pipeline type was analyzed over a range of pipeline diameters ranging from 24" to 72". Construction costs included the pipe, pumping stations, and a reception reservoir, with the time of the cost taken to be the commissioning date of 2025. Operating and maintenance costs starting in 2026 were included, and administration, engineering fees, contingencies, and taxes were also accounted for.

The best alternative was chosen on the basis of a present worth comparison with a 4 percent discount rate. In the analysis, real 1993 dollars were used and an inflation rate of 2 percent was assumed for the period of study. The result was that a 360-diameter high-pressure pipeline was economically best at a present cost $7.5 million lower than for the best conventional pipeline.

Discussion

Estimating future inflation is difficult. The average inflation in many developed countries over the past 50 years has been about 4 percent, but there have been periods of several years when it has been 2 percent to 2.5 percent. For some other periods, inflation has averaged over 10 percent. Historically, many countries have experienced hyperinflation (extreme inflation) or even deflation. How can we estimate future inflation?

One way is simply to assume that inflation will remain at the current value. This is probably wrong; as has been seen, inflation typically changes over time. However, there are factors that are controlling the inflation rate. Lacking knowledge of any reason why these controlling factors might change, the current rate seems to be a reasonable choice.

A second approach is to use the long-term average. Knowing that inflation will change over time suggests that the long-term average is a good choice even if inflation is lower or higher than the average right now. After all, those controlling factors have changed in the past and are likely to change again.

A third way is to take into account the controlling factors for inflation. These include government policy: A government committed to social welfare is likely to induce more inflation than one committed to fiscal responsibility. Trends in business and consumer behaviour affect inflation: Large labour-contract increases presage inflation, as does high consumer borrowing. Social trends like the aging of the baby boomers also have an effect on inflation.

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Understanding the effect of the controlling factors for inflation in detail is very difficult. So usually decision makers make a broad judgment based on both the current inflation rate and the historical average, and perhaps informed by a general understanding of the contributing factors.

Questions

1. How significant would the difference have been to the savings of the high-pressure pipeline if an inflation rate of 4 percent had been used instead? Assume the only difference between the concrete- and steel-pipe systems was the capital cost, expended in 2025. Would the decision be any different? Could it be different for any assumed inflation rate?
2. Design two cash flow structures for projects that start in 2025, such that the present worth in the current year at a discount rate of 4 percent is higher for one project than the other at an inflation rate of 2 percent, but lower at an inflation rate of 4 percent. Is there a significant opportunity to control the best choice in a decision situation by selecting the appropriate inflation rate?
3. Why would the analysts have chosen to separate the inflation rate from the discount rate for this problem rather than combining them into a current dollar discount rate? Do you think the analysts estimated the current dollar cost of the alternatives in 2025, or would they have used the real costs?

Appendix 9A Computing a Price Index

We can represent changes in average prices over time with a **price index**. A price index relates the average price of a given set of goods in some time period to the average price of the same set of goods in another period. Commonly used price indexes work with weighted averages because simple averages do not reflect the differences in importance of the various goods and services in which we are interested.

Many different ways of weighting changes in prices may be used, and each method leads to a different price index. We shall discuss only the most commonly used index, the **Laspeyres price index**. It can be explained as follows.

Suppose there are n goods in which we are interested. We want to represent their prices at a time, t_1, relative to a **base period**, t_0—the period from which the expenditure shares are calculated.

The prices of the n goods at times t_0 and t_1 are denoted by $p_{01}, p_{02}, \ldots, p_{0n}$ and $p_{11}, p_{12}, \ldots, p_{1n}$. The quantities of the n goods purchased at t_0 are denoted by $q_{01}, q_{02}, \ldots, q_{0n}$. The share, s_{0j}, of good j in the total expenditure for the period, t_0, is defined as

$$s_{0j} = \frac{p_{0j}q_{0j}}{p_{01}q_{01} + p_{02}q_{02} + \ldots + p_{0n}q_{0n}}$$

Note that

$$\sum_{j=1}^{n} s_{0j} = 1$$

A Laspeyres price index, π_{01}, is defined as a weighted average of relative prices.

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$$\pi_{01} = \left(\frac{p_{11}}{p_{01}} s_{01} + \frac{p_{12}}{p_{02}} s_{02} + \ldots + \frac{p_{1n}}{p_{0n}} s_{0n}\right) \times 100$$

The term in the brackets is a weighted average because the weights (the expenditure shares in the base period) sum to one. The relative prices are the prices of the individual goods in period t_1 relative to the base period, t_0. The weighted average is multiplied by 100 to put the index in percentage terms.

EXAMPLE 9A.1

A student uses four foods for hamburgers: (1) ground beef, (2) hamburger buns, (3) onions, and (4) breath mints. Suppose that, in one year, the price of ground beef fell by 10 percent, the price of buns fell by 1 percent, the price of onions rose by 5 percent, and the price of breath mints rose by 50 percent.

The price and quantity data for the student's hamburger are shown in Table 9A.1.

Table 9A.1 Price and Quantity Data for Hamburger

	Quantity at t_0	Price at t_0 (\$)	Price at t_1 (\$)
Ground beef (kg)	0.25	3.5/kg	3.15/kg
Buns	1	0.40	0.396
Onions	1	0.20	0.21
Breath mints	1	0.10	0.15

The Laspeyres price index is calculated in four steps:

1. Compute the base period expenditure for each ingredient.
2. Compute the share of each ingredient in the total base period expenditure.
3. Compute the relative price for each ingredient.
4. Use the shares to form a weighted average of the relative prices.

These computations are shown in Table 9A.2.

Table 9A.2 The Laspeyres Price Index Calculation

	Price at t_0 (\$)	Share at t_0	Relative Price	Weighted Relative Price
Ground beef (kg)	0.875	0.556	0.900	0.500
Buns	0.400	0.254	0.990	0.251
Onions	0.200	0.127	1.050	0.133
Breath mints	0.100	0.063	1.500	0.095
Sums	1.575	1.000		0.980

As an example of the computations, the price of the ground beef per hamburger at t_0 is found by multiplying the price per kilogram by the weight of the hamburger used:

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\$3.50/kg × 0.25 kg = \$0.875. Similar computations for each of the other ingredients lead to a total cost of \$1.575 per hamburger. The ground beef then represents a share of 0.875/1.575 = 0.556 of the total cost. The relative price for the hamburger is 3.15/3.5 = 0.9 and thus the weighted relative price is 0.556 × 0.9 = 0.50. Similar computations for the other ingredients lead to a total weighted average of 0.98. After multiplying by 100, the Laspeyres price index is 98 (it is understood that this is a percentage). Therefore, the cost of the hamburger ingredients at t_1 was 2 percent lower than in the base period. ■

Governments compile many Laspeyres price indexes. The consumer price index (CPI) is a Laspeyres price index in which the weights are the shares of urban consumers' budgets in the base year. Another well-known Laspeyres price index is the gross national product (GNP) deflator. For the GNP deflator, the weights are the shares of total output in the base year.

The CPI and the GNP deflator are global indexes in that they represent an economy-wide set of prices. As well, Laspeyres price indexes can be calculated by sector. For example, there are price indexes for durable consumer goods, for exports, and for investment by businesses. It is up to the analyst to know the composition of the different indexes and to decide which is best for his or her purposes.

EXAMPLE 9A.2

We can classify consumer goods and services into four classes: durable goods, semi-durable goods, non-durable goods, and services. Assume the classes had the following prices in 2005 and 2012:

	Price (\$)	
Category	**2005**	**2012**
Durable	2.421	2.818
Semi-durable	2.849	3.715
Non-durable	4.926	6.404
Services	4.608	6.263

Quantities in 2005 were

Quantity in 2005 (Units)	
Durable	21.304
Semi-durable	11.315
Non-durable	19.159
Services	31.422

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Find the Laspeyres price index for 2012 with 2005 as a base. We first calculate the relative prices:

	Price ($)		
Category	2005	2012	Relative Price
Durable	2.421	2.818	1.164
Semi-durable	2.849	3.715	1.304
Non-durable	4.926	6.404	1.300
Services	4.608	6.263	1.359

We next determine expenditure shares in 2005:

Category	Expenditure	Share
Durable	51.583	0.1597
Semi-durable	32.235	0.0998
Non-durable	94.381	0.2922
Services	144.801	0.4483
Total	323.000	

We then multiply the relative prices by the shares and sum. We get the index by multiplying the sum by 100. For example, the term for durable goods is given by 1.164(0.1597) = 0.186.

	Index
Durable	0.186
Semi-durable	0.130
Non-durable	0.380
Services	0.609
Total	1.305

This gives a Laspeyres price index of 130.5. ■

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CHAPTER 10

Dealing With Uncertain and Risk

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ENGINEERING ECONOMICS IN ACTION, PART 10A

Trees from Another Planet

Bill Astad and Naomi were working through the market demand figures provided by Powerluxe for the new Adaptamatic vacuum. They had to determine if the project was really going to be viable and make money for Canadian Widgets.

"These figures are pretty ambiguous," Bill said. "We have three approaches: a set of opinions taken from focus groups and surveys of customers, the same thing from dealers and distributors, and an analysis of trends in a set of parallel products such as fuzzy-logic appliances." Marketing was Bill's area of expertise, so Naomi was listening carefully.

"What we should do," Bill continued, "is come up with three scenarios: low demand, expected demand, and high demand. If we behave according to expected demand and the true demand is low, we will lose money because our capital investments won't be recouped as fast and we may have passed up other opportunities. Similarly, if the demand is high, we will lose by having to pay overtime, paying for contracting out, or dropping customers. But if we make money in all three cases, there really isn't much of a problem."

Naomi nodded. "But we also might have the Erie Gadget competitive product. That's going to mess things up too."

"Yeah, that's right," Bill replied, a bit gloomily. "We've got to get this sorted out soon—this is on the critical path!" Bill was showing off with this last statement, so Naomi gave him the smile he expected, but his point was real. They had to figure out quickly if there was a real opportunity for Canadian Widgets. Everything else was waiting for this.

"I think we can do this, Bill. The key word is *trees*."

Bill looked at Naomi as if she were from another planet. "Trees! Trees?"

10.1 Introduction

To this point in our coverage of engineering economics, we have assumed that project parameters such as prices, interest rates, and the magnitude and timing of cash flows have values that are known with certainty. In fact, many of these values are estimates and are subject to some uncertainty. Since the results of an evaluation can be influenced by variations in uncertain parameters, it is important to know how *sensitive* the outcome is to variations in these parameters.

There are several reasons why there may be uncertainty in estimating project parameter values. Technological change can unexpectedly shorten the life of a product or piece of equipment. A change in the number of competing firms may affect sales volume or market share or the life of a product. In addition, the general economic environment may affect inflation and interest rates and overall activity levels within an industry. All these factors may result in cash flows different from what was expected in both timing and size, or in other changes to the parameters of an evaluation.

Making decisions under uncertainty is challenging because the overall impact of uncertainty on project evaluation may initially not be well understood. **Sensitivity analysis** is an approach to project evaluation that can be used to gain a better understanding of how uncertainty affects the outcome of the evaluation by examining how sensitive the outcome is to changes in the uncertain parameters. It can help an engineer decide whether it is worthwhile to get more accurate data as part of a more detailed evaluation, or whether it may be necessary to control or limit project uncertainties. Sometimes we

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have enough information to characterize uncertain outcomes according to their chance or likelihood. This converts a problem from one of uncertainty to one of *risk*.

Decisions made under risk are those where the analyst can characterize a possible range of future outcomes and has available an estimate of the probability of each outcome. The term *risk* is also often used to refer to the probability distribution of outcomes associated with a project, or the probability of an undesirable outcome (this last definition of risk is not utilized in this text, although it is commonly used in the financial literature). Knowledge of the probability distribution of outcomes often permits us to draw more authoritative conclusions than we can draw using sensitivity analysis alone.

Economic analyses are not complete unless we try to assess the potential effects of project uncertainties on the outcomes of the evaluations. Because parameter estimates can be so hard to determine, analysts usually consider a range of possible values for uncertain components of a project. There is then naturally a range of values for present worth, annual worth, or whatever the relevant performance measure is. In this way, the analyst can get a better understanding of the range of possible outcomes and can make better decisions.

In this chapter, we will first look at the use of *sensitivity graphs*. Sensitivity graphs illustrate the sensitivity of a particular measure (e.g., present worth or annual worth) to one-at-a-time changes in the uncertain parameters of a project. Sensitivity graphs can reveal key parameters that have a significant impact on the performance measures of interest, and hence we should be particularly careful to get good estimates for these key parameters.

Next, in order to understand risk, we review some of the basic principles of probability. This allows us to introduce *decision trees*. Decision trees allow probabilistic information about the outcomes of a decision to be structured so that the best choice can be made.

Sensitivity graphs and decision trees are tools that allow us to enrich an economic analysis to help deal with the uncertainties and risks of the real world. However, they are simply two of a large number of methods, each with its own strengths and weaknesses. A good economic analysis should include a method of dealing with uncertainty and risk that is appropriate to the specifics of that particular problem.

10.2 Sensitivity Graphs

Sensitivity graphs are used to assess the effect of one-at-a-time changes in key parameter values of a project on an economic performance measure. We usually begin with a "base case" where all the estimated parameter values are used to evaluate the present worth, annual worth, or IRR of a project, whatever the appropriate measure is. We then vary parameters above and below the base case one at a time, *holding all other parameters fixed*. A graph of the changes in a performance measure brought about by these one-at-a-time parameter changes is called a **sensitivity graph**. From the graph, the analyst can see which parameters have a significant impact on the performance measure and which do not.

EXAMPLE 10.1

Cogenesis Corporation is replacing its current steam plant with a six-megawatt cogeneration plant that will produce both steam and electric power for operations. The new plant will use wood as a source of fuel, which will eliminate the need for Cogenesis to purchase a large amount of electric power from a public utility. To move to the new system, Cogenesis will have to integrate a new turbogenerator and cooling tower with

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its current system. The estimated first cost of the equipment and installation is \$3 000 000, though there is some uncertainty surrounding this estimate. The plant is expected to have a 20-year life and no scrap value at the end of this life. In addition to the first cost, the turbogenerator will require an overhaul with an estimated cost of \$35 000 at the end of years 4, 8, 12, and 16. The cooling tower will need an overhaul at the end of 10 years. This is expected to cost \$17 000.

The cogeneration system is expected to have higher annual operating and maintenance costs than the current system, and will require the use of chemicals to treat the water used in the new plant. These incremental costs are estimated to be \$65 000 per year. The incremental annual costs of wood fuel are estimated to be \$375 000. The cogeneration plant will save Cogenesis from having to purchase 40 000 000 kilowatt-hours of electricity per year at \$0.025 per kilowatt-hour, an annual savings of \$1 000 000. Cogenesis uses a MARR of 12 percent. What is the present worth of the incremental investment in the cogeneration plant? What is the impact of a 5 percent and 10 percent increase and decrease in each of the parameters of the problem?

$$\begin{aligned}
&\text{PW(cogeneration plant)}\\
&\quad = -3\,000\,000 - (65\,000 + 375\,000 - 1\,000\,000)\,(P/A,12\%,20)\\
&\qquad - 17\,000(P/F,12\%,10)\\
&\qquad - 35\,000[(P/F,12\%,4) + (P/F,12\%,8) + (P/F,12\%,12)\\
&\qquad + (P/F,12\%,16)]\\
&\quad = 1\,126\,343
\end{aligned}$$

The present worth of the incremental investment is \$1 126 343. On the basis of this assessment, the project appears to be economically viable.

In order to better understand the situation, analysts for Cogenesis have also completed some sensitivity graphs that indicate how sensitive the present worth is to changes in some of the parameters. In particular, they feel that some of the cash flows may turn out to be different from their estimates, and they would like to get a feel for what impact these errors may have on the evaluation of the cogeneration plant. To investigate, they have labelled their current estimates the "base case" and have generated other cash flow estimates that are 5 percent and 10 percent above and below the base case for each major cash flow category. These are summarized in Table 10.1.

For example, the initial investment may be more than the estimate of \$3 000 000 if the company runs into unforeseen difficulties in the installation. Or the savings in electricity costs may be overestimated if the cost per kilowatt-hour drops in the future. The analysts would like to get a better understanding of which of these changes would have the greatest impact on the evaluation of the plant.

To keep the illustration simple, we will consider changes to the initial investment; annual chemical, operations, and maintenance costs; the MARR; and the savings in electrical costs. Each of these is varied one at a time, leaving all other cash flow estimates at the base case values. For example, if the initial investment is 10 percent below the initial estimate of \$3 000 000, and all other estimates are as in the base case, the present worth of the project will be \$1 426 343 (see the first row of Table 10.2, under –10 percent). Similarly, if the first cost is 10 percent more than the original estimate, the present worth drops to \$826 343.

Interest rate uncertainty will almost always be present in an economic analysis. If Cogenesis's MARR increases by 10 percent (with all other parameters at their base case values), the present worth of the project drops to \$835 115, about the same impact as if the first cost ended up being 10 percent more than expected. Other variations are shown in

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Table 10.1 Summary Data for Example 10.1

Cost Category	−10%	−5%	Base Case	+5%	+10%
Initial investment	$2 700 000	$2 850 000	$3 000 000	$3 150 000	$3 300 000
Annual chemical, operations, and maintenance costs	58 500	61 750	65 000	68 250	71 500
Cooling tower overhaul (after 10 years)	15 300	16 150	17 000	17 850	18 700
Turbogenerator overhauls (after 4, 8, 12, and 16 years)	31 500	33 250	35 000	36 750	38 500
Annual wood costs	337 500	356 250	375 000	393 750	412 500
Annual savings in electricity costs	900 000	950 000	1 000 000	1 050 000	1 100 000
MARR	0.108	0.114	0.12	0.126	0.132

Table 10.2. A sensitivity graph, shown in Figure 10.1, illustrates the impact of one-at-a-time parameter variations on the present worth.

Small changes in the annual chemical, operations, and maintenance costs do not have much of an impact on the present worth of the project, as can be seen from Table 10.2 and Figure 10.1. What appears to have the greatest impact on the viability of the project is the savings in electricity costs. A 10 percent drop in the savings causes the present worth of the project to drop to about one-third of the base case estimate. This change could occur because of a drop in electricity rates or a drop in demand.

Table 10.2 Present Worth of Variations from Base Case in Example 10.1

Cost Category	−10%	−5%	Base Case	+5%	+10%
Initial investment	$1 426 343	$1 276 343	$1 126 343	$ 976 343	$ 826 343
Annual chemical, operations, and maintenance costs	1 174 894	1 150 619	1 126 343	1 102 067	1 077 792
Cooling tower overhaul (after 10 years)	1 126 890	1 126 617	1 126 343	1 126 069	1 125 796
Turbogenerator overhauls (after 4, 8, 12, and 16 years)	1 131 450	1 128 897	1 126 343	1 123 789	1 121 236
Annual wood costs	1 406 447	1 266 395	1 126 343	986 291	846 239
Savings in electricity costs	379 399	752 871	1 126 343	1 499 815	1 873 287
MARR	1 456 693	1 286 224	1 126 343	976 224	835 115

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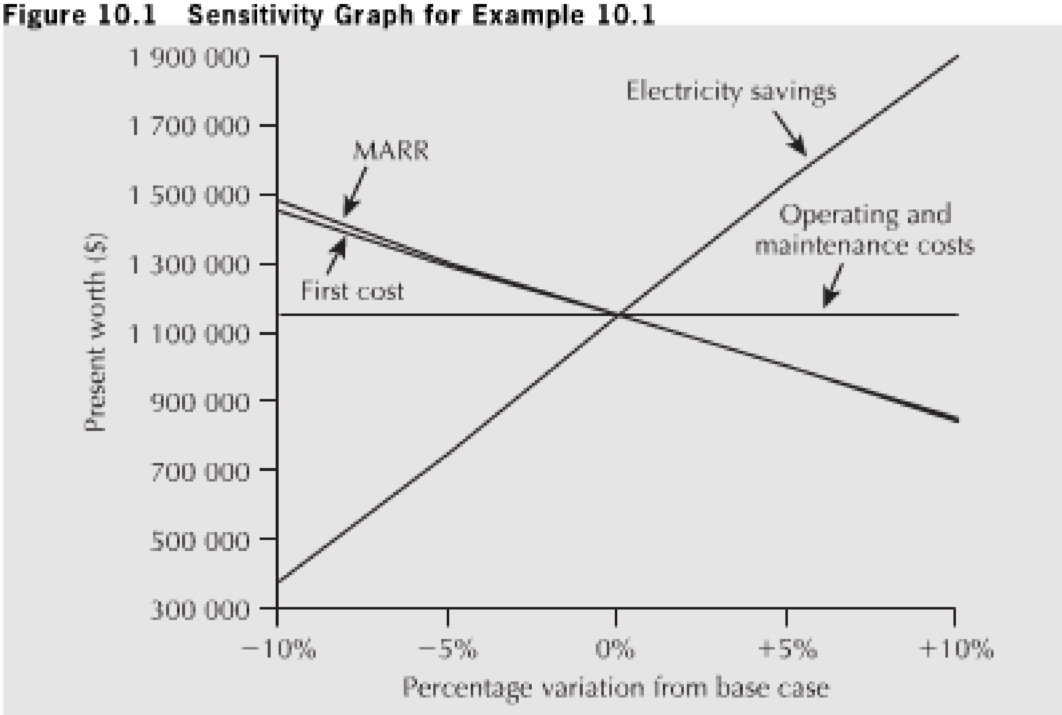
Figure 10.1 Sensitivity Graph for Example 10.1



Alternatively, the present worth of the project increases to almost $1 900 000 if the savings are higher than anticipated. This could, once again, occur because of a change in either rates or demand for power. Clearly, if Cogenesis is to expend effort in getting better forecasts, it should be for energy consumption and power rates.

One final point about this example should be noted. If management feels that, individually, the cash flow estimates will fall within the ±10 percent range, the investment looks economically viable (i.e., yields a positive present worth) and the company should go ahead with it. ■

As we can see from Example 10.1, the benefit of a sensitivity graph is that it can be used to select key parameters in an economic analysis. It is easy to understand and communicates a lot of information in a single diagram. There are, however, several shortcomings of sensitivity graphs. First, they are valid only over the range of parameter values in the graph. The impact of parameter variations outside the range considered may not be simply a linear extrapolation of the lines in the graph. If you need to assess the impact of greater variations, the computations should be redone. Second, and probably the greatest drawback of sensitivity graphs, is that they do not consider the possible interaction between two or more parameters. You cannot simply "add up" the impacts of individual changes when several parameters are varied, producing an interaction effect.

10.3 Break-Even Analysis

In this section, we cover a second type of sensitivity analysis called break-even analysis. Once again, we are trying to answer the question of what impact changes (or errors) in parameter estimates will have on the economic performance measures we use in our analyses, or on a decision made on the basis of an economic performance measure. In general, **break-even analysis** is the process of varying a parameter of a problem and determining what parameter value causes the performance measure to reach some threshold or "break-even" value. In Example 10.1, we saw that an increase in the MARR

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caused the present worth of the cogeneration plant to decrease. If the MARR were to increase sufficiently, the project might have a zero present worth. A break-even analysis could answer the question "What MARR will result in a zero present worth?" This analysis would be particularly useful if Cogenesis were uncertain about the MARR and wanted to find a threshold MARR above which the project would not be viable. Other such break-even questions could be posed for the cogeneration problem to try to get a better understanding of the impact of changes in parameter values on the economic analysis.

Break-even analysis can also be used in the comparison of two or more projects. We have already seen in Chapter 5 that the best choice among mutually exclusive alternatives may depend on the interest rate, the production level, or a variety of other problem parameters. Break-even analysis applied to multiple projects can answer questions like "Over what range of interest rates is project A the best choice?" or "For what output level are we indifferent between two projects?" Notice that we are varying a single parameter in two or more projects and asking when the performance measure for the projects meets some threshold or break-even point. The point of doing this analysis is to try to get a better understanding of how sensitive a decision is to changes in the parameters of the problem.

10.3.1 Break-Even Analysis for a Single Project

In this section, we show how break-even analysis can be applied to a single project to illustrate how sensitive a project evaluation is to changes in project parameters. We will continue with Example 10.1 to expand upon the information provided by the sensitivity graphs.

EXAMPLE 10.2

Having completed the sensitivity graph in Example 10.1, management recognizes that the present worth of the cogeneration plant is quite sensitive to the savings in electricity costs, the MARR, and the initial costs. Since there is some uncertainty about these estimates, the company wants to explore further the impact of changes in these parameters on the viability of the project. You are to carry out a break-even analysis for each of these parameters to find out what range of values results in a viable project (i.e., PW > 0) and to determine the "break-even" parameter values that make the present worth of the project zero. You are also to construct a graph to illustrate the present worth of the project as a function of each parameter.

First, Figure 10.2 shows the present worth of the project as a function of the MARR. It shows that the break-even MARR is 17.73 percent. In other words, the project has a positive present worth for any MARR less than 17.73 percent (all other parameters fixed) and a negative present worth for a MARR more than 17.73 percent. Notice that the break-even interest rate is, in fact, the IRR for the project.

A similar break-even chart for the first cost, Figure 10.3, shows that the first cost can be as high as $4 126 350 before the present worth declines to zero. Assuming that all other cost estimates are accurate, the project will be viable as long as the first cost is below this break-even amount. One issue management should assess is the likelihood that the first cost will exceed $4 126 350.

Finally, a break-even chart for the savings in electrical power costs is shown in Figure 10.4. We have already seen from the sensitivity graph that the viability of the project is very sensitive to the savings in electricity produced by the cogeneration plant.

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Figure 10.2 Break-Even Chart for the MARR

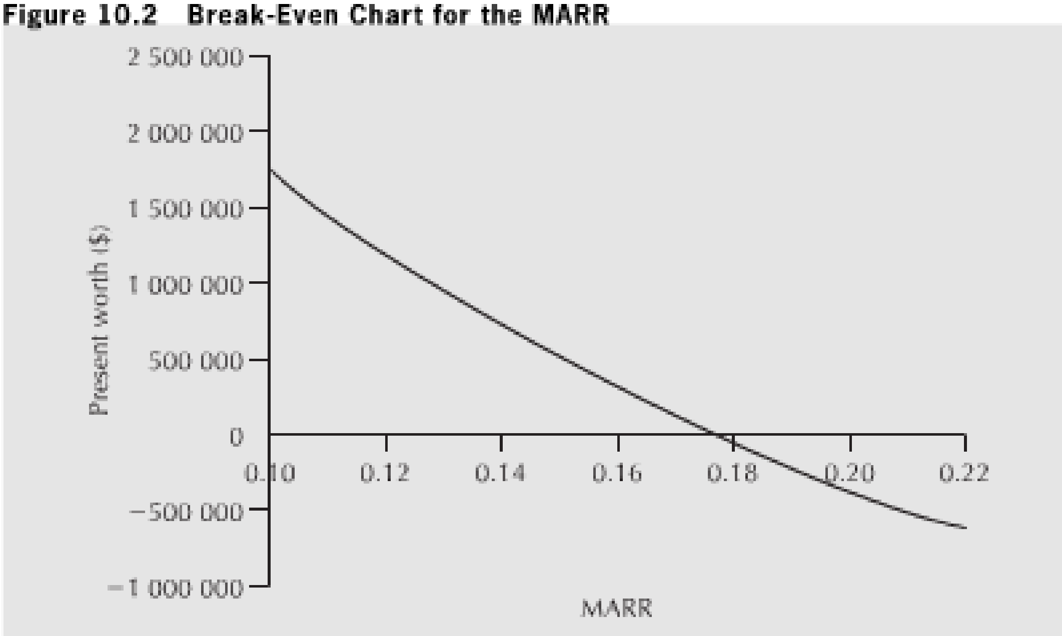


Figure 10.3 Break-Even Chart for First Cost

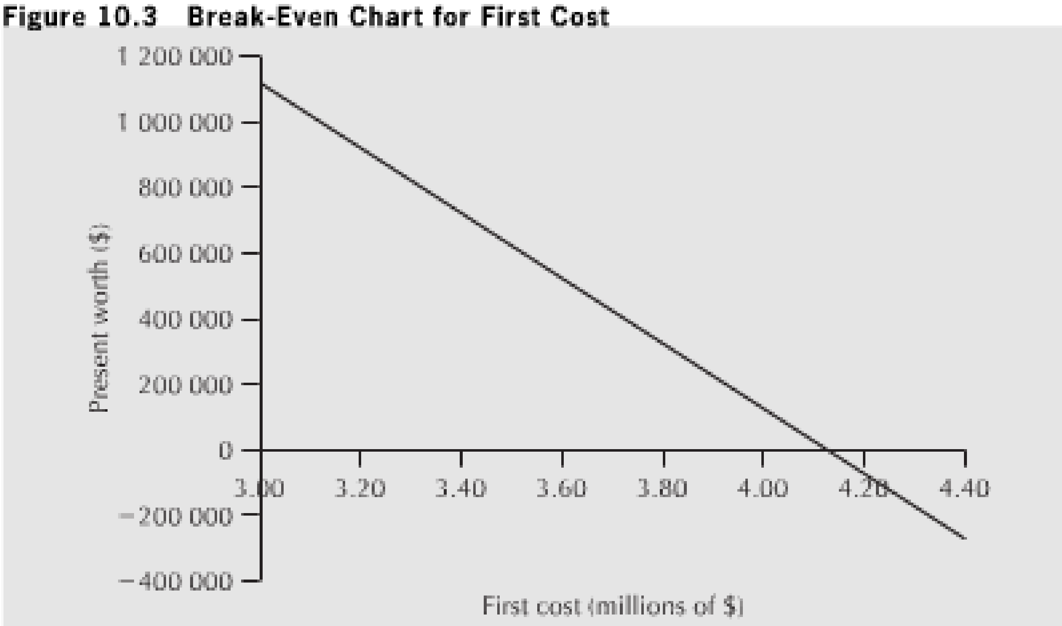
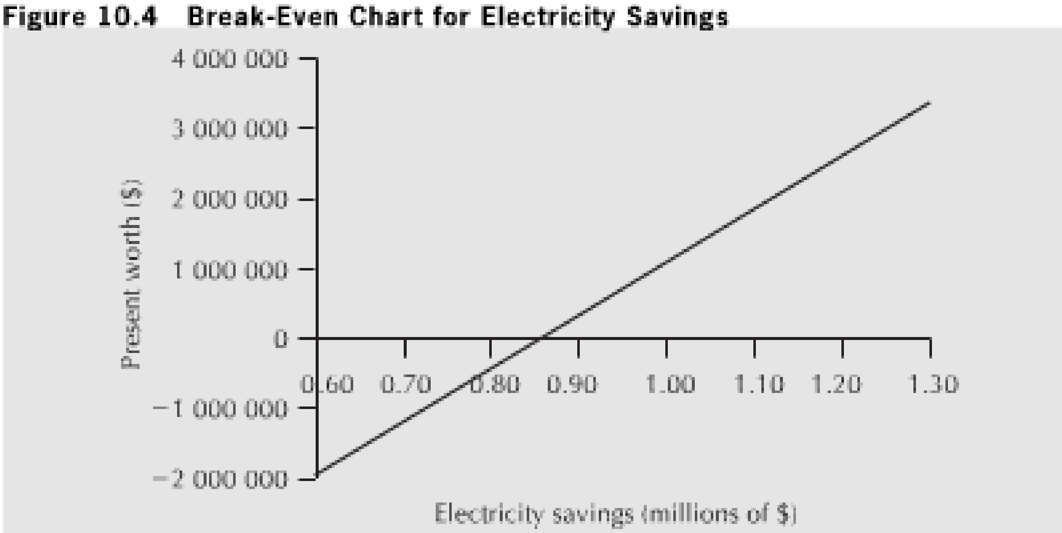


Figure 10.4 Break-Even Chart for Electricity Savings



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Provided that the annual savings are above \$849 207, the project is viable. Below this break-even level, the present worth of the project is negative. If the actual saving in electrical power costs is likely to be much below the estimate, this will put the project's viability at risk. Given the particular sensitivity of the present worth to the savings, it may be worthwhile to spend additional time looking into the two factors that make up these savings: the cost per kilowatt-hour and the total kilowatt-hours of demand provided for by the new plant. ■

Break-even analysis done for a single project expands upon the information that sensitivity graphs provide. It has the advantage that it is easy to apply and allows us to determine the range of values for a parameter within which the project is viable or some other criteria are met. It can provide us with break-even parameter values that give an indication of how much a parameter can change from its original estimate before the project's viability becomes a concern. Graphical presentation of the break-even analysis, as in Figures 10.2, 10.3, and 10.4, summarizes the information in an easily understood way.

10.3.2 Break-Even Analysis for Multiple Projects

In the previous section, we saw how break-even analysis can be applied to a single project in order to understand more clearly the impact of changes in parameter values on the evaluation of the project. This analysis may influence a decision on whether the project should be undertaken. When there is a choice among several projects, be they independent or mutually exclusive, the basic question remains the same. We are concerned with the impact that changes in problem parameters have on the relevant economic performance measure, and, ultimately, on the decision made with respect to the projects. With one project, we are concerned with whether the project should be undertaken and how changes in parameter values affect this decision. With multiple projects, we are concerned about how changes in parameter values affect which project or projects are chosen.

For multiple independent projects, assuming that there are sufficient funds to finance all projects, break-even analysis can be carried out on each project independently, as was done for a single project in the previous section. This will lead to insights into how robust a decision is under changes in the parameters.

For mutually exclusive projects, the best choice will seldom stand out as clearly superior from all points of view. Even if we have narrowed down the choices, it is still likely that the best choice may depend on a particular interest rate, level of output, or first cost. A break-even comparison can reveal the range over which each alternative is preferred and can show the break-even points where we are indifferent between two projects. Break-even analysis will provide a decision maker with further information about each of the projects and how they relate to one another when parameters change.

EXAMPLE 10.3

Westmount Waxworks (see Problem 5.26 on page 189) is considering buying a new wax melter for its line of replicas of statues of government leaders. Westmount has two choices of suppliers: Finedetail and Simplicity. The proposals are as follows:

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	Finedetail Wax Melter	Simplicity Wax Melter
Expected life	7 years	10 years
First cost	$200 000	$350 000
Maintenance	$10 000/year + $0.05/unit	$20 000/year + $0.01/unit
Labour	$1.25/unit	$0.50/unit
Other costs	$6 500/year + $0.95/unit	$15 500/year + $0.55/unit
Salvage value	$5 000	$20 000

The marketing manager has indicated that sales have averaged 50 000 units per year over the past five years. In addition to this information, management thinks that it will sell about 30 000 replicas per year if there is stability in world governments. If the world becomes very unsettled so that there are frequent overturns of governments, sales may be as high as 200 000 units per year. There is also some uncertainty about the "other costs" of the Simplicity wax melter. These include energy costs and an allowance for scrap. Though the costs are estimated to be $0.55 per unit, the Simplicity model is a new technology, and the costs may be as low as $0.45 per unit or as high as $0.75 per unit. Westmount Waxworks would like to carry out a break-even analysis on the sales volume and on the "other costs" of the Simplicity wax melter. It wants to know which the preferred supplier would be as sales vary from 30 000 per year to 200 000 per year. The company also wishes to know which is the preferred supplier if the "other costs" per unit for the Simplicity model are as low as $0.45 per unit or as high as $0.75 per unit. Westmount Waxworks uses an after-tax MARR of 15 percent for equipment projects. It pays taxes in Canada with a tax rate of 40 percent. The CCA rate for such equipment is 30 percent.

Assuming that the "other costs" of the Simplicity wax melter are $0.55 per unit, a break-even chart that shows the present worth of the projects as a function of sales levels can give much insight into the supplier selection. Table 10.3 gives the annual cost of each of the two alternatives, and Figure 10.5 shows the break-even chart for sales level.

A sample computation for the Finedetail wax melter at the 60 000 sales level is

$$\begin{aligned}
\text{AW(Finedetail)} &= \text{CTF}(200\,000)(A/P,15\%,7) \\
&\quad - \text{CSF}(5000)(A/F,15\%,7) \\
&\quad + (1 - t)[10\,000 + 6500 + (0.05 + 1.25 + 0.95)(\text{sales level})] \\
&= 0.75073(200\,000)(0.24036) - 0.73333(5000)(0.09036) \\
&\quad + (1 - 0.4)[16\,500 + 2.25(60\,000)] \\
&= \$126\,658
\end{aligned}$$

where

$$\text{CSF} = 1 - \frac{td}{(i+d)} = 1 - \frac{(0.4)(0.3)}{(0.15 + 0.30)} = 0.73333$$

$$\text{CTF} = 1 - \frac{td(1 + \frac{i}{2})}{(i+d)(1+i)} = 1 - \frac{(0.4)(0.3)(1 + 0.075)}{(0.15 + 0.30)(1 + 0.15)} = 0.75073$$

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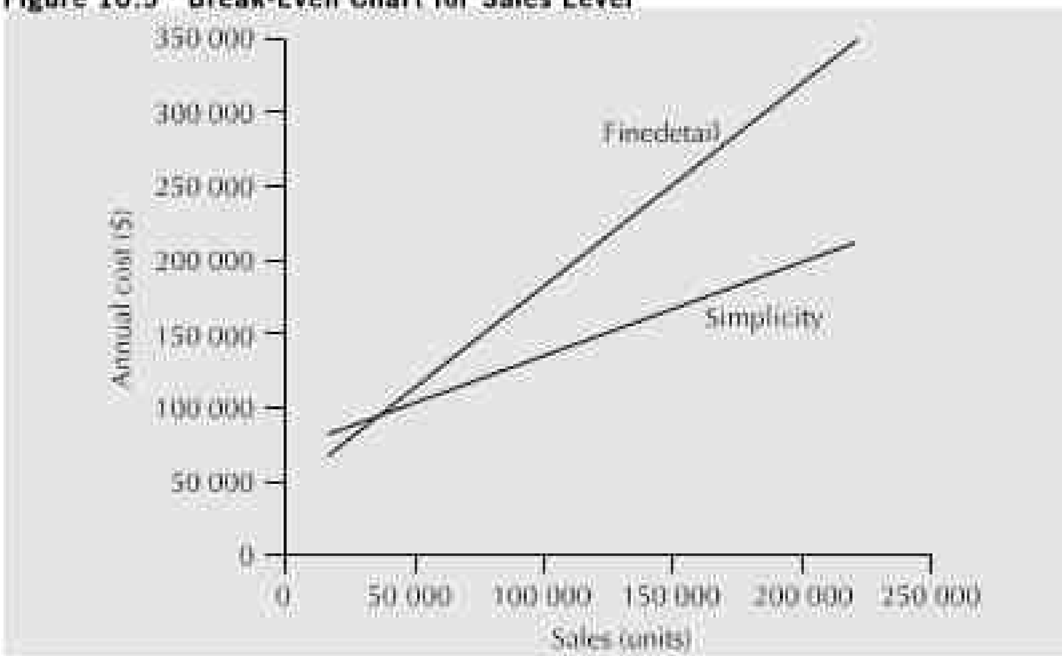
Table 10.3 Annual Cost as a Function of Sales

Sales (Units)	Annual Costs ($) Finedetail	Simplicity
20 000	72 658	85 651
60 000	126 658	111 091
100 000	180 658	136 531
140 000	234 658	161 971
180 000	288 658	187 411
220 000	342 658	212 851

Figure 10.5 Break-Even Chart for Sales Level



If sales are 30 000 units per year, the Finedetail wax melter is slightly preferred to the Simplicity melter. At a sales level of 200 000 units per year, the preference is for the Simplicity wax melter. Interpolation of the amounts in Table 10.3 indicates that the break-even sales level is 38 199 units. That is to say, for sales below 38 199 per year, Finedetail is preferred; and Simplicity is preferred for sales levels of 38 199 units and above.

Since 30 000 units per year is the lowest sales will likely be, and sales have averaged 50 000 units per year over the past five years, it appears that the Simplicity wax melter would be the preferred choice, assuming that its "other costs" per unit are $0.55. The robustness of this decision may be affected by the other types of costs, such as maintenance and labour, of the Simplicity melter.

To assess the sensitivity of the choice of wax melter to the variable other costs of Simplicity, a break-even analysis similar to that for sales level can be carried out. We can vary the "other costs" from the estimate of $0.45 per unit to $0.75 per unit and observe the effect on the preferred wax melter. Table 10.4 gives the annual costs for the two wax melters as a function of the "other costs" of the Simplicity model for sales levels of 30 000, 50 000, and 200 000 units per year. In each case, we see that the best choice is not sensitive to the "other costs" of the Simplicity wax melter. In fact, for a sales level of 30 000 units

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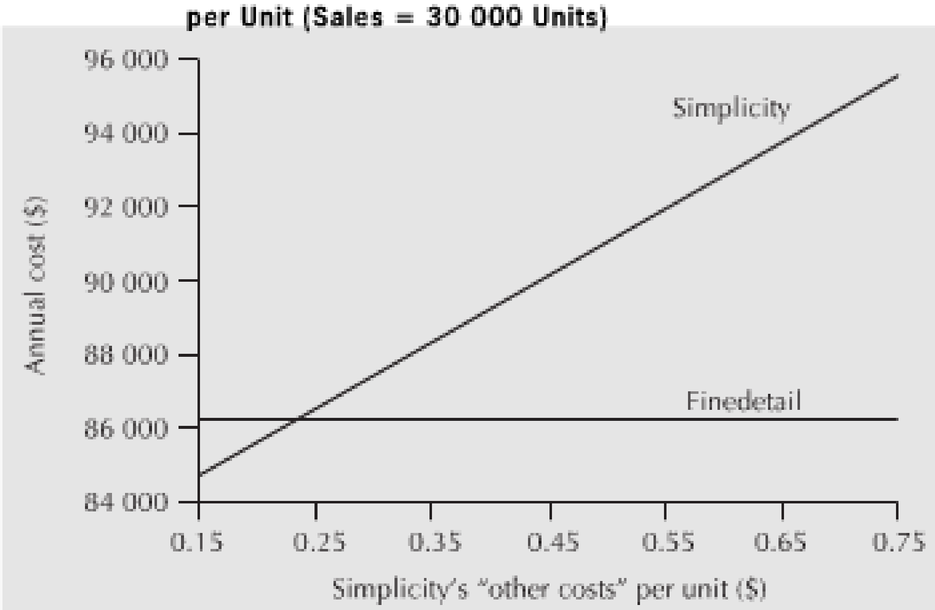
Table 10.4 Annual Cost as a Function of Simplicity's Other Costs per Unit

Other Costs per Unit ($)	Sales = 30 000 Units/Year Annual Costs ($) Finedetail	Sales = 30 000 Units/Year Annual Costs ($) Simplicity	Sales = 50 000 Units/Year Annual Costs ($) Finedetail	Sales = 50 000 Units/Year Annual Costs ($) Simplicity	Sales = 200 000 Units/Year Annual Costs ($) Finedetail	Sales = 200 000 Units/Year Annual Costs ($) Simplicity
0.45	86 158	90 211	113 158	101 731	315 658	188 131
0.55	86 158	92 011	113 158	104 731	315 658	200 131
0.65	86 158	93 811	113 158	107 731	315 658	212 131
0.75	86 158	95 611	113 158	110 731	315 658	224 131

per year, the break-even "other costs" are less than \$0.25, as shown in Figure 10.6. This means that the other costs per unit would have to be lower than \$0.25 for the best choice to change from Finedetail to Simplicity. For a sales level of 200 000 per year, the break-even "other costs" are much higher, at \$1.51 per unit, and for a sales level of 50 000 units per year the break-even cost per unit is \$0.83. For both of the latter sales levels, the Simplicity model is preferred.

Figure 10.6 Break-Even Chart for Simplicity's Other Costs per Unit (Sales = 30 000 Units)



Having done the break-even analysis for both sales level and "other costs" per unit for the Simplicity wax melter, it would appear that the Simplicity model is the better choice if sales are at all likely to exceed the break-even sales level of 38 199. Historically, sales have exceeded this amount. Even if sales in a particular year fall below the break-even level, the Simplicity wax melter does not have annual costs far in excess of those of the Finedetail model, so the decision would appear to be robust with respect to possible sales levels. Similarly, the decision is not sensitive to the other costs per unit of the Simplicity wax melter. ■

We have seen in this section that break-even analysis for either a single project or multiple projects is a simple tool and that it can be used to extract insights from a

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modest amount of data. It communicates threshold (break-even) parameter values where preference changes from one alternative to another or where a project changes from being economically justified to not justified. Break-even analysis is a popular means of assessing the impact of errors or changes in parameter values on an economic performance measure or a decision. The main disadvantage of break-even analysis is that it cannot easily capture interdependencies among variables. Although we can vary one or two parameters at a time and graph the results, more complicated analyses are not often feasible. For example, an engineer may wish to incorporate into the analysis the impact of several outcomes for uncertain future events.

One tool used by engineers to structure and make decisions when the alternatives involve risk is a decision tree. A decision tree decomposes a problem clearly into its decision alternatives and uncertain events. Before we introduce the use of decision trees, though, we need to review some basic concepts of probability.

10.4 Basic Concepts of Probability

Suppose you are concerned with the market success of a new fuel-cell technology, but you are uncertain about its outcome. It could be that the fuel cell fails to gain market acceptance, it may produce adequate sales, or it could gain market dominance. In the terminology of decision analysis, "market success" is referred to as a *random variable*. A **random variable** is a parameter or variable that can take on a number of possible outcomes. Only one of these outcomes will eventually occur, but which one will occur is unknown at the time a decision is being made. For example, if market success is considered to be a random variable, then the set of possible outcomes are failure to gain market acceptance, adequate sales, or market dominance. To construct a model of this uncertainty, you will need to know the probability associated with each possible outcome. This is accomplished through a probability distribution function.

Consider a random variable X (e.g., the market success of a fuel cell) that can take on m discrete outcomes $x_1, x_2, \ldots, x_m$. If these events are mutually exclusive (if one occurs, another cannot) and collectively exhaustive (one of them must occur), a **probability distribution function** $p(x)$ is a set of numerical measures $p(x_i)$ such that:

$$0 \le p(x_i) \le 1 \quad \text{for } i = 1, \ldots, m$$

and

$$\sum_{i=1}^{m} p(x_i) = 1$$

with the intuitive interpretation that the higher $p(x_i)$, the more likely it is that x_i will occur.

The first statement above says that the **probability** associated with each outcome must be positive and must be between 0 and 1 (inclusive). Intuitively, this means that any outcome cannot have a chance of occurring less than 0 percent or more than 100 percent. The second statement above says that since the outcomes are mutually exclusive and collectively exhaustive, only one of the outcomes will occur, and one *must* occur.

Over the years, various views on probability have emerged. Each is appropriate in different circumstances. Close-Up 10.1 summarizes different views on probability and when they are useful.

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CLOSE-UP 10.1 Views on Probability

Classical or symmetric probability: This was the first view of probability and relies on games of chance such as dice, where the outcomes are equally likely. For example, if there are m possible outcomes for an uncertain event, since only one can and must occur, and each is assumed to be equally likely, then the chance of each occurring is $1/m$. For example, the probability that a coin toss will result in "heads" is 1/2 because there are two sides and each is equally likely.

Relative frequency: The outcome of an random event E is observed over a large number of experiments, N. If the number of times the outcome e_i occurs is n_i, then we can estimate the probability of event $p(e_i)$ by n_i/N. More formally, the relative frequency view on probability says that $p(e_i) = \lim_{N \to \infty} n_i / N$. An example of this is flipping a coin 1000 times and discovering that it lands on its edge five times in 1000. An estimate of the probability of the coin landing on its edge is then 5/1000 = 0.005.

Subjective probability: Subjective or personal probability is an attempt to deal with unique events that cannot be repeated and hence can't be given a frequency interpretation. In rough terms, subjective probability can be interpreted as the odds one would personally give in betting on an event, or it may be a matter of human judgment and intuition as formed by physical relationships and experimental results. An example of this is a person who judges that the chance of winning a coin toss with one of the authors of this text is very low, say 1/1000, because, in that person's experience, the authors usually cheat.

Axiomatic probability: One of the problems associated with defining probabilities is that the definition of probability requires using probability itself. To get around this circular logic, axiomatic probability makes no attempt to define probability, but simply states the rules or axioms it follows. Other properties can then be derived from the basic axioms.

Each of the above methods may be correct, given the circumstances. When the physics of a process suggest a clear judgment of probability, the classical approach makes sense. Where formal experimentation is possible, the relative frequency method may be justified. In many real-world cases, subjective probability supported by historical information and other data is frequently used.

When the number of outcomes for a random variable X is discrete, $p(x)$ is referred to as a **discrete probability distribution function** (PDF). Examples of discrete random variables are the number of good items in a batch of 100 tested products, the number of car accidents at an intersection each year, the number of days since the last plant shutdown, or the number of bugs found in software testing. Whether $p(x)$ is estimated using the classical, the relative frequency, or the subjective approach, the same terminology for the probability distribution function, $p(x)$, is used.

Various symbols may be used to define a random variable. The normal convention is to capitalize the symbol used for the random variable, and to use subscript lowercase letters to denote its various outcomes. For example, for a discrete random variable X, outcomes are denoted by $x_1, x_2, x_3, \ldots$ and its probability distribution function is $p(x)$. The probability that X takes on the value x_1 is written as $\Pr(X = x_1) = p(x_1)$.

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EXAMPLE 10.4

Suppose that you are testing solder joints on a printed circuit board and that you are interested in determining the probability distribution function for the random variable X—the number of open joints in three tested joints (to keep it simple). Prior to testing, you don't know how many open joints there will be. Since there are three joints and each will be either open or closed, X is a discrete random variable that can take on four possible values: $x_1 = 0$, $x_2 = 1$, $x_3 = 2$, and $x_4 = 3$.

Note that there are eight distinct test result sequences that can occur. Denoting the result of a single test with O for open and C for closed, the set of possible test results are (O,O,O), (O,O,C), (O,C,O), (C,O,O), (O,C,C), (C,C,O), (C,O,C), and (C,C,C). We must look through the set of individual test results to see which corresponds to $x_1 = 0$, $x_2 = 1$, $x_3 = 2$, and $x_4 = 3$ open solder joints.

You know from previous data collection efforts that the result of a single test is uncertain. The probability that a single tested joint will be open is 20 percent. In other words, the outcome of the test is a random variable, say, Y, where the result of a single test can have two outcomes: $y_1 = \text{O} = \text{open}$ and $y_2 = \text{C} = \text{closed}$, and $\Pr(Y = \text{O}) = p(\text{O}) = 0.2$ and $\Pr(Y = C) = p(C) = 0.8$. Further, suppose it is reasonable to assume that the quality of a solder joint does not change from joint to joint (i.e., the test results are independent of one another). Then the probability that a test sequence results in three open joints is calculated by

$$\Pr(X = 3) = p(x_4) = p(\text{O}) \times p(O) \times p(\text{O}) = (0.2) \times (0.2) \times (0.2) = 0.008$$

Similar calculations, shown in Table 10.5, yield the probabilities for each of the eight possible test sequences.

Finally, the probability distribution function of X, the number of "open" joints in the three tests, is

$$\Pr(X = 0) = p(x_1) = 0.512$$
$$\Pr(X = 1) = p(x_2) = 0.384$$
$$\Pr(X = 2) = p(x_3) = 0.096$$
$$\Pr(X = 3) = p(x_4) = 0.008$$

Note that the two important properties of probabilities hold: $p(x_i) \geq 0$ for all i, and $\sum p(x_i) = 1$.

Table 10.5 Probability Corresponding to the Outcomes of the Solder Joint Testing With a 20% Chance of an Open Joint

Test Sequence	Number of "Opens"	Probability
(O,O,O)	3	$0.008 = 0.2 \times 0.2 \times 0.2$
(O,O,C)	2	$0.032 = 0.2 \times 0.2 \times 0.8$
(O,C,O)	2	$0.032 = 0.2 \times 0.8 \times 0.2$
(C,O,O)	2	$0.032 = 0.8 \times 0.2 \times 0.2$
(O,C,C)	1	$0.128 = 0.2 \times 0.8 \times 0.8$
(C,C,O)	1	$0.128 = 0.8 \times 0.8 \times 0.2$
(C,O,C)	1	$0.128 = 0.8 \times 0.2 \times 0.8$
(C,C,C)	0	$0.512 = 0.8 \times 0.8 \times 0.8$

■

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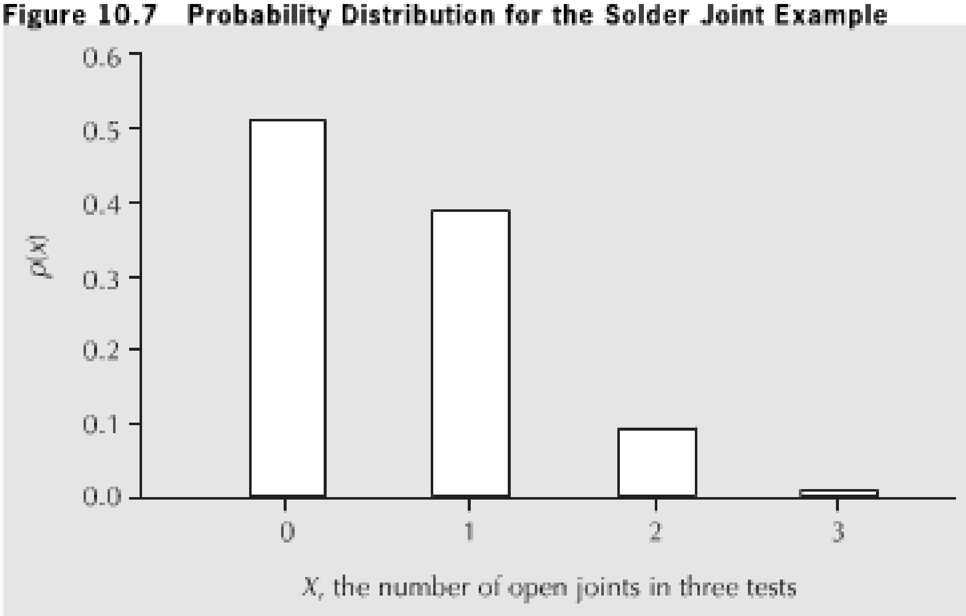
Figure 10.7 Probability Distribution for the Solder Joint Example



It is often useful to display a probability distribution function in graphical format. Such a graph is referred to as a histogram. Figure 10.7 shows the probability distribution function associated with the solder joint testing results.

In contrast to a discrete random variable, a continuous random variable can take on any real value over a defined interval. For example, daily demand for drinking water in a municipality might be anywhere between 10 million litres and 200 million litres. The actual amount consumed—the outcome—is a continuous random variable with a minimum value of 10 million litres and a maximum value of 200 million litres.

In this chapter, we focus on applications of discrete random variables in engineering economics analysis. We do not use continuous random variables because proper treatment requires more advanced mathematical concepts such as differential and integral calculus. Also, continuous random variables can be well approximated as discrete random variables by grouping the possible output values into a number of categories or ranges. For example, rather than treating demand for drinking water as a continuous random variable, demand could be characterized as high, medium, or low. Figure 10.8 shows an example of a probability distribution associated with future demand for water, approximated by a discrete random variable denoted by D.

The probability distribution of a random variable contains a great deal of information that can be useful for decision-making purposes. However, certain summary statistics are often used to capture an overall picture rather than working with the entire distribution. One particularly useful summary statistic is the **expected value**, or **mean**, of a random variable. The expected value of a discrete random variable X, $E(X)$, which can take on values $x_1, x_2, \ldots, x_m$, is defined as follows:

$$E(X) = \sum_{i=1}^{m} x_i p(x_i)$$

You will no doubt observe that computing the expected value of a random variable is much like computing the centre of mass for an object. The expected value is simply the centre of the probability "mass."

How are random variables, probability distributions, and expected values relevant to engineering economics? In conducting engineering economic studies, costs and benefits

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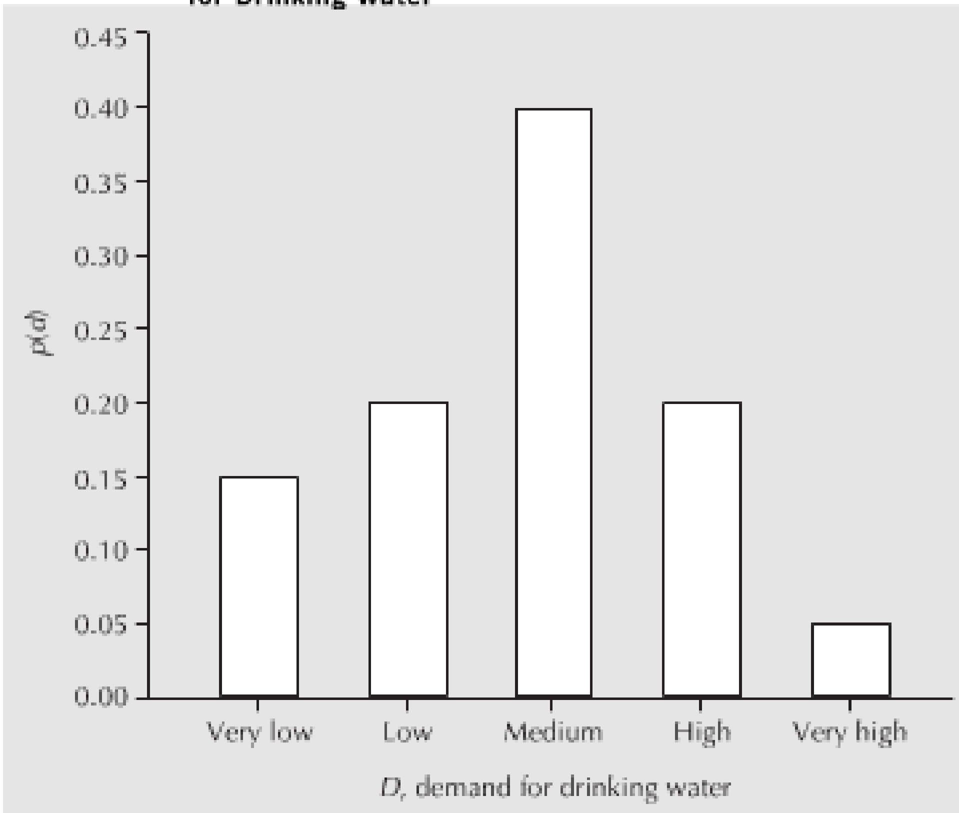
Figure 10.8 Probability Distribution Function of the Demand for Drinking Water



can be influenced by several uncertain factors. Often, an engineer does not know the outcome of a project or may not know with certainty the actual value of one or more parameters important to a project. The life of a product may shorten or lengthen unexpectedly due to market forces, the maintenance costs may be difficult to state with certainty, a car may have safety features that may increase or decrease the liability for the vendor, or product demand may be more or less than anticipated. In each case, if the engineer can determine the range of outcomes and their associated probabilities, this information can present a much richer view for the decision-making process. Random variables and their probability distributions are, in fact, the building blocks for many tools that are useful in decision making under risk.

Examples 10.5 and 10.6 illustrate how the expected value and probability distribution information may be used in a decision-making context.

EXAMPLE 10.5

Recall from Example 10.3 that the management of Westmount Waxworks had some uncertainty about the future sales levels of its line of statues of government leaders. Expert opinion helped it assess the probability of the pessimistic, expected, and optimistic sales scenarios. Management thinks that the probability that sales will be 50 000 per year for the next few years is roughly 50 percent and that the pessimistic and optimistic scenarios have probabilities of 20 percent and 30 percent, respectively. Table 10.6 reproduces the annual cost information for the two wax melters, Finedetail and Simplicity. On the basis of expected annual costs, which is the best choice?

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Table 10.6 Annual Cost Information for the Finedetail and Simplicity Wax Melters

Scenario	Annual Cost for Finedetail	Annual Cost for Simplicity	Probability
Pessimistic	$ 85 314	$ 94 381	0.2
Expected	112 314	103 501	0.5
Optimistic	314 814	186 901	0.3

The sales level can be represented by a discrete random variable, X. The possible values for X are: x_1 = pessimistic, x_2 = expected, and x_3 = optimistic.

The expected annual cost of the Finedetail wax melter is:

E(Finedetail, annual cost)

$$= (85\ 314)p(x_1) + (112\ 314)p(x_2) + (314\ 814)p(x_3)$$

$$= (85\ 314)(0.2) + (112\ 314)(0.5) + (314\ 814)(0.3)$$

$$= 167\ 663$$

The expected annual cost of the Simplicity wax melter is:

E(Simplicity, annual cost)

$$= (94\ 381)p(x_1) + (103\ 501)p(x_2) + (186\ 901)p(x_3)$$

$$= (94\ 381)(0.2) + (103\ 501)(0.3) + (186\ 901)(0.4)$$

$$= 126\ 697$$

The expected annual cost of the Simplicity wax melter is lower than that of the Finedetail melter. Hence, the Simplicity melter is preferred. ■

EXAMPLE 10.6

Regional Express is a small courier service company. At the central office, all parcels from the surrounding area are collected, sorted, and distributed to the appropriate destinations. Regional Express is considering the purchase of a new computerized sorting device for its central office. The device is so new—in fact, it is still under continuous improvement—that its maximum capacity is somewhat uncertain at the present time. The company has been told that the possible capacity can be 40 000, 60 000, or 80 000 parcels per month, regardless of the size of the parcels. It has estimated the probabilities corresponding to the three capacity levels. Table 10.7 shows this information. What is the expected capacity level for the new sorting device? Regional Express is growing steadily, so such a computerized sorting device will be a necessity in the future. However, if Regional Express currently deals with an average of 50 000 parcels per month, should it seriously consider purchasing the device now or should it wait?

If the discrete random variable X denotes the capacity of the device, then the expected capacity level $E(X)$ is

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Table 10.7 Probability Distribution Function for Capacity Levels of the New Sorting Device

i	Capacity Level (Parcels/Month)	$p(x_i)$
1	40 000	0.3
2	60 000	0.6
3	80 000	0.1

$$\begin{aligned} E(X) &= (40\,000)p(x_1) + (60\,000)p(x_2) + (80\,000)p(x_3) \\ &= (40\,000)(0.3) + (60\,000)(0.6) + (80\,000)(0.1) \\ &= 56\,000 \text{ parcels per month} \end{aligned}$$

The expected capacity level exceeds the average monthly demand of 50 000 parcels per month, so according to the expected value analysis alone, Regional Express should consider buying the sorting device now. However, by studying the probability distribution, we see that there is a 30 percent probability that the capacity level may fall below 50 000 parcels per month. Perhaps Regional Express should include this information in its decision making, and ask itself whether a 30 percent chance of not meeting its demand is too risky or costly if it decides to purchase the sorting device. ■

In summary of this section, engineers can be faced with a variety of uncertain events in project evaluation. When the outcomes of each event can be characterized by a probability distribution, this greatly enhances the analyst's ability to develop a deeper understanding of the risks associated with various decisions. This section provided an introduction to random variables and probability distributions as a starting point for an analysis of project risk.

10.5 Structuring Decisions With Decision Trees

Many different types of uncertainties exist in decision making. When an economic analysis becomes complex due to these uncertainties, formal analysis methods can help in several ways. First, formal methods can help by providing a means of decomposing a problem and structuring it clearly. Second, formal methods can help by suggesting a variety of decision criteria to help with the process of selecting a preferred course of action. This section provides an introduction to decision trees, which are a graphical means of structuring a decision-making situation where the uncertainties can be characterized by probability distributions. Other means of structuring decisions such as influence diagrams are available, but are beyond the scope of our coverage.

Decision trees help decompose and structure problems characterized by a sequence of one or more decisions and event outcomes. For example, a judgment about the chance of a thunderstorm tomorrow will affect your decision to plan for a picnic tomorrow afternoon. Similarly, the success or failure of a new product may largely depend on future demand for the product. As another example, a decision on the replacement interval for an asset relies on an assessment of its economic life, which can be highly uncertain if the equipment employs an emerging technology.

When a decision is influenced by outcomes of one or more random events, the decision

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section presents a useful tool for structuring such problems, called a decision tree. It is particularly suited to decisions and events that have a natural sequence in time or space.

A **decision tree** is a graphical representation of the logical structure of a decision problem in terms of the sequence of decisions to be made and outcomes of chance events. It provides a mechanism to decompose a large and complex problem into a sequence of small and essential components. In this way, a decision tree clarifies the options a decision maker has and provides a framework with which to deal with the risk involved.

Example 10.7 introduces the overall approach to constructing a decision tree. A detailed explanation of the components and structure of the decision tree is included in the example.

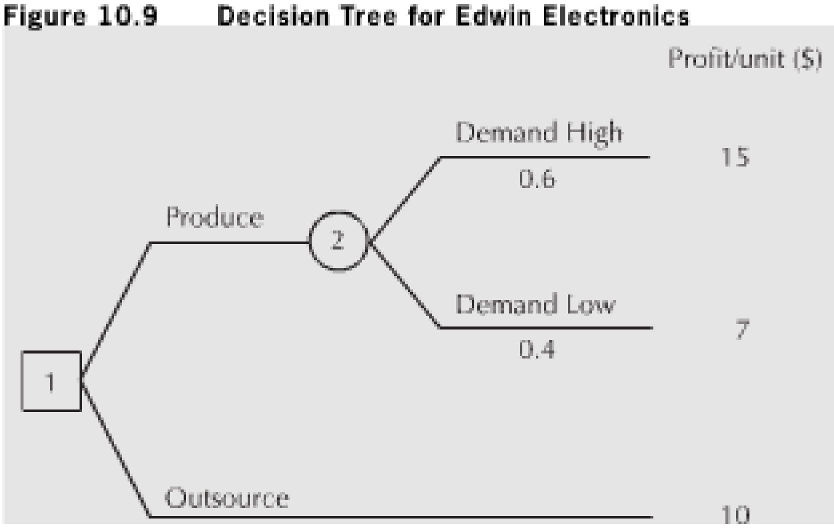
EXAMPLE 10.7

Edwin Electronics (EE) has a factory for assembling TVs. One of the key components is the TV screen. EE does not currently produce TV screens onsite; they are outsourced to a supplier elsewhere. Recently, EE's industrial engineering team asked if it should continue outsourcing the TV screens or produce them in-house. The team realized that it was important to consider the uncertainty in demand for the company's TVs. If the future demand is low, outsourcing seems to be the reasonable option in order to save production costs. On the other hand, if the demand is high, then it may be worthwhile to produce the screens onsite, thus getting economies of scale. EE's engineers analyzed the effect of the demand uncertainty in their decision making. They represented their decision problem in a graphical manner with a decision tree. Figure 10.9 represents EE's decision tree.

There are four main components in a decision tree: decision nodes, chance nodes, branches, and leaves. A decision node represents a decision to be made by the decision maker and is denoted by a square in the tree diagram. In Figure 10.9, the single square node represents the decision to produce or outsource TV screens (node 1). A chance node represents an event whose outcome is uncertain, but which has to be considered during decision making. The outcome of a chance node is a discrete random variable, as it has a number of distinct outcomes and each outcome has an associated probability. The circle in the diagram denotes a chance node. The chance node in Figure 10.9 represents the uncertain demand for TV screens (node 2). The branches of a tree are the lines connecting nodes depicting the sequence of possible decisions and chance events. Finally, the leaves indicate the values, or payoffs, associated with each branch of the decision tree.

A decision tree grows from left to right and usually begins with a decision node. The leftmost decision node represents an immediate decision faced by the decision maker.

Figure 10.9 Decision Tree for Edwin Electronics



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The branches extending from a decision node represent the decision options available for the decision maker at that node, whereas the branches extending from a chance node represent the possible outcomes of the chance event. Each branch extending from a chance node has an associated probability. In Edwin Electronics' case, the two decision options, to produce or to outsource, are represented by the two branches extending from the decision node. The two branches from the chance node indicate that the future demand may be high or low. It is important in decision making that all branches out of a node, whether a decision node or chance node, constitute a set of mutually exclusive and collectively exhaustive consequences. In other words, when a decision is made, exactly one option is taken, or when uncertainty is resolved, exactly one outcome occurs as a result.

Whenever a chance node follows a decision node, as in Figure 10.9, it implies that the decision maker must anticipate the outcome of future uncertain events in decision making. On the other hand, when a decision node follows a chance node, it implies that a decision must be made assuming that a particular outcome of a chance event has occurred. Finally, the rightmost branches lead to the leaves of the decision tree, indicating all possible outcomes of the overall decision situation represented by the tree. Each leaf has an associated valuation, referred to as a "payoff"; quite typically, the payoff is a monetary value. Edwin Electronics uses profit per TV unit as its performance measure.

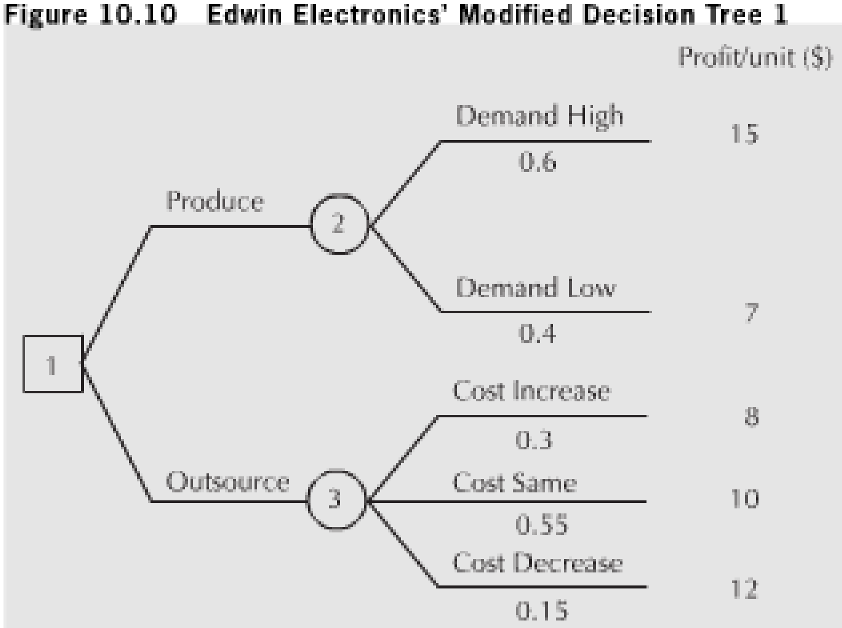
The decision tree for Edwin Electronics from Figure 10.9 can be modified to show more complex decision situations.

EXAMPLE 10.8

The EE engineering team from Example 10.7 has realized that the cost per TV screen may vary in the future, especially since EE is subject to purchasing conditions set by the supplier. How does this affect the decision tree?

Figure 10.10 includes the additional uncertainty in the TV screen cost charged by the supplier. The cost may increase, remain the same, or decrease in the future, as shown at node 3.

Figure 10.10 Edwin Electronics' Modified Decision Tree 1



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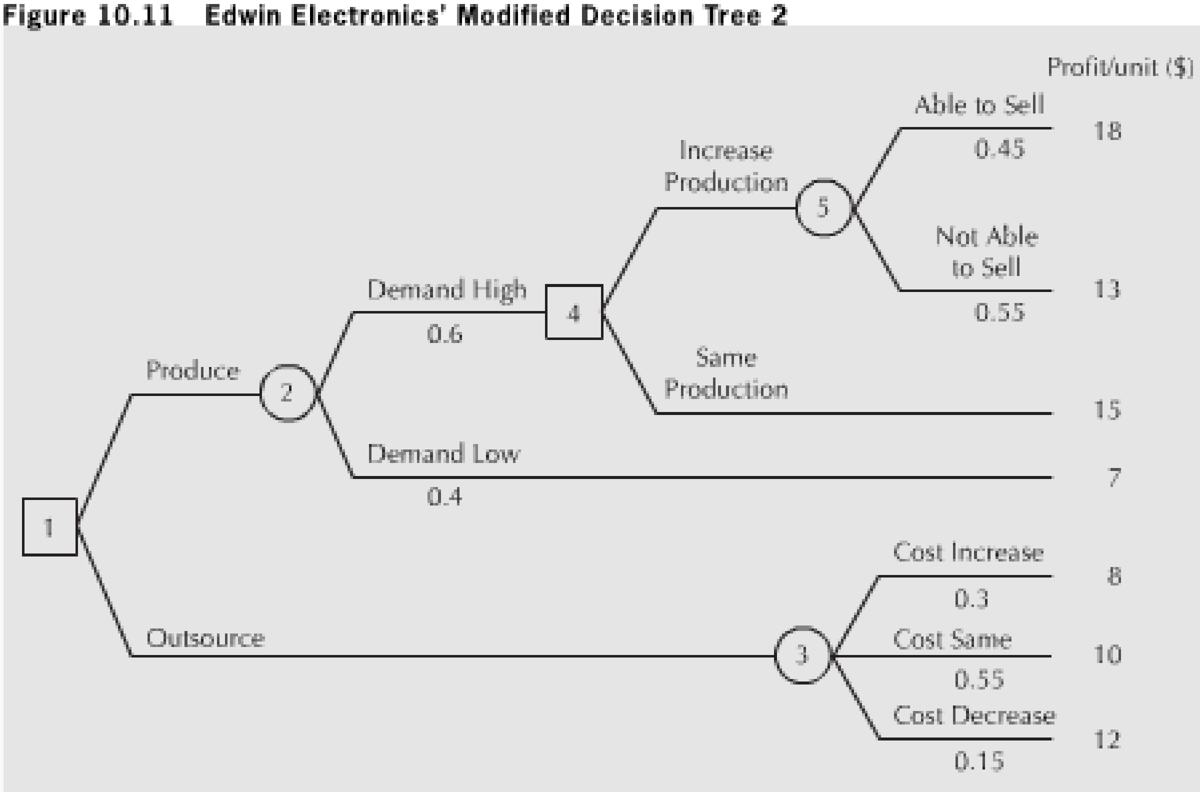
EXAMPLE 10.9

The EE engineering team then considered increasing in-house production of the TV screens if the demand is high. This raises an additional uncertainty about the ability of the market to absorb the increased production. How does this change the decision tree?

Figure 10.11 further modifies Figure 10.10 to include a new decision component and a chance event (see nodes 4 and 5). The decision component indicates the choice of whether to increase production. If production is increased, a new chance node captures the uncertainty about Edwin's ability to sell the excess production.

Figure 10.11 Edwin Electronics' Modified Decision Tree 2



One criterion for selecting among alternatives when there are risky outcomes is to pick the alternative that has the highest expected value, EV. If the units of value associated with the rightmost branches of a decision tree are measured in dollars, then this criterion may be referred to as *expected monetary value*, or EMV.

When a decision problem has been structured with a decision tree, finding the expected value of a particular decision is obtained by a procedure referred to as "rolling back" the decision tree. The procedure is as follows.

1. *Structure the problem:* Develop a decision tree representing the decision situation in question.
2. *Rollback:* Execute the **rollback procedure** (also known as **backward induction**) on the decision tree from right to left as follows:

   (a) At each chance node, compute the expected value of the possible outcomes. The resulting expected value becomes the value associated with the chance node and the branch on the left of that node (if there is one).

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(b) At each decision node, select the option with the best expected value (best may be highest value or lowest cost depending on the context). The best expected value becomes the value associated with the decision node and the branch on the left of that node (if there is one). For the option(s) not selected at this time, indicate their termination by a double-slash (//) on the corresponding branch.

(c) Continue rolling back until the leftmost node is reached.

3. *Conclusion:* The expected value associated with the final node is the expected value of the overall decision. Tracing forward (left to right), the non-terminated decision options indicate the set of recommended decisions at each subsequent node.

NET VALUE 10.1

Decision Tree Software

Constructing decision trees is awkward for a variety of reasons. For one thing, they are a combination of diagrams, words, and numbers, so standard software is of limited value. They can be extensive, so a single sheet of paper may not be large enough to hold the whole tree. Mathematical errors can be made. Also, making changes to a tree that has already been constructed is very difficult.

All of these issues are easily solved by using an application program designed for building and managing decision trees. There are many on the market, and a simple internet search for "decision tree software" will bring up a variety of choices. Some examples include: TreeAge Software (www.treeage.com), Vanguard Software (www.vanguard.com), Insight Tree (www.visionarytools.com), and Palisades PrecisionTree (www.palisade.com). Most vendors provide a trial version at no charge so that if you are building decision trees only occasionally (like for a course at school!), you can have all the functionality needed for developing high-quality decision trees without having to invest in purchasing software.

EXAMPLE 10.10

Carry out a decision tree analysis on Edwin Electronics' modified tree in Figure 10.10 using the expected value criterion.

Since the decision tree is already provided, step 1 is complete. The rollback procedure described in step 2 has two phases in this case. First, the tree is rolled back to each of the chance nodes as in step 2(a) (phase 1). The expected values at nodes 2 and 3 are computed as follows:

$$EV(2) = 0.6(15) + 0.4(7) = 11.80$$

$$EV(3) = 0.3(8) + 0.55(10) + 0.15(12) = 9.70$$

Figure 10.12 shows the rollback so far.

Next, the tree is further rolled back to the decision node as in step 2(b) (phase 2). The expected value at node 1 is then EV(1) = \$11.80, which is equal to EV(2) since EV(2) is higher than EV(3). Figure 10.13 shows this result. As for step 3, the following conclusion is made: The expected value of the overall decision is \$11.80 per unit and the recommended decision is to produce TV screens in-house.

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Figure 10.12 Phase 1 of Step 2: Rolling Back to the Chance Nodes

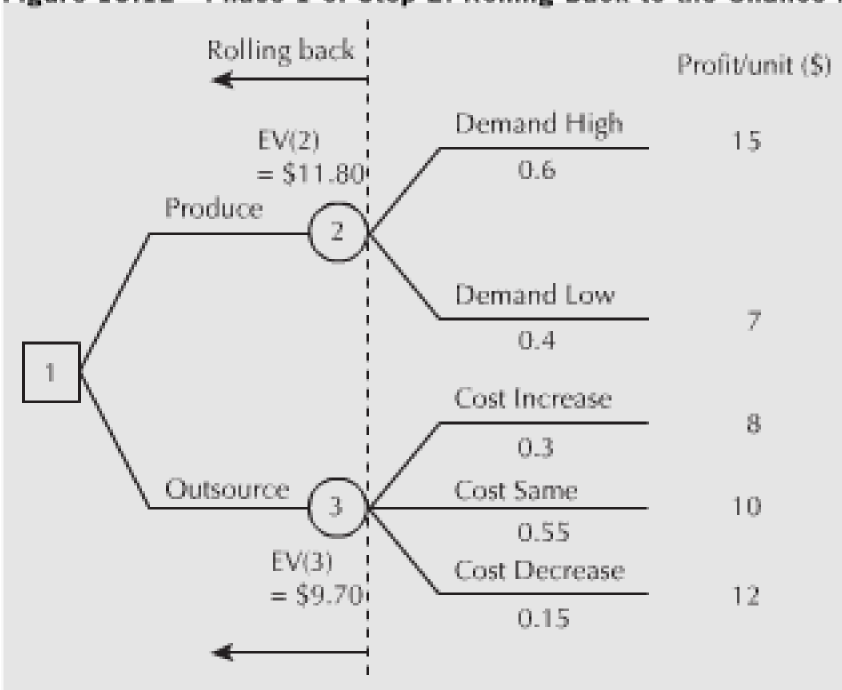
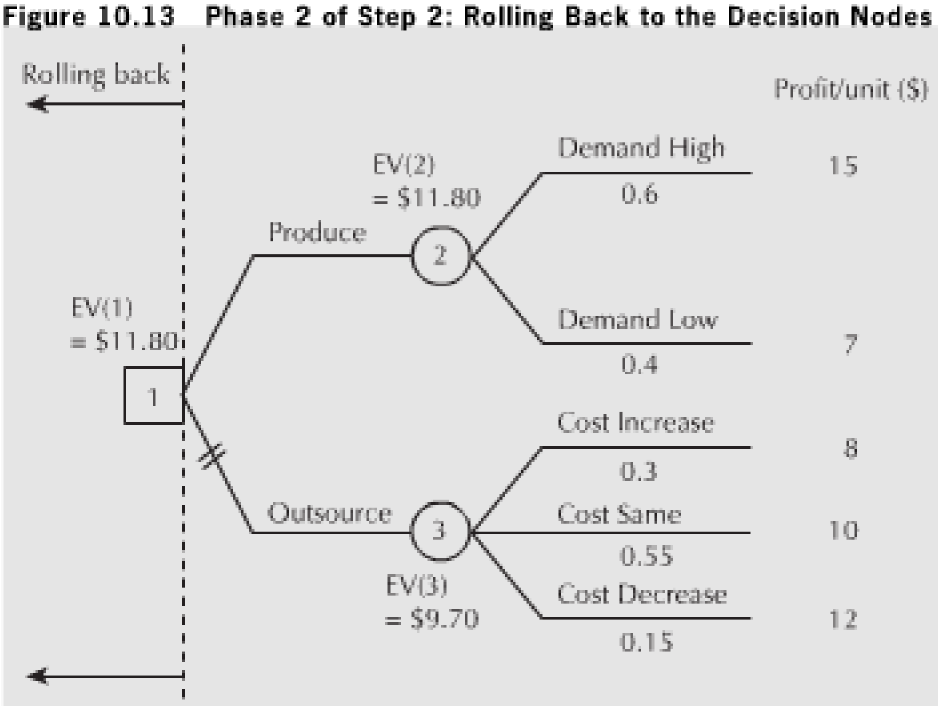


Figure 10.13 Phase 2 of Step 2: Rolling Back to the Decision Nodes



EXAMPLE 10.11

Perform decision tree analysis on Edwin Electronics' second modified tree in Figure 10.11.

The result of this analysis is shown in Figure 10.14. The overall expected profit for this tree is $11.95 per unit. The recommended decision is to produce TV screens in-house, and if the demand is high, the production level should be increased.

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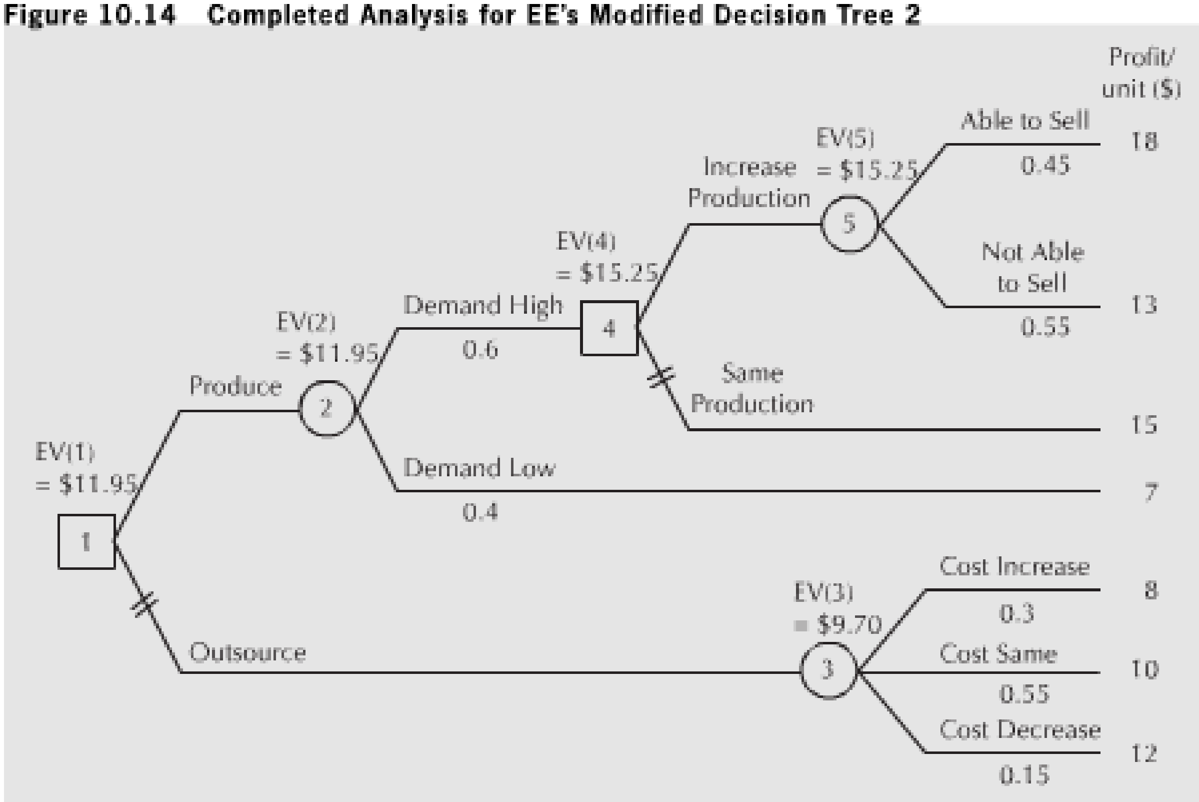
Figure 10.14 Completed Analysis for EE's Modified Decision Tree 2



REVIEW PROBLEMS

The following case is the basis of Review Problems 10.1 and 10.2.

Betteryet Insurance Inc. is considering two independent energy efficiency improvement projects. Each has a lifetime of 10 years and will have a scrap value of zero at the end of this time. Betteryet can afford to do both if both are economically justified. The first project involves installing high-efficiency motors in the air-conditioning system. High-efficiency units use about 7 percent less electricity than the current motors, which represents annual savings of 70 000 kilowatt-hours. They cost $28 000 to purchase and install and will require maintenance costs of $700 annually.

The second project involves installing a heat exchange unit in the current ventilation system. During the winter, the heat exchange unit transfers heat from warm room air to the cold ventilation air before the air is sent back into the building. This will save about 2 250 000 cubic feet of natural gas per year. In the summer, the heat exchange unit removes heat from the hot ventilation air before it is added to the cooler room air for recirculation. This saves about 29 000 kilowatt-hours of electricity annually. Each heat exchange unit costs $40 000 to purchase and install and annual maintenance costs are $3200.

Betteryet Insurance would like to evaluate the two projects, but there is some uncertainty surrounding what the electricity and natural gas prices will be over the life of the project. Current prices are $0.07 per kilowatt-hour for electricity and $3.50 per thousand cubic feet of natural gas, but some changes are anticipated. The company uses a MARR of 10 percent.

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REVIEW PROBLEM 10.1

Construct a sensitivity graph to determine the effect that a 5 percent and 10 percent drop or increase in the cost of electricity and the cost of natural gas would have upon the present worth of each project.

ANSWER

Table 10.8 gives the costs of electricity and natural gas with 5 percent and 10 percent increases and decreases from the base case of \$0.07 per kilowatt-hour for electricity and \$3.50 per 1000 cubic feet of natural gas. The table also shows the present worths of the two energy efficiency projects as the costs vary. A sample calculation for the heat exchange unit with base case costs is

$$\begin{aligned}\text{PW(Heat exchanger)} &= -40\,000 + (P/A,10\%,10) \\ &\quad \times [29\,000(0.07) + 2250(3.50) - 3200] \\ &\cong 1199\end{aligned}$$

Figure 10.15 is a sensitivity graph for the high-efficiency motor. It graphically illustrates the effect of changes in the costs of electricity and natural gas on the present worth of a motor. The high-efficiency motor is not economically viable at the current prices for electricity and gas. Only if there is an increase of almost 10 percent in electricity costs for the life of the project will the motor produce sufficient savings for the project to have a positive present worth.

Figure 10.16 is the sensitivity graph for the heat exchange unit. The heat exchange unit has a positive present worth for the current prices, but the present worth is quite sensitive to the price of natural gas. A drop in the price of natural gas in the range of only 2 percent to 3 percent (reading from the graph) will cause the project to have a negative present worth. ■

Table 10.8 Costs Used as the Basis of the Sensitivity Graph for Review Problem 10.1

	–10%	–5%	0%	+5%	+10%
Cost of electricity (\$/kWh)	0.063	0.0665	0.07	0.0735	0.077
Cost of natural gas (\$/1000 cubic feet)	3.15	3.325	3.5	3.675	3.85
PW of high-efficiency motor (\$)					
With changes to electricity costs	–5204	–3698	–2193	–687	818
With changes to natural gas cost	–2193	–2193	–2193	–2193	–2193
PW of heat exchanger (\$)					
With changes to electricity costs	–48	576	1199	1823	2447
With changes to natural gas cost	–3640	–1220	1199	3619	6038

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Figure 10.15 **Sensitivity Graph for the High-Efficiency Motor**

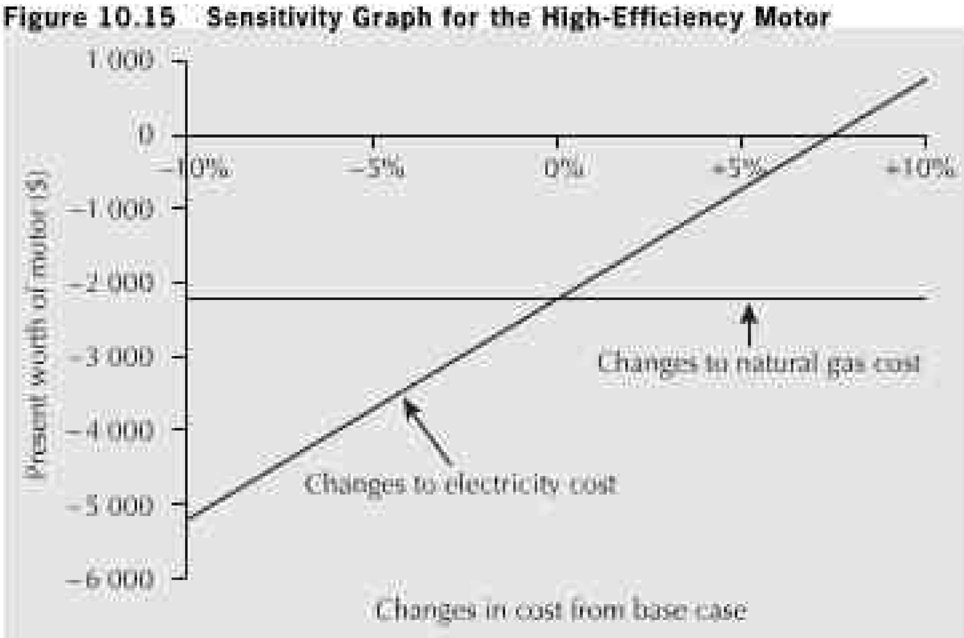
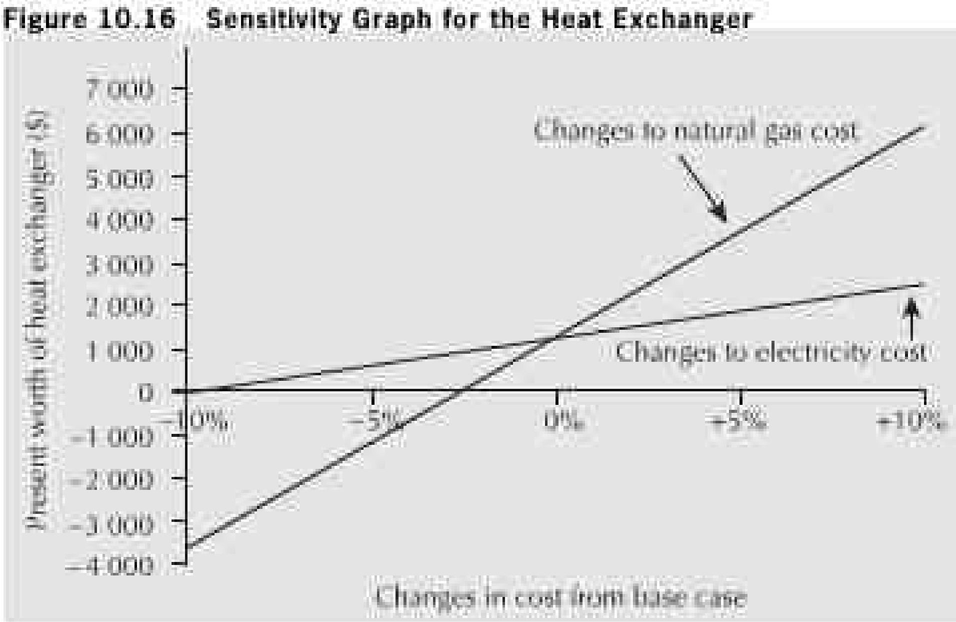


Figure 10.16 **Sensitivity Graph for the Heat Exchanger**



REVIEW PROBLEM 10.2

Refer to Review Problem 10.2. How much of a drop in the cost of natural gas will result in the heat exchange unit's having a present worth of zero? Construct a break-even graph to illustrate this break-even cost.

ANSWER

By varying the cost of natural gas from the base case, the break-even graph shown in Figure 10.17 can be constructed. The break-even cost of natural gas is $3.41 per 1000 cubic feet, which is not much below the current price for gas. Betteryet Insurance should probably look more seriously into forecasts of natural gas prices for the life of the heat exchange unit. ■

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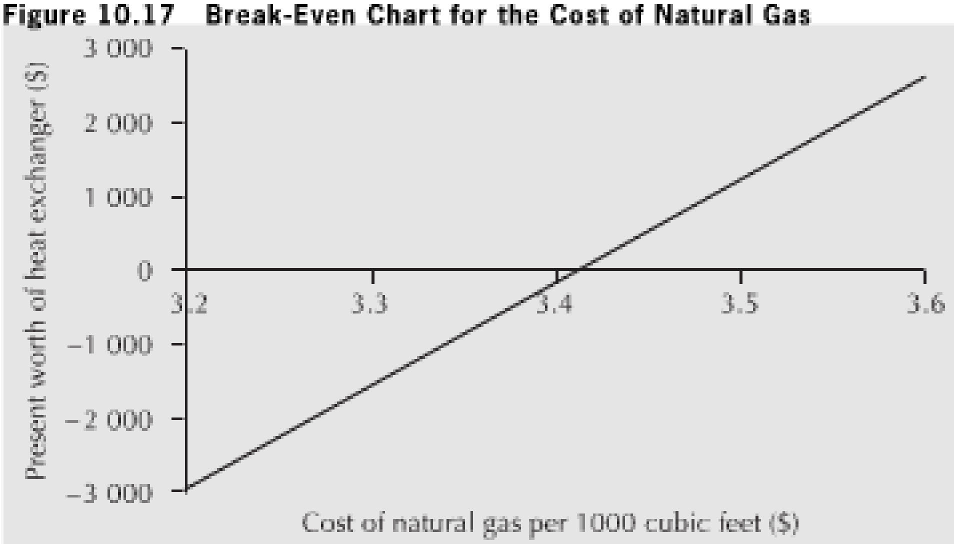
Figure 10.17 Break-Even Chart for the Cost of Natural Gas



REVIEW PROBLEM 10.3

Power Tech is a North America–based company that specializes in building power-surge protection devices. Power Tech has been focusing its efforts on the North American market until now. Recently, a deal with a Chinese manufacturing company has surfaced. If Power Tech decides to become partners with this manufacturing company, its market will expand to include Asia. It is, however, concerned with the uncertainty associated with possible changes in North American demand and Asian demand. From studying the current economy, Power Tech feels that the chance of no change or an increase in demand in North America over the next three years is 60 percent and the chance of demand decrease is 40 percent. After discussions with its potential partners in China, Power Tech estimates that Asian demand may increase (or remain the same) with a probability of 30 percent and decrease with a probability of 70 percent over the next three years. Power Tech has estimated the revenue increase that can be expected under different scenarios if it establishes the partnership; this information is shown in Table 10.9.

Conduct a decision tree analysis for Power Tech and make a recommendation regarding the partnership with the Chinese company.

Table 10.9 Expected Revenue Increase for Power Tech

	North American Demand	Asian Demand	Revenue Increase (millions of $)
	increase	increase	2
Partnership	increase	decrease	0.75
with Chinese	decrease	increase	0.5
company	decrease	decrease	−1
	increase	increase	0.75
No partnership	increase	decrease	0.5
with Chinese	decrease	increase	0.1
company	decrease	decrease	0.3

ANSWER

The result of the analysis is shown in Figure 10.18. The expected value calculations at each chance node are shown below.

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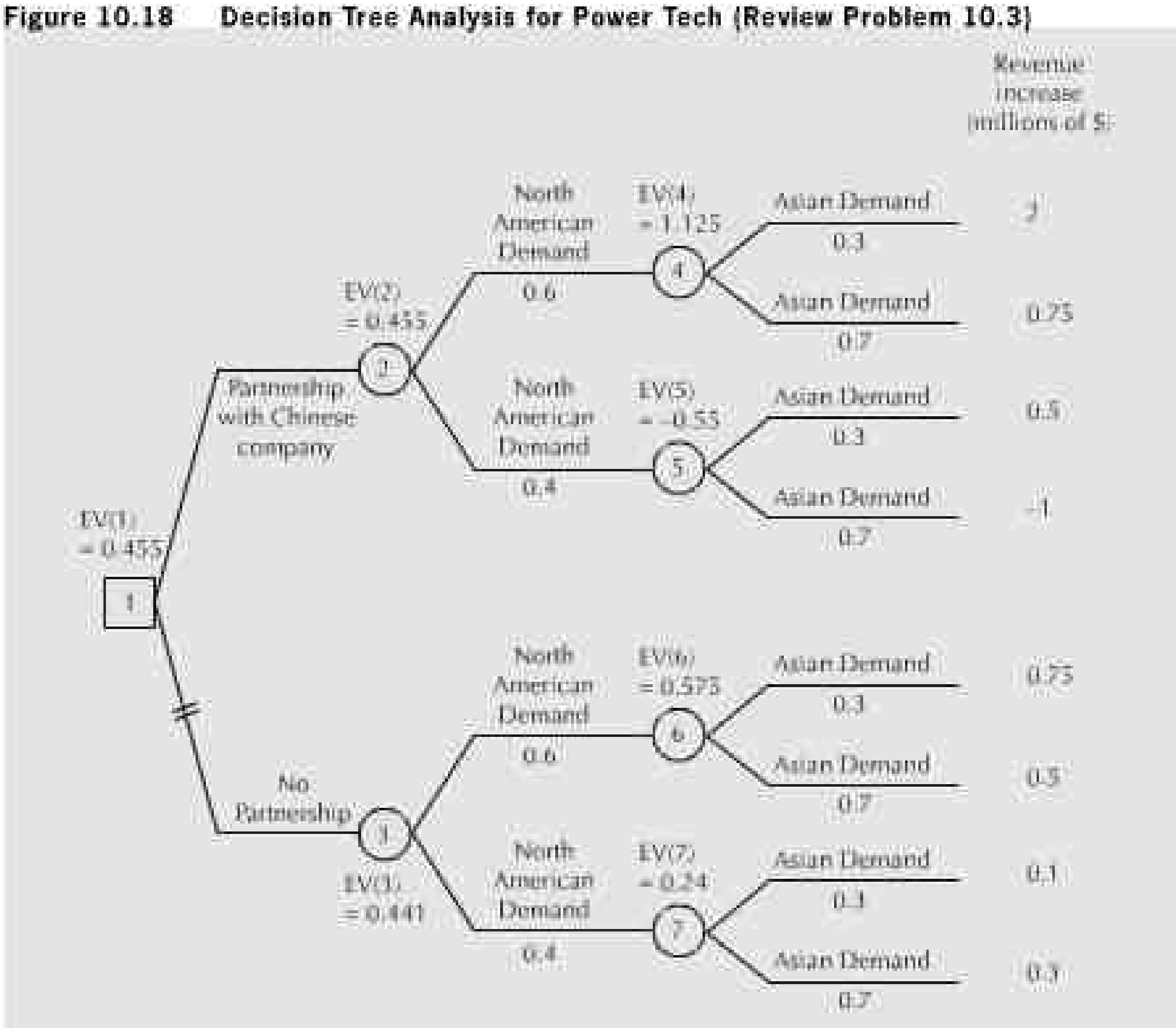
Figure 10.18 Decision Tree Analysis for Power Tech (Review Problem 10.3)



The first phase of rollback (in millions of dollars):

$EV(4) = 0.3(2) + 0.7(0.75) = 1.125$

$EV(5) = 0.3(0.5) + 0.7(-1) = -0.55$

$EV(6) = 0.3(0.75) + 0.7(0.5) = 0.575$

$EV(7) = 0.3(0.1) + 0.7(0.3) = 0.24$

The second phase of rollback (in millions of dollars):

$EV(2) = 0.6(1.125) + 0.4(-0.55) = 0.455$

$EV(3) = 0.6(0.575) + 0.4(0.24) = 0.441$

According to the expected value criterion, the partnership with the Chinese company is recommended, since the expected value for forming the partnership is higher than for not forming it. However, Power Tech should also note that these expected values have only a marginal difference. It is perhaps wise to collect more information regarding other aspects of this proposed partnership. ■

REVIEW PROBLEM 10.4

A telephone company called LOTell thinks the introduction of a new internet service package for rural residential customers would give it an advantage over its competitors. However, a survey of the potential growth of rural internet home users would take at least three months. LOTell has two options at present: first, to introduce the internet

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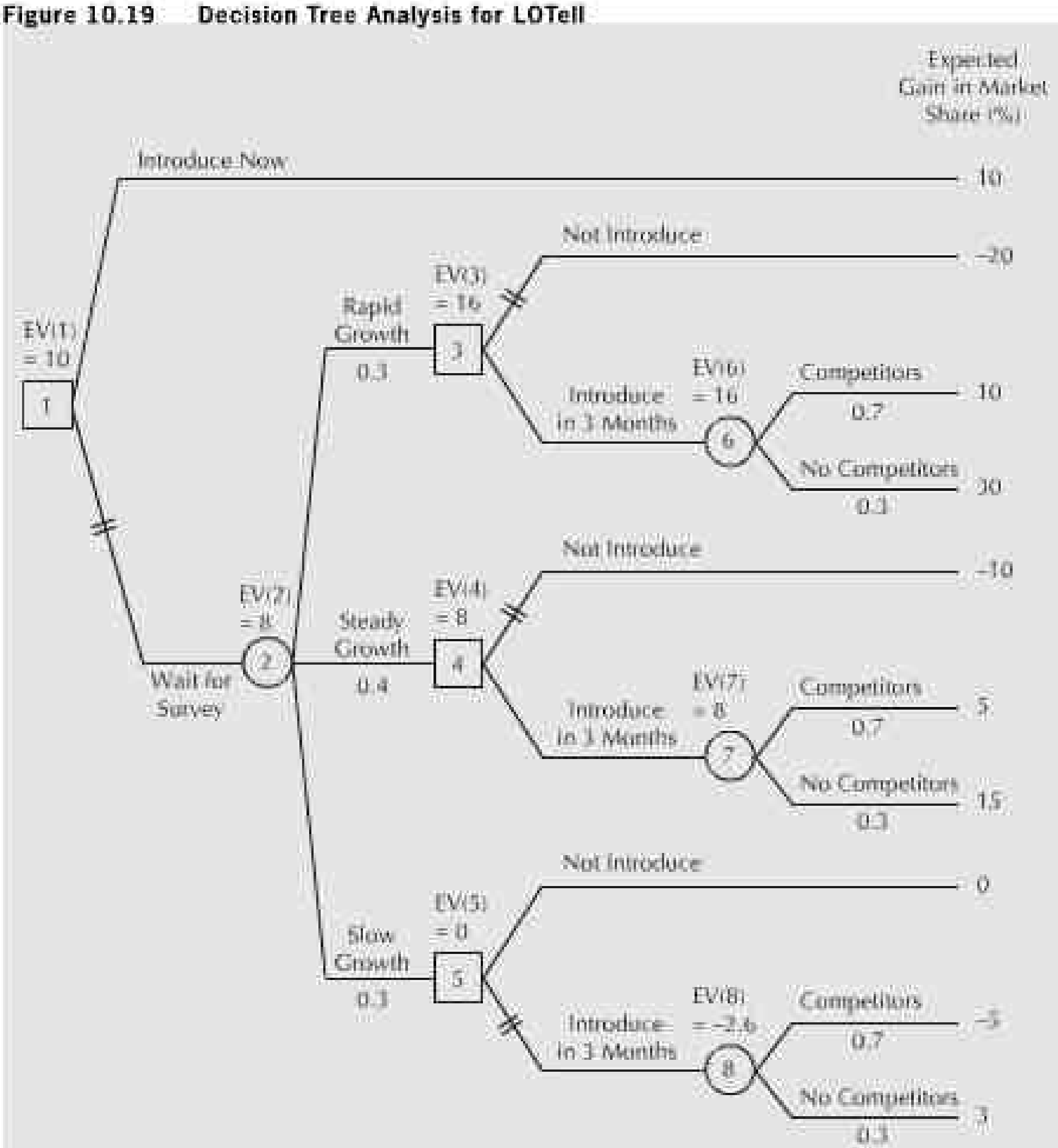
at the time of market entry, and second, to wait for the survey result in order to minimize the risk of failing to attract enough customers. If LOTell decides to wait for the survey result, there are three possible outcomes: the market growth is rapid (30 percent probability), steady (40 percent), or slow (30 percent). Depending on the survey result, LOTell may decide to introduce or not introduce the new internet service. If it decides to launch the new service after the survey, which is three months from now, then there is a 70 percent chance that the competitors will come up with a similar service package. What decision will result in the highest expected market share for LOTell?

ANSWER

A decision tree for the problem is shown in Figure 10.19, which also shows the results of the analysis. The recommended decision is to introduce the internet service now because it produces a higher expected gain in market share compared to waiting for the survey results. ■

Figure 10.19 Decision Tree Analysis for LOTell



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SUMMARY

In this chapter, we considered three basic methods used by analysts to better understand the effect that uncertainties and risks in estimated cash flows have on economic decisions. The first was the use of sensitivity graphs. Sensitivity graphs illustrate the sensitivity of a particular measure (e.g., present worth or annual worth) to changes in one or more of the parameters of a project. The second method was the use of break-even analysis for evaluating both individual projects and comparisons among projects. Finally, decision trees were introduced. A decision tree is a graphical representation of the logical structure of a decision problem in terms of the sequence of decisions and outcomes of chance events. An analysis based on decision trees can therefore account for the sequential nature of decisions.

ENGINEERING ECONOMICS IN ACTION, PART 10B

Chances Are Good

"So let me get this straight," Clem started in, a few days later. "You structured this as a tree. We—Canadian Widgets—have the first decision of whether to proceed with development of the Adaptamatic at all. Then the next node represents the probability that the Adaptamatic will have a competitor. Then there is our choice of going into production or not. Then there are the customers, which we represent as chance nodes, who can have low, medium, and high demand. Finally, there are the outcomes, each of which has a dollar value associated with it. Is that right?"

"Perfect," Naomi said.

"And the dollar values came from . . . ?"

"Well, some reasonable assumptions about the marketplace," Naomi replied. "We had enough information to quantify three levels of demand. We figured we had as much consumer acceptance as any competitor because of our association with Powerluxe, so when a competitive product was in the marketplace, we assumed we would have the same market share as anyone else."

"What about the probabilities?" Clem continued.

"That was harder," Bill answered. Naomi couldn't help but smile. A few days ago, she didn't know anything about marketing and Bill didn't know about decision trees, but now she was answering the questions about marketing and he was answering the ones about decision trees! Go figure.

"We had no hard information on probabilities," Bill continued. "We set it all up as a spreadsheet so that we could adjust the probabilities freely. First we put in our best guesses—subjective probabilities. We talked to Prabha in marketing and to a bunch of people at Powerluxe, and refined that down. Finally, we tested it for a whole range of possibilities. Bottom line: Chances are good that we will make a killing."

Clem looked at the decision tree and at the table Bill gave him that reported the expected value of proceeding with the Adaptamatic development under various assumptions. "Are you sure this is right? How come we make more money if we have a competitor than if we don't?"

"Good observation, Clem." Bill was beaming. "That's interesting, isn't it? That's what's called 'building the category' in marketing. The principle is that when you have a new product, you have to spend a lot of resources educating the consumer. If you have to do that yourself, it's really costly. But a competitor can work for you by taking a share of those education costs and actually making it cheaper for you. That's what happens here."

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"It was the decision tree approach that revealed this dynamic in this case," Bill went on. "By ourselves, we could lose money if demand was low, even though the expected value was fairly high. However, with a competitor on the market, we can almost guarantee making money because the efforts of our competitor reduce our marketing costs and expand the market at the same time. Combine them both in the decision tree and we have a high expected value with almost no risk. Cool, eh?"

"Really cool." Clem glanced at Naomi with an appraising look. "Speaking of chances—chances are good that Anna's going to like this. Nice job."

PROBLEMS

A. Key Concepts

10.1 Identify possible parameters that are involved in economic analysis for the following situations:

(a) Buying new equipment

(b) Supplying products to a foreign country with a high inflation rate

10.2 For the following examples of parameters, how would you assign a reasonable base case and a range of variation so that you can carry out sensitivity analysis? Assign specific numerical figures wherever you can.

(a) Canada's inflation rate

(b) U.S. dollar exchange rate for Canadian dollars

(c) Expected annual savings from a new piece of equipment similar to the one you already have

(d) Expected annual revenue from an internet-based business

(e) Salvage value of a personal computer

10.3 Which sensitivity analysis method may be appropriate for analyzing the following uncertain situations?

(a) Corral Cartage leases trucks to service its shipping contracts. Larger trucks have cheaper operating costs if there is sufficient business, but are more expensive if they are not full. Corral Cartage is not certain about future demand.

(b) Joan runs a dog kennel. She is considering installing a heating system for the interior runs that will allow her to operate all year. Joan is not sure how much the annual heating expenses will be.

(c) Pushpa runs a one-person company producing custom paints for hobbyists. She is considering buying printing equipment to produce her own labels. However, she is not sure if she will have enough orders in the future to justify the purchase of the new equipment.

(d) Lemuel is an engineer working for the electric company. He is estimating the total cost for building transmission lines from a distant nuclear plant to new industrial parks north of the city. Lemuel is uncertain about the construction cost (per kilometre) of transmission lines.

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(e) Thanh's company is growing very quickly and has a hard time meeting its orders. An opportunity to purchase additional production equipment has arisen. She is not certain if the company will continue to grow at the same rate in the future, and she is not even certain how long the growth may last.

10.4 The Kelowna Go-Kart Klub has decided to build a clubhouse and track several years from now. The club needs to accumulate \$50 000 by setting aside a uniform amount at the end of every year. It believes it is possible to set aside \$7000 every year at 10 percent interest. It wishes to know how many years it will take to save \$50 000 and how sensitive this result is to a 5 percent and a 10 percent increase or decrease in the amount saved per year and in the interest rate. Construct a sensitivity graph to illustrate the situation.

10.5 A chemical plant is considering installing a new water purification system that costs \$21 500. The expected service life of the system is 10 years and the salvage value is computed using the declining-balance method with a depreciation rate of 20 percent. The operating and maintenance costs are estimated to be \$5 per hour of operation. The expected savings are \$10 per operating hour.

(a) Find the annual worth of the new water purification system if the current operating hours are 1500 per year on average. The MARR is 10 percent.

(b) What is the break-even level of operating hours? Construct a graph showing the annual worth for various levels of operating hours.

10.6 Fantastic Footwear can invest in one of two different automated clicker cutters. The first, A, has a \$100 000 first cost. A similar one, B, with many extra features, has a first cost of \$400 000. A will save \$50 000 per year over the cutter now in use. B will save between \$120 000 and \$150 000 per year. Each clicker cutter will last five years and have a zero scrap value.

(a) If the MARR is 10 percent, and B will save \$150 000 per year, which alternative is better?

(b) B will save between \$120 000 and \$150 000 per year. Determine the IRR for the incremental investment from A to B for this range, in increments of \$5000. Plot savings of B versus the IRR of the incremental investment. Over what range of savings per year is your answer from part (a) valid? What are the break-even savings for alternative B such that below this amount, A is preferred and above this amount, B is preferred?

10.7 Ridgely Custom Metal Products (RCMP) must purchase a new tube bender. It is considering two alternatives that have the following characteristics:

	Model T	Model A
First cost	\$100 000	\$150 000
Economic life	5 years	5 years
Yearly savings	\$50 000	\$62 000
Salvage value	\$20 000	\$30 000

Construct a break-even graph showing the present worth of each alternative as a function of interest rates between 6 percent and 20 percent. Which is the preferred choice at

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8 percent interest? Which is the preferred choice at 16 percent interest? What is the break-even interest rate?

10.8 Julia must choose between two different designs for a safety enclosure. Model A has a life of three years, has a first cost of $8000, and requires maintenance of $1000 per year. She believes that a salvage value can be estimated for model A using a depreciation rate of between 30 percent and 40 percent and declining-balance depreciation. Model B will last four years, has a first cost of $10 000, and has maintenance costs of $700 per year. A salvage value for model B can be estimated using straight-line depreciation and the knowledge that after one year the salvage value will be $7500. Interest is at 11 percent. Which of the two models would you suggest Julia choose? What break-even depreciation rate for model A will make her indifferent between the two models? Construct a sensitivity graph showing the break-even depreciation rate.

10.9 An investment has possible rates of return of 7 percent, 10 percent, and 15 percent over five years. The probabilities of attaining these rates, estimated on the basis of the current economy, are 0.65, 0.25, and 0.1, respectively. If you have $10 000 to invest, what is the expected rate of return from this investment?

10.10 Rockies Adventure Wear, Inc., sells athletic and outdoor clothing through catalogue sales. Its managers want to upgrade their order-processing centre so that they have less chance of losing customers by putting them on hold. The upgrade may result in a processing capacity of 30, 40, 50, or 60 calls per hour with the probabilities of 0.2, 0.4, 0.3, and 0.1, respectively. Market research indicates that the average number of calls that Rockies may receive is 50 per hour. How many customers are expected to be lost per hour due to the lack of processing capacity?

10.11 Power Tech builds power-surge protection devices. One of the components, a plastic moulded cover, can be produced by two automated machines, A1 and X1000. Each machine produces a number of defects with probabilities shown in the following table.

A1		X1000	
No. of Defects (out of 100)	Probability	No. of Defects (out of 100)	Probability
0	0.3	0	0.25
1	0.28	1	0.33
2	0.15	2	0.26
3	0.15	3	0.1
4	0.1	4	0.05
5	0.02	5	0.01

Which machine is better with regard to the expected number of defective products?

10.12 Lightning City is famous for having many thunderstorms during the summer months (from June to August). One of the CB Electronix factories is located in Lightning City. It has collected information, shown in the table that follows, regarding the number of blackouts caused by lightning.

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Number of Blackouts (per Month)	Probability (Summer Months)	Probability (Non-Summer Months)
0	0	0.45
1	0.4	0.4
2	0.25	0.15
3	0.2	0
4	0.1	0
5	0.05	0

For the first three blackouts in a month, the cost due to suspended manufacturing is \$800 per blackout. For the fourth and fifth blackouts, the cost increases to \$1500 per blackout. A local insurance company offers protection against lightning-related expenses. The monthly payment is \$500 for complete annual coverage. Assume that the number of blackouts in any month is independent of those in any other month. What is the expected cost related to blackouts over the summer months? Over the non-summer months? Should CB consider purchasing the insurance policy?

10.13 Randall at Churchill Circuits (CC) has just received an emergency order for one of CC's special-purpose circuit boards. Five are in stock at the moment. However, when they were tested last week, two were defective but were mixed up with the three good ones. There is not enough time to retest the boards before shipment to the customer. Randall can either choose one of the five boards at random to ship to the customer or he can obtain a proven non-defective one from another plant. If the customer gets a bad board, the total incremental cost to CC is \$10 000. The incremental cost to CC of getting the board from another plant is \$5000.

(a) What is the chance that the customer gets a bad board if Randall sends one of the five in stock?

(b) What is the expected value of the decision to send the customer one of the five boards in stock?

(c) Draw a decision tree for Randall's decision. On the basis of EV, what should he do?

10.14 St. Jacobs Cheese Factory (SJCF) is getting ready for a busy tourist season. SJCF wants to either increase production or produce the same amount as last year, depending on the demand level for the coming season. SJCF estimates the probabilities for high, medium, and low demands to be 0.4, 0.35, and 0.25, respectively, on the basis of the number of tourists forecasted by the local recreational bureau. If SJCF increases production, the expected profits corresponding to high, medium, and low demands are \$750 000, \$350 000, and \$100 000, respectively. If SJCF does not increase production, the expected profits are \$500 000, \$400 000, and \$200 000, respectively. Construct a decision tree for SJCF. On the basis of EV, what should SJCF do?

10.15 LOTell, a telephone company, has two options for its new internet service package: It can introduce a combined rate for the residential phone line and the internet access or it can offer various add-on internet service rates in addition to the regular phone rate. LOTell can only afford to introduce one of the packages at this point. The expected gain in market share by introducing the internet service would likely differ for different market growth rates. LOTell has estimated that if it introduces the combined rate, it would gain 30 percent, 15 percent, and 3 percent of the market share with rapid, steady,

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or slow market growth. If it introduces the add-on rates, it gains 15 percent, 10 percent, and 5 percent of the market share with rapid, steady, or slow market growth. Construct a decision tree for LOTell. If it wishes to maximize expected market share growth, which package should LOTell introduce to the market now?

B. Applications

10.16 A new software package is expected to improve productivity at Suretown Insurance. However, because of training and implementation costs, savings are not expected to occur until the third year of operation. Annual savings of approximately \$10 000 are expected, increasing by about \$1000 per year for the following five years. After this time (eight years from implementation), the software will be abandoned with no scrap value. Construct a sensitivity graph showing what would happen to the present worth of the software with 7.5 percent and 15 percent increases and decreases in the interest rate, the \$10 000 base savings, and the \$1000 savings gradient. MARR is 15 percent.

10.17 A regional municipality is studying a water supply plan for the area to the end of the year 2050. To satisfy the water demand, one suggestion is to construct a pipeline from a distant lake. It is now the end of 2010. Construction would start in the year 2015 (five years from now) and take five years to complete at a cost of \$20 million per year. Annual maintenance and repair costs are expected to be \$2 million and will start the year following project completion (all costs are based on current estimates). From a predicted inflation rate of 3 percent per year, and the real MARR, city engineers have determined that a MARR of 7 percent per year is appropriate. Assume that all cash flows take place at the end of the year and that there is no salvage value at the end of 2055.

(a) Find the present worth of the project.

(b) Construct a sensitivity graph showing the effects of 5 percent and 10 percent increases and decreases in the construction costs, maintenance costs, and inflation rate. To which is the present worth most sensitive?

10.18 The city of Brandon is installing a new swimming pool in the downtown recreation centre. One design being considered is a reinforced concrete pool that will cost \$6 000 000 to install. Thereafter, the inner surface of the pool will need to be refinished and painted every 10 years at a cost of \$40 000 per refinishing. Assuming that the pool will have essentially an infinite life, what is the present worth of the costs associated with the pool design? The city uses a MARR of 5 percent. If the installation costs, refinishing costs, and MARR are subject to 5 percent or 10 percent increases or decreases, how is the present worth affected? To which parameter is the present worth most sensitive?

10.19 You and two friends are thinking about setting up a grocery delivery service for local residents to finance your last two years at university. In order to start up the business, you will need to purchase a car. You have found a used car that costs \$6000 and you expect to be able to sell it for \$3000 at the end of two years. Insurance costs are \$600 for each six months of operation, starting now. Advertising costs (e.g., flyers, newspaper advertisements) are estimated to be \$100 per month, but these might vary as much as 20 percent above or below the \$100, depending on the intensity of your advertising. The big questions you have now are how many customers you will have and how much of a service fee to charge per delivery. You estimate that you will have 300 deliveries every month, and are thinking of setting a \$2-per-delivery fee, payable at the end of each month. The interest rate over the two-year period is expected to be 8 percent per year, compounded monthly, but may be 20 percent above or below this figure.

Using equivalent monthly worth, construct a sensitivity graph showing how sensitive the monthly worth of this project will be to the interest rate, advertising costs, and

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the number of deliveries you make each month. To which parameter is the equivalent monthly worth most sensitive?

10.20 Timely Testing (TT) does subcontracting work for printed circuit board manufacturers. It performs a variety of specialized functional tests on the assembled circuit boards. TT is considering buying a new probing device that will assist the technicians in diagnosing functional defects in the printed circuit boards. Two vendors have given the company quotes on first costs and expected operating costs over the life of its equipment.

	Vendor A	Vendor B
Expected life	7 years	10 years
First cost	\$200 000	\$350 000
Maintenance costs	\$10 000/year + \$0.05/unit	\$20 000/year + \$0.01/unit
Labour costs	\$1.25/unit	\$0.50/unit
Other costs	\$6 500/year + \$0.95/unit	\$15 000/year + \$0.55/unit
Salvage value	\$5 000	\$20 000

Production levels vary for TT. They may be as low as 20 000 boards per year or as high as 200 000 boards per year if a contract currently under negotiation comes through. TT expects, however, that production quantities will be about 50 000 boards. Timely Testing uses a MARR of 15 percent for equipment projects and will be using an annual worth comparison for the two devices.

Timely Testing is aware that the equipment vendors have given estimates only for costs. In particular, TT would like to know how sensitive the annual worth of each device is to the first cost, annual fixed costs (maintenance + other), variable costs (maintenance + labour + other), and the salvage value.

(a) Construct a sensitivity graph for vendor A's device, showing the effects of 5 percent and 10 percent decreases and increases in the first cost, annual fixed costs, variable costs, and the salvage value. Assume an annual production level of 50 000 units.

(b) Construct a sensitivity graph for vendor B's device, showing the effects of 5 percent and 10 percent decreases and increases in the first cost, annual fixed costs, variable costs, and the salvage value. Assume an annual production level of 50 000 units.

10.21 Refer back to Problem 10.19.

(a) Assuming base case figures for advertising costs and interest rates, what is the break-even number of deliveries per month? Construct a graph showing the break-even number.

(b) Assuming base case figures for advertising costs and number of deliveries per month, what is the break-even interest rate? Construct a graph illustrating the break-even interest rate.

10.22 Merry Metalworks would like to implement a local area network (LAN) for file transfer, email, and database access throughout its facility. Two feasible network topologies have been identified, which it has labelled alternative A and alternative B. The three main components of costs for the network are (1) initial hardware and installation costs, (2) initial software development costs, and (3) software and hardware maintenance costs. The installation and hardware costs for both systems are somewhat uncertain, as prices for the components are changing and Merry Metalworks is not

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sure of the installation costs for the LAN hardware. The costs for each alternative are summarized below.

	Alternative A	Alternative B
Initial hardware and installation costs ($):		
Optimistic estimate	70 000	86 000
Average estimate	92 500	105 500
Pessimistic estimate	115 000	125 000
Initial software cost ($)	138 750	158 250
Annual maintenance costs ($)	9250	10 550
Annual benefits ($):		
Optimistic estimate	80 000	94 000
Average estimate	65 000	74 000
Pessimistic estimate	50 000	54 000

Benefits from the LAN are increased productivity because of faster file transfer times, reduced data redundancy, and improved data accuracy because of the database access. The benefits were difficult to quantify and are stated below as only a range of possible values and an average.

Merry Metalworks uses a 15 percent MARR and has established a 10-year study period for this decision. It wishes to compare the projects on the basis of annual worth.

(a) Construct a sensitivity graph for alternative A. For the base case, use the average values for the initial hardware cost and the annual benefits. Each graph should indicate the effect of a 5 percent and a 10 percent drop or increase in the initial hardware cost and the annual benefits. Which of the two factors most affects the annual worth of alternative A?

(b) Construct a sensitivity graph for alternative B. For the base case, use the average values for the initial hardware cost and the annual benefits. Each graph should indicate the effect of a 5 percent and a 10 percent drop or increase in the initial hardware cost and the annual benefits. Which of the two factors most affects the annual worth of alternative B?

10.23 Refer back to Problem 10.4. Members of the Go-Kart Klub do not wish to wait for more than five years to build their clubhouse. They have decided to start a fundraising campaign to increase their ability to save each year between $7000 and whatever is necessary to have $50 000 saved in five years. Construct a table and a graph that illustrate how the number of years they must wait depends on the amount they save each year. What additional funds per year will allow them to save $50 000 in five years? Use a 10 percent interest rate.

10.24 The Bountiful Bread Company produces home bread-making machines. Currently, it pays a custom moulder $0.19 per piece (not including material costs) for the clear plastic face on the control panel. Demand for the bread-makers is forecast to be 200 000 machines per year, but there is some uncertainty surrounding this estimate. Bountiful is considering installing a plastic moulding system to produce the parts itself. The moulder costs $20 000 plus $7000 to install, and has an expected life of six years. Operating and maintenance costs are expected to be $30 000 in the first year and to rise at the rate of 5 percent per year. Bountiful estimates its capital costs using a declining-balance depreciation model with a rate of 40 percent, and uses a MARR of 15 percent for such investments.

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Determine the total equivalent annual cost of the new moulder. What is the cost per unit, assuming that production is 200 000 units per year? Also, determine the break-even production quantity. That is, what is the production quantity below which it is better to continue to purchase parts and above which it is better to purchase the moulder and make the parts in-house?

10.25 Tenspeed Trucking (TT) is considering the purchase of a new \$65 000 truck. The truck is expected to generate revenues between \$12 000 and \$22 000 each year, and will have a salvage value of \$20 000 at the end of its five-year life. TT pays taxes at the rate of 35 percent. TT is located in Canada and the CCA rate for trucks is 30 percent. TT's after-tax MARR is 12 percent. Find the annual worth of the truck if the annual revenues are \$12 000, and for each \$1000 revenue increment up to \$22 000. What is the break-even annual revenue? Provide a graph to illustrate the break-even annual revenue.

10.26 A new bottle-capping machine costs \$45 000, including \$5000 for installation. Operating and maintenance costs are expected to be \$3000 for the first year, increasing by \$1000 each year thereafter. The salvage value is calculated by straight-line depreciation where a value of zero is assumed at the end of the service life.

(a) Construct a spreadsheet that computes the equivalent annual cost (EAC) for the bottle capper. What is the economic life if the expected service life is 6, 7, 8, 9, or 10 years? Interest is 12 percent.

(b) How sensitive is the economic life to the different length of service life? Construct a sensitivity graph to illustrate this point.

10.27 Sam is considering buying a new lawnmower. He has a choice between a "Lawn Guy" model or a Bargain Joe's "Clip Job" model. Sam has a MARR of 5 percent. The mowers' salvage values at the end of their respective service lives are zero. Sam has collected the following information about the two mowers.

	Lawn Guy	Clip Job
First cost	\$350	\$120
Life	10 years	4 years
Annual gas	\$60	\$40
Annual maintenance	\$30	\$60

Although Sam has estimated the maintenance costs of the Clip Job at \$60, he has heard that the machines have had highly variable maintenance costs. One friend claimed that her Clip Job had maintenance costs comparable to those of the Lawn Guy, but another said the maintenance costs could be as high as \$80 per year. Construct a table that shows the annual worth of the Clip Job for annual maintenance costs varying from \$30 per year to \$80 per year. What Clip Job maintenance costs would make Sam indifferent about the choice between the two mowers, on the basis of annual worth? Construct a graph showing the break-even maintenance costs. Which mower would you recommend to Sam?

10.28 Ganesh is considering buying a \$24 000 car. After five years, he thinks he will be able to sell the car for \$8000, but this is just an estimate that he is not certain about. He is confident that gas will cost \$2000 per year, insurance \$800 per year, and parking \$600 per year, and that maintenance costs for the first year will be \$1000, rising by \$400 per year thereafter.

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The alternative is for Ganesh to take taxis everywhere. This will cost an estimated \$7000 per year. If he has no car, Ganesh will rent a car for the family vacation every year at a total (year-end) cost of \$1000. Ganesh values money at 11 percent annual interest. If the salvage value of the car is \$8000, should he buy the car? Base your answer on annual worth. Determine the annual worth of the car for a variety of salvage values so that you can help Ganesh decide whether this uncertainty will affect his decision. At what break-even salvage value will he be indifferent between taking taxis and buying a car? Construct a break-even graph showing the annual worth of both alternatives as a function of the salvage value of the car. What advice would you give Ganesh?

10.29 A new wave-soldering machine is expected to generate monthly savings of either \$800 000, \$1 000 000, \$1 200 000, or \$1 400 000 over the next two years. The manager is not sure about the likelihood of the four savings scenarios, so she assumes that they are equally likely. What is the present worth of the expected monthly savings? Use a MARR of 12 percent, compounded monthly, for this problem.

10.30 Regional Express is a small courier service. By introducing a new computerized tracking device, it anticipates some increase in revenue, currently estimated at \$2.75 per parcel. The possible new revenue ranges from \$2.95 to \$5.00 per parcel, with probabilities shown in the table below. Assuming that Regional's monthly capacity is 60 000 parcels and the monthly operating and maintenance costs are \$8000, what is the present worth of the expected revenue over 12 months? Regional's MARR is 12 percent, compounded monthly.

Revenue per parcel	\$2.95	\$3.25	\$3.50	\$4.00	\$5.00
Probability	0.1	0.35	0.3	0.15	0.1

10.31 Katrina is thinking about buying an automobile. She figures her monthly payments will be €90 for insurance, €30 for gas, and €20 for general maintenance. The car she would like to buy may last for four, five, or six years before a major repair, with probabilities of 0.4, 0.4, and 0.2, respectively. Calculate the present worth of the monthly expenses over the expected life of the car (before a major repair). Katrina's MARR is 10 percent, compounded monthly.

10.32 Pharma-Excel is a pharmaceutical company. It is currently studying the feasibility of a research project that involves improvement of vitamin C pills. To examine the optimistic, expected, and pessimistic scenarios for this project, it gathered the data shown below. What is the expected annual cost of the vitamin C project? Assume Pharma-Excel's MARR is 15 percent. Note that the lead time is different for each scenario.

	Optimistic	**Expected**	**Pessimistic**
Research and development costs (at the end of research)	\$75 000	\$240 000	\$500 000
Lead time to production (years)	1	2	3
Probability	0.15	0.5	0.35

10.33 Mega City Hospital is selling lottery tickets. All proceeds go to its cancer research program. Each ticket costs \$100, but the campaign catchphrase promises a 1-in-1000

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chance of winning the first prize. The first prize is a "dream" house, which is worth \$250 000. On the basis of decision tree analysis, is buying a ticket worthwhile?

10.34 See Problem 10.33. Determine the price of a ticket so that not buying a ticket is the preferred option and determine the chance of winning so that not buying a ticket is the preferred option.

10.35 Bockville Brackets (BB) uses a robot for welding small brackets onto car-frame assemblies. BB's R&D team is proposing a new design for the welding robot. The new design should provide substantial savings to BB by increasing efficiency in the robot's mobility. However, the new design is based on the latest technology, and there is some uncertainty associated with the performance level of the robot. The R&D team estimates that the new robot may exhibit high, medium, and low performance levels with the probabilities of 0.35, 0.55, and 0.05 respectively. The annual savings corresponding to high, medium, and low performance levels are \$500 000, \$250 000, and \$150 000 respectively. The development cost of the new robot is \$550 000.

(a) On the basis of a five-year study period, what is the present worth of the new robot for each performance scenario? Assume BB's MARR is 12 percent.

(b) Construct a decision tree. On the basis of EV, should BB approve the development of a new robot?

10.36 Refer to Review Problem 10.3 on page 391. Power Tech is still considering the partnership with the Chinese manufacturing company. The analysis in Review Problem 10.3 has shown that the partnership is recommended (by a marginal difference in the expected revenue increase between the two options). Power Tech now wants to further examine the possible shipping delay and quality control problems associated with the partnership. Power Tech estimates that shipping may be delayed 40 percent of the time due to the distance. Independently of the shipping problem, there may be a quality problem 25 percent of the time due to communication difficulties and lack of close supervision by Power Tech. The payoff information is estimated as shown below. Develop a decision tree for Power Tech's shipping and quality control problems and analyze it. On the basis of EV, what is the recommendation regarding the possible partnership?

Shipping Problem	Quality Problem	Gain in Annual Profit
No shipping delay	Acceptable quality	\$ 200 000
No shipping delay	Poor quality	25 000
Shipping delay	Acceptable quality	100 000
Shipping delay	Poor quality	−100 000

10.37 Refer to Problem 10.10. Rockies Adventure Wear, Inc. has upgraded its order-processing centre in order to improve the processing speed and customer access rate. Before completely switching to the upgraded system, Rockies has an option of testing it. The test will cost Rockies \$50 000, which includes the testing cost and loss of business due to shutting down the business for a half-day. If Rockies does not test the system, there is a 55 percent chance of severe failure (\$150 000 repair and loss of business costs), a 35 percent chance of minor failure (\$35 000 repair and loss of business costs), and a 10 percent chance of no failure. If Rockies tests the system, the result can be favourable with the probability of 0.34, which requires no modification, and not favourable with the probability of 0.66. If the test result is not favourable, Rockies has two options: minor modification and major modification. The minor modification costs \$5000 and the major modification costs

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$30 000. After the minor modification, there is still a 15 percent chance of severe failure ($150 000 costs), a 45 percent chance of minor failure ($35 000 costs), and a 40 percent chance of no failure. Finally, after the major modification, there is still a 5 percent chance of severe failure, a 30 percent chance of minor failure, and a 65 percent chance of no failure. What is the recommended action for Rockies, using a decision tree analysis?

More Challenging Problems

10.38 Refer back to Problem 10.22 in which Merry Metalworks is considering two LAN alternatives.

(a) For alternative A, by how much will the installation cost have to rise before the annual worth becomes zero? In other words, what is the break-even installation cost? Is the break-even level within or above the range of likely values Merry Metalworks has specified?

(b) What is the break-even annual benefit for alternative A? Use the average installation costs. Is the break-even level within or above the range of likely values Merry Metalworks has specified?

10.39 Repeat Problem 10.38 for alternative B.

10.40 Refer back to Timely Testing, Problem 10.20.

(a) TT charges $3.25 per board tested. Assuming that costs are as in vendor A's estimates, what production level per year would allow TT to break even if it selects vendor A's equipment? That is, for what production level would annual revenues equal annual costs? Construct a graph showing total revenues and total costs for various production levels, and indicate on it the break-even production level.

(b) Repeat part (a) for vendor B's equipment.

10.41 Your neighbour, Kelly Strome, is trying to make a decision about his growing home-based copying business. He needs to acquire colour copiers able to handle maps and other large documents. He is looking at one set of copiers that will cost $15 000 to purchase. If he purchases the equipment, he will need to buy a maintenance contract that will cost $1000 for the first year, rising by $400 per year afterward. He intends to keep the copiers for five years, and expects to salvage them for $2500. The CCA rate for office equipment is 20 percent.

Rather than buy the copiers, Kelly could lease them for $5500 per year with no maintenance fee. His business volume has varied over the past few years, and his tax rate has varied from a low of 20 percent to a high of 40 percent. Kelly's current cost of capital is 8 percent. Kelly has asked you for some help in deciding what to do. He wants to know whether he should lease or buy the copiers and, moreover, he wants to know the impact of his tax rate on the decision. Evaluate both alternatives for him for a variety of tax rates between 20 percent and 40 percent so that you can advise him confidently. What do you advise?

10.42 Western Insurance wants to introduce a new accounting software package for its human resources department. A small-scale version is sufficient and economical if the number of employees is less than 50. A large-scale version is effective for managing 80 employees or more. All relevant information on the two packages is shown in the following table. Western Insurance's business is growing, and the number of employees has increased from 10 to 40 in the past three years. Construct a graph showing the annual worth of the two software packages as a function of the number of employees ranging from 40 to 100. On the basis of break-even analysis, which accounting package is a better choice for Western Insurance? MARR is 12 percent.

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Parameter		Small-Scale	Large-Scale
First cost ($)		6000	10 000
Training cost at the time of installation ($)		1500	3500
Service life (years)		5	5
Salvage value		0	0
Expected annual savings ($ per employee) if the average number of employees over the next 5 years is:	Less than 50	200	250
	Between 50 and 80	170	300
	Greater than 80	120	400

10.43 Refer to Problem 10.32. As a part of Pharma-Excel's feasibility study, it wants to include information on the acceptance attitude of the public toward the new vitamin C product. Regardless of the optimistic, expected, and pessimistic scenarios for research and development, there is a chance the general public may not feel comfortable with the new product because it is based on a new technology. It estimates that the likelihood of the public accepting the product (and purchasing it) is 33.3 percent and not accepting it is 66.7 percent. The expected annual profit after the research is $1 000 000 if the public accepts the new product and $200 000 if the public does not accept it.

(a) Calculate the annual worth for all possible combinations of three R&D scenarios (optimistic, expected, and pessimistic) and two scenarios for public reaction (accept or not accept). Pharma-Excel's MARR is 15 percent.

(b) Using the annual worth information as the payoff information, build a decision tree for Pharma's problem. Should it proceed with the development of this new vitamin C product?

10.44 Baby Bear Beads (BBB) found itself confronting a decision problem when a packaging line suffered a major breakdown. Ross, the manager of maintenance, Rita, the plant manager, and Ravi, the company president, met to discuss the problem.

Ross reported that the current line could be repaired, but the cost and result were uncertain. He estimated that for $40 000, there was a 75 percent chance the line would be as good as new. Otherwise, an extra $100 000 would have to be spent to achieve the same result.

Rita's studies suggested that for $90 000, the whole line might be replaced by a new piece of equipment. However, there was a 40 percent chance an extra $20 000 might be required to modify downstream operations to accept a slightly different package size.

Ravi, who had reviewed his sales projections, revealed that there was a 30 percent chance the packaging line would no longer be required anyway, but that this wouldn't be known until after a replacement decision was made. Rita then pointed out that there was an 80 percent chance the new equipment she proposed could easily be adapted to other purposes, so that the investment, including the modifications to downstream operations, could be completely recovered even if the line was no longer needed. On the other hand, the repaired packaging line would have to be scrapped with essentially no recovery of the costs.

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The present worth of the benefit of having the line running is \$150 000. Use decision tree analysis to determine what BBB should do about the packaging line.

10.45 Refer to Review Problem 10.3 on page 391. Power Tech feels comfortable about the probability estimate regarding the change in North American demand. However, it would like to examine the probability estimate for Asian demand more carefully. Perform sensitivity analysis on the probability that Asian demand increases. Try the following values, {0.1, 0.2, 0.3, 0.4, 0.5}, in which 0.3 is the base case value. Analyze the result and give a revised recommendation as to Power Tech's possible partnership.

10.46 Refer to Review Problem 10.4 on page 392. LOTell is happy with the decision recommendation suggested by the previous decision tree analysis considering information on market growth. However, LOTell feels that the uncertainty in market growth is the most important factor in the overall decision regarding the introduction of the internet service package. Hence, it wishes to examine the sensitivity of the probability estimates for the market growth. Answer the following questions on the basis of the decision tree developed for Review Problem 10.4.

(a) Let p_1 be the probability of rapid market growth, p_2 be the probability of steady growth, and p_3 be the probability of slow market growth. Express the expected value at Node 2, EV(2), in terms of p_1, p_2, and p_3.

(b) If EV(2) < 10, then the option to introduce the package now is preferred. Using the expression of EV(2) that was developed in part (a), graph all possible values of p_1 and p_2 that lead to the decision to introduce the package now. (You will see that p_3 from part (a) is not involved.) What can you observe from the graph regarding the values of p_1 and p_2?

10.47 SoftWaire Inc., a United States–based software development company, is contemplating outsourcing a portion of its operations to Bangalore, India. The primary attractions for SoftWaire are the lower salaries in India and the availability of English-speaking engineers. The average salary of the 20 people it is thinking of replacing with an offshore operation is US\$75 000 per year, while the salary of a comparable engineer in India is 600 000 rupees. With an exchange rate of 40 rupees per dollar, the salary costs in India are about 20 percent of what they are in the United States. This could bring substantial savings to SoftWaire; however, there appear to be numerous uncertainties associated with outsourcing. You have been asked to conduct an analysis so that SoftWaire Inc. can better understand the potential benefits and risks of the project.

Based on your initial data gathering, you have found the following information.

1. The salaries of software developers in India are indeed lower than those in the United States; however, demand from other local and international employers is strong and is causing salaries to increase at a rate of 10 percent–15 percent per year, with some forecasts as high as 20 percent per year. By comparison, American salaries are expected to grow at a rate of roughly 5 percent per year.
2. Due to the high level of competition for good software developers in India, there is a high turnover rate in the industry. Estimates run from 20 percent to 30 percent. The American market is stable by comparison.
3. Most foreign companies use the services of a recruiter to find suitable employees. Recruiters typically charge a fee of about 30 percent of the salary of the successful employee to solicit applications, screen candidates, and present alternatives for final selection.
4. Training costs for new employees in their first year can be up to 70 percent of their salary for education in best practices and procedures used by the employer. Their

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productivity is typically about 50 percent of a trained employee's due to the learning process.

5. For development outsourcing to be successful, other firms report that they spend considerable time ensuring that software specifications are precise, that quality assurance procedures are clearly spelled out and followed, and that developers adhere to best practices. The cost of this additional project management has been estimated to add 10 percent–20 percent to salary costs.
6. Periodic problems with infrastructure and cultural differences have been reported to reduce overall development productivity to about 70 percent of that in the United States.
7. Setting up an outsourced team can entail considerable start-up costs. Travel, recruiter selection, facilities selection, and equipment installation for a team of 20 can range from \$300 000 to \$500 000.
8. SoftWaire would lay off 20 software engineers at the start of the project. This will cost one year's salary per person.
9. Office space lease costs will be roughly the same whether SoftWaire outsources or not.
10. SoftWaire uses a MARR of 25 percent.
11. The American dollar has fluctuated against the Indian rupee in recent years, and there is some concern that the rupee may strengthen against the dollar by as much as 10 percent in coming years.

You have decided to set up a spreadsheet to help with your analysis. From the information above, you plan to use the following as variables in a sensitivity analysis: (1) salary growth rates for both American and overseas software developers, (2) turnover rate of overseas employees, (3) overseas recruiting costs, as a percent of salary, (4) training costs, as a percent of salary, (5) productivity rate of an employee in training, (6) productivity rate of a trained employee, (7) additional project management costs, as a percent of salary, (8) SoftWaire's MARR, (9) the exchange rate between the rupee and the American dollar (currently 40 rupees per dollar), and (10) start-up costs.

(a) Construct a spreadsheet with the above variables to project the costs of outsourcing for a study period of 10 years. Start with the basic projected salaries, and adjust for recruiting and training costs, then for training and long-term productivity costs, and finally for project management, start-up, and layoff costs. Assume that the overseas developers are hired at time zero. When a range of values has been given for a variable, use the midpoint as the base case.

(b) Determine the present worth of outsourcing.

(c) Determine the present worth of insourcing—that is, using the United States–based developers.

(d) What is the present worth of the benefits of outsourcing?

(e) Using the spreadsheet, conduct a sensitivity analysis for each of the uncertain factors, varying each factor by 10 percent to determine which has the greatest impact on the present worth of the benefits of outsourcing.

(f) What factors have the greatest impact on the present worth of the benefits of outsourcing? What would you advise at this point?

(g) At what exchange rate would the present worth of outsourcing be zero?

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(h) At what productivity rate would the present worth of outsourcing be zero?

(i) Drawing on specific examples from this problem, describe some of the drawbacks of sensitivity analysis when making the decision to outsource or not.

MINI-CASE 10.1

China Steel Australia Limited

Stainless steel is an alloy of iron, chromium, and other metals. It has valuable uses for applications where strength and resistance to corrosion are important. Uses include kitchen cookware, surgical tools, building structures, aircraft, food processing equipment, and automotive components.

There are numerous grades of stainless steel, depending on the needs of the particular application. They vary by the alloying elements and the consequent crystalline structure of the steel. About 70 percent of stainless steel production, on a global basis, is *austenitic* stainless steel, which is composed of a maximum of 0.15 percent carbon and a minimum of 18 percent chromium, along with a significant percentage of nickel. A typical grade used for household flatware has 18 percent chromium and 10 percent nickel, for example.

In recent years, the cost and availability of nickel have created a bottleneck for stainless steel producers. There are a limited number of nickel ore deposits, and the majority of deposits consist of *laterite* nickel ore, which is generally not used for producing refined nickel because of its low nickel content.

China Steel has a plant in Linyi, Shandong Province, China, that produces nickel pig iron from laterite nickel ore. This nickel pig iron contains 5 percent–11 percent nickel, which can substitute for refined nickel in the production of austenitic stainless steel. The growth of Chinese manufacturing has created very strong demand for stainless steel in general, and for China Steel's nickel pig iron in particular. The Linyi plant is running at full capacity and has offtake commitments in place for the next five years. There is currently a substantial demand for nickel pig iron that cannot be met. Consequently, China Steel wants to expand its plant to increase capacity in order to take advantage of this opportunity.

In February 2008, China Steel released a prospectus seeking investors to fund its expansion plans. A prospectus is a document that lays out an investment opportunity according to specific rules legislated to ensure that potential investors are treated fairly. The prospectus in this case sought AUS$15 000 000 (Australian dollars) to provide a foundation for plant expansion by setting up a structure that would facilitate access to capital markets in Australia and elsewhere.

In order to demonstrate the economic viability of the company, the prospectus included a forecast of earnings for 2008. The forecast was based on expected costs and revenues, barring unusual deviations in the economic and competitive environment. Under these conditions, the profit after income tax expenditures for 2008 was estimated to be AUS$12 304 000.

However, to enrich this estimate, the prospectus also shows the effect of changes in key assumptions on the estimated profit..

Discussion

Predicting the future can never be done with complete assurance because everything is uncertain. We can only make our best guess at the future, recognizing that things might turn out differently than we thought.

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Table 10.10 Sensitivity Analysis for China Steel Australia

Parameter	Variation	Increase ($)	Decrease ($)
Revenue	10% change	2 105 000	–2 105 000
Cost of sales	10% change	–1 185 000	1 185 000
Administrative expenses	10% change	–102 000	102 000
Corporate overheads	10% change	–51 000	51 000
Cost of borrowing	1%	442 000	–461 000
Australian dollar/yuan exchange rate	10% change	–745 000	909 000

Engineering design often assumes that the world is much simpler than it really is. When an engineer designs a roof truss, for example, he or she often assumes that the lumber making up the truss will behave in a standard, predictable manner. Similarly, the engineer who designs a circuit will assume that the electrical components will behave according to their nominal values. But lumber is a natural product, and individual pieces will be weaker or stronger than expected. Electrical components, similarly, will have actual values and behaviour different, in general, from their nominal values and mathematical models.

Good engineers understand this and design accordingly. The truss builder specifies a certain grade of lumber or makes sure that redundant support is built into the design. The circuit designer similarly specifies the tolerances of significant components, or designs the circuit in a robust way.

The role of sensitivity analysis in economic studies is exactly the same. We don't know the cash flow of a project exactly, just as we don't know the behaviour of a piece of wood or a circuit component exactly. We want to design the project to control the uncertainty of the economic elements as well as the physical ones. In the China Steel Australia prospectus, the expected future was insufficient to adequately explain what a prospective investor might expect in terms of financial performance. This needed to be augmented by explaining the effects of variations on this future view.

Questions

1. Most of the changes made by China Steel were for plus or minus 10 percent. Does this make sense? If not, what amounts would have been a better choice? Why was the variation on the cost of borrowing only 1 percent?
2. It is clear that a 10 percent change in revenue has the biggest effect on profit. Does it necessarily mean that this is also the biggest risk to China Steel's viability as a company?
3. If you were considering investing in China Steel, what would you do to help reduce the uncertainty of the investment?
4. Derek has been assigned the task of designing a parking facility for an insurance company. He must keep in mind a number of different issues, including land acquisition costs, building costs (if a parking building is required), expected usage, fee method (monthly fees, hourly fees, or in-and-out fees), whether the company will subsidize the facility in part or completely, etc. His boss is particularly concerned about reducing the uncertainty of the future cash flows associated with the project. How would you advise Derek?

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Appendix 10A Decision Matrices

Most of this book has been concerned with making decisions based on a single economic measure such as present worth, annual worth, or internal rate of return. This is natural, since many of the decisions that are made by an individual, and most that are made by businesses, have the financial impact of a project as a primary consideration. However, rarely are costs and benefits the only consideration in evaluating a project. Sometimes other considerations are paramount.

For decisions made by and for an individual, cost may be relatively unimportant. One individual may buy vegetables on the basis of their freshness, regardless of the cost. A dress or suit may be purchased because it is fashionable or attractive. A car may be chosen for its comfort and not its cost.

Traditionally, firms were different from individuals in this way. It was felt that all decisions for a firm *should* be made on the basis of the costs and benefits as measured in money (even if they sometimes were not, in practice), since the firm's survival depended solely on being financially competitive.

Society has changed, however. Companies now make decisions that apparently involve factors that are very difficult to measure in monetary terms. Money spent by firms on charities and good causes provides a benefit in image that is very hard to quantify. Resource companies that demonstrate a concern for the environment incur costs with no clear financial benefit. Companies that provide benefits for employees beyond statute or collective agreement norms gain something that is hard to measure.

The fact that firms are making decisions on the basis of criteria other than only money most individuals would hail as a good thing. It seems to be a good thing for the companies, too, since those that do so tend to be successful. However, it can make the process of decision making more difficult, because there is no longer a single measure of value.

Money has the convenient feature that, in general, more is better. For example, of several mutually exclusive projects (of identical service lives), the one with the highest present worth is the best choice. People prefer a higher salary to a lower one. However, if there are reasons to make a choice other than just the cost, things get somewhat more difficult. For example, which is better: the project with the higher present worth that involves clear-cutting a forest, or the one with lower present worth that preserves the forest? Does a high salary compensate for working for a company that does business with a totalitarian government?

Although such considerations have had particular influence in recent years, the problem of including both qualitative *and* quantitative criteria in engineering decisions has always been present. This leads to the question of how a decision maker deals with multiple objectives, be they quantitative or qualitative.

One approach to choosing the best alternative is to put numerical weights on the criteria. For example, if cost were most important, it would have a high weight, while a less important criterion might be given a low weight. If criteria are evaluated according to a scale that can be used directly as a measure of preference, then the weights and preference measures can be combined mathematically to determine a best alternative.

In a **decision matrix**, the rows of the matrix represent the criteria and the columns the alternatives. There is an extra column for the weights of the criteria. The cells of the matrix (other than the criteria weights) contain an evaluation of the alternatives on a scale from 0 to 10, where 0 is worst and 10 is best. The weights are chosen so that they sum to 10.

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The following algorithm can be used:

1. Give a weight to each criterion to express its relative importance: the higher the weight, the more important the criterion. Choose the weight values so that they sum to 10.
2. For each alternative, give a rating from 0 to 10 of how well it meets each criterion. A rating of 0 is given to the worst possible fulfillment of the criterion and 10 to the best possible.
3. For each alternative, multiply each rating by the corresponding criterion weight, and sum to give an overall score.
4. The alternative with the highest score is best. The value of the score can be interpreted as the percentage of an ideal solution achieved by the alternative being evaluated.
5. Carry out some sensitivity analysis with respect to weights or rating estimates to verify the indicated decision or to determine under which conditions different choices are made.

Example 10A.1

Skiven is evaluating surveillance cameras for a security system. The criteria he is taking into account, in order of importance for him, are low-light performance, picture clarity, weight, and price. The details for six models are shown in Table 10A.1. Which model is best?

In order to follow the steps given above, we need to determine the criteria weights. It is usually fairly easy for a decision maker to determine which criteria are more important than others, but generally more difficult to specify particular weights. There exist many formal methods for establishing such weights in a rigorous way, but in practice, estimating weights on the basis of careful consideration or a discussion with the decision maker is sufficient. Recall that a sensitivity analysis forms part of the overall decision process, and this compensates somewhat for the imprecision of the weights.

Skiven suggests that weights of 1, 1.5, 3.5, and 4 for price, weight, picture clarity, and low-light performance, respectively, are appropriate weights for this problem. These weights are listed as the second column of Table 10A.2.

Table 10A.1 Set of Surveillance Camera Alternatives

Camera	Price ($)	Weight (Grams)	Picture Clarity (0–10 Scale)	Low-Light Performance (0–10 Scale)
1	230	900	3	6
2	243	640	5	4
4	313	433	5	7
6	415	330	6	6
7	418	552	7	5
10	765	255	9	5

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Table 10A.2 Decision Matrix for Example 10A.1

Criterion	Criterion Weight	Alternatives 1	2	4	6	7	10
Price	1.0	10.0	9.8	8.4	6.5	6.5	0.0
Weight	1.5	0.0	4.0	7.2	8.8	5.4	10.0
Clarity	3.5	3.0	5.0	5.0	6.0	7.0	9.0
Low-light performance	4.0	6.0	4.0	7.0	6.0	5.0	5.0
Score	10.0	44.5	49.3	64.8	64.8	59.1	66.5

The ratings for each alternative for picture clarity and low-light performance are already on a scale from 0 to 10, so those ratings can be used directly. To select ratings for the price and weight, two different measures could be used.

1. *Normalization:* The rating r for the least preferred alternative (α) is 0 and the most preferred (β) is 10. For each remaining measure (γ) the rating r can be determined as

   $$r = 10 \times \frac{\gamma - \alpha}{\beta - \alpha}$$

   For this problem, the rating of alternative 6 for price would be

   $$r_{6,price} = 10 \times \frac{415 - 765}{230 - 765} = 6.54$$

   The advantage of normalization is that it provides a mathematical basis for the rating evaluations. One disadvantage is that the rating may not reflect the value as perceived by the decision maker. A second disadvantage is that it may overrate the best alternative and underrate the worst, since these are set to the extreme values. A third disadvantage is that the addition or deletion of a single alternative (the one with the highest or lowest evaluation for a criterion) will change the entire set of ratings.

2. *Subjective evaluation:* Ask the decision maker to rate the alternatives on the 0 to 10 scale. For example, asked to rate alternative 6 for cost, Skiven might give it a 7. The advantages of subjective evaluation include the fact that it is relatively immune to changes in the alternative set, and that it may be more accurate since it includes perceptions of worth that cannot be directly calculated from the criteria measures. Its main disadvantage is that people often make mistakes and give inconsistent evaluations.

For the ratings shown in Table 10A.2, the normalization process was used. The overall score is then calculated by summing for each alternative the rating for a criterion multiplied by the weighting for that criterion. From Table 10A.2, the total score for alternative 1 is calculated as

$$1 \times 10 + 1.5 \times 0 + 3.5 \times 3 + 4 \times 6 = 44.5$$

It can be seen in Table 10A.2 that the highest score is for alternative 10. This means essentially that the greatest total benefit is achieved if alternative 10 is taken.

Also note that a "perfect" alternative—that is, one that rated 10 on every criterion—would have a total score of 100. Thus the 66.5 score for alternative 10 means that it is

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only about 66.5 percent of the score of a perfect alternative. The practice of making weights sum to 10 and rating the alternatives on a scale from 0 to 10 is done specifically so that the resulting score can be interpreted as a percentage of the ideal; if this is not desired, any relative weights or rating scale can be used.

Alternative 10 is the best choice for the particular weights and ratings given, but some sensitivity analysis should be done to verify its robustness. There are several ways to do this sensitivity analysis, but the most sensible is to vary the weights of the criteria to see how the results change. This is easy to do when a spreadsheet is being used to calculate the scores.

Table 10A.3 Sensitivity Analysis for the Surveillance Camera

Criterion	Criterion Weights						
Price	1	1	1	1	2	2.5	1
Weight	1.5	2	1	2	2	2.5	1
Picture clarity	3.5	3	3	2	2	2.5	4
Low-light performance	4	4	5	5	4	2.5	4
Alternative	**Alternative Scores**						
Camera 1	44.5	43.0	49.0	46.0	50.0	47.5	46.0
Camera 2	49.3	48.8	48.8	47.8	53.6	57.0	49.8
Camera 4	64.8	65.9	**65.7**	**67.9**	**69.4**	67.2	63.7
Camera 6	64.8	66.2	63.4	66.2	66.8	**68.4**	63.4
Camera 7	59.1	58.3	57.9	56.3	57.8	59.7	59.9
Camera 10	**66.5**	**67.7**	62.0	63.6	58.0	60.0	**66.0**

Table 10A.3 shows a range of criteria weights and the corresponding alternative scores. It can be seen that cameras 4 and 6 can also be identified as best in some of the criteria weight possibilities. For the final recommendation, it may be necessary to review these results with Skiven to let him determine which of the weight possibilities are most appropriate for him. ■

As has been seen in Example 10A.1, the decision matrix approach structures information about multiple objectives of the problem. An additive utility model permits the calculation of an overall score for each alternative. A comparison of the scores permits the best one to be selected. Doing a sensitivity analysis may reveal promising alternatives from relatively small changes in the alternative weight assumptions.

PROBLEMS

10A.1 A large city's transit commission is considering building a new subway line. Twelve alternatives are being considered. All the alternatives are shown in the tables, along with their criteria values. The relevant criteria are:

C1 Population and jobs served per kilometre

C2 Projected daily traffic per kilometre

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C3 Capital cost per kilometre (in millions of dollars)

C4 IRR

C5 Structural effect on urbanization

It is desirable to have high population served, high traffic, low capital cost per kilometre, and a high IRR. Criterion C5 concerns the benefits for urban growth caused by the subway location and is measured on a scale from 0 to 10, with the higher values being preferred.

Alternative Subway Lines

	A	B	C	D	E	F	G
C1	81 900	36 500	31 800	28 200	31 100	16 100	11 500
C2	25 500	10 300	11 600	7 400	10 500	3 500	7 100
C3	65	13.2	45	30	35	10	29
C4	8.6	3	6.3	6	14.1	11.8	4.5
C5	3	6	7	10	6	4	4

(a) Establish ratings for a decision matrix for each of the subway line alternatives through normalization. The weights of the five criteria are C1: 1.5, C2: 2, C3: 2.5, C4: 3, C5: 1. Construct a decision matrix and determine the best subway route.

(b) If the criteria weights were C1: 2, C2: 2, C3: 2, C4: 2, C5: 2, would the recommended alternative be different?

10A.2 Francis has several job opportunities for his co-op work term. He would like a job with good pay that is close to home, contributes to his engineering studies, and is with a smaller company.

	Criteria			
Job	**Pay**	**Home**	**Studies**	**Size**
1. Spinoff Consulting	1700	2	3	5
2. Nub Automotive	1600	5	3	500
3. Soutel	2200	80	4	150
4. Turbine Hydro	1800	100	3	3000
5. Fitzsimon Associates	1700	100	1	20
6. General Auto	2000	150	2	2500
7. Ring Casper	2200	250	5	300
8. Jones Mines	2700	500	3	20
9. Resources, Inc.	2700	2000	2	40

Pay: Monthly salary in dollars
Home: Distance from home in kilometres
Studies: Contribution to engineering studies, 0 = none, 5 = a lot
Size: Number of employees at that location

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(a) Some of these alternatives can immediately be removed from further consideration. For example, the job with Nub Automotive (Job 2) is worse in all respects than the one with Spinoff Consulting (Job 1). It is said that Job 1 dominates Job 2. Only four of these 10 alternatives cannot be dominated by another. Which are the four jobs that Francis should consider further?

(b) Francis feels that the following weights can represent the importance of his four criteria:

Pay:	4.0
Home:	2.5
Studies:	2.0
Size:	1.5

Using normalization to establish the ratings, which job is best?

ENGINEERING ECONOMICS IN ACTION, PART 10C

Moving On

Three weeks later, Naomi was seated in Anna Kulkowski's office. The Powerluxe project report had been submitted two days before.

"Naomi, the work you and Bill did and your report are first-rate," Anna said. "We're going to finalize our negotiations with Powerluxe to bring the Adaptamatic line of vacuum cleaners to market. I had no idea anybody could make such clear recommendations on such a complex problem. Congratulations on a good job."

Naomi thought back on all the people who had helped her in her almost two years at Canadian Widgets—how Clem had taught her practical problem solving, how Dave had shown her the ropes, and how Terry had helped her realize the benefits of attention to detail. Bill had shown her how the real world mixes engineering with marketing, business, and government. Anna, too, had shown her how to manage people. "Thank you very much, Ms. Kulkowski," Naomi responded, a small break in her voice betraying her emotion.

"Do you enjoy this kind of work?" Anna asked.

"Yes, I do," Naomi replied. "It's exciting to see how engineering relates to everything else."

"I think we have a new long-term assignment for you," Anna said. "This is just the first step for Canadian Widgets in developing new products. We have a first-rate team of engineers. We want to make better use of them. Ed Burns is going to head up a product development group. He read your report on the Adaptamatic line of vacuum cleaners and was quite impressed. He and I would like you in that development group. We need someone with analytic skills who can manage projects and who can understand the marketing side, too. What do you say?"

"I'm in!" Naomi had a big grin on her face.

A few days later, Naomi answered the phone.

"Hey, Naomi, it's Terry. I hear you got promoted!"

"Hi, Terry. Nice to hear from you. Well, the money's about the same, but it sure will be interesting. How are things with you?" Naomi had fond memories of working with Terry.

"Well, I graduate next month and I have a job. Guess where?"

Naomi knew exactly where; Clem had told her about the interviews. It wasn't really fair to the other candidates—Clem had decided to hire Terry as soon as he applied. "Here? Really?"

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Risk Management

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PROJECT PROFILE

The Building That Melted Cars

Driving a car in London just got a lot more dangerous. A soon-to-be-completed skyscraper in the downtown area is having an impact that no one could have imagined: It is starting fires and melting cars. The building—designed by internationally renowned architect Rafael Viñoly—is a dramatic edifice with curved exterior walls. Built at 20 Fenchurch Street in London's financial center, the 38-story skyscraper is known locally as "the Walkie-Talkie" for its unusual shape. But that curvilinear shape is exactly what's causing the problem: The south-facing exterior wall is covered in reflective glass, and because it's concave, it focuses the sun's rays onto a small area, not unlike the way a magnifying glass directs sunbeams onto a superhot pinpoint of light.

"Fundamentally it's reflection. If a building creates enough of a curve with a series of flat windows, which act like mirrors, the reflections all converge at one point, focusing and concentrating the light," says Chris Shepherd, from the UK's Institute of Physics. "It's like starting a fire with a parabolic mirror."

The beam caused by the curved skyscraper concentrating the sun's rays was measured at more than 110 degrees Celsius (230 degrees Fahrenheit) in September. So far, the building has been responsible for partially destroying a parked Jaguar XJ luxury car, catching carpets on fire in nearby shops, and shattering slate tiles at local restaurants. This situation is likely to be a recurring problem for any structure built within range of the powerful reflected light coming from the building.

Because the effect is caused by the sun's elevation in the sky at certain times of the day and during a specific time of the year, experts expect the intense light and dangerous heating effect will last about two hours a day over a period of three weeks. To help in the short term, the building's owners have contracted with local authorities to block off a limited number of parking spaces that are right in the reflected beam's path. Longer term solutions are more problematic; the design of the building will not change and of course, the sun's path is not likely to alter in the near future!

Figure 11.1 London's Walkie-Talkie Building

Source: Lionel Derimais/Corbis

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This isn't the first time Viñoly's architecture has been the subject of similar controversy: His Vdara Hotel in Las Vegas has been criticized for directing sunbeams onto the swimming pool deck that are hot enough to melt plastic and singe people's hair. The technical term for the phenomenon is a solar convergence, but the hotspot more popularly became known as the "Vdara death ray." The Vdara resolved the "death ray" effect with larger sun umbrellas, but fixing the problem in London might take a lot more work. "There are examples in the past where an architect has had to rebuild the façade," said Philip Oldfield, an expert in tall buildings at the University of Nottingham's Department of Architecture. "If this is serious, then I dread to think how expensive it will be."

Architectural critic Jonathan Glancey says the story is not unprecedented. In 2003, the opening of the Walt Disney Concert Hall in Los Angeles, designed by architect Frank Gehry, had a similar problem. "The building was clad from head to toe, right down to the pavement, in stainless steel panels, and they would send the sun dazzling across the sidewalks to hotspots where people were. It was measured up to 60C (140F). Local people living there complained they were having to crank their air conditioning up to maximum to cool things down," he says. Blinding glare also affected drivers passing the building. After computer models and sensor equipment identified the panels causing the problem, they were sanded down to break up the sun's rays.

In the case of the London Walkie-Talkie building, developers could employ a number of possible solutions. "They could coat the windows to reduce reflection—which would be a cheap fix—but the downside of that is it could reduce the light entering the building. Another solution would be for them to misalign the window frames, to slightly alter them by about a millimeter, but that would be very expensive," Chris Shepherd noted.[1]

11.1 Introduction

Projects operate in an environment composed of uncertainty. There is uncertainty regarding project funding, the availability of necessary resources, changing client expectations, potential technical problems—the list is seemingly endless. This uncertainty forms the basis for project risk and the need to engage in risk management. **Risk management,** which recognizes the capacity of any project to run into trouble, is defined as the art and science of identifying, analyzing, and responding to risk factors throughout the life of a project and in the best interests of its objectives. The difference between projects that fail and those that are ultimately successful has nothing to do with the fact that one lacks problems the other has. The key lies in the plans that have been made to deal with problems once they arise. The Project Management Institute defines **project risk** as "an uncertain event or condition that, if it occurs, has a positive or negative effect on one or more project objectives such as scope, schedule, cost, or quality. A risk may have one or more causes and if it occurs, may have one or more impacts." This definition is important because, unlike the past, when project risk was automatically assumed to lead to negative consequences, it is now recognized as the source of either opportunities *or* threats. As a result, whereas in the past leading project management researchers assumed that project risk was "an estimate of the probability of loss from a large population of unwanted circumstances,"[2] risk in the modern sense argues that the uncertainty that exists in any project can result in either positive or negative outcomes. Project managers must acknowledge the possibility that the same risk event may bring several outcomes, of both a positive and detrimental effect on the project. Underlying these definitions is the recognition that many events, both within the organization and outside its control, can affect our best efforts to successfully complete projects.

Risk management consists of anticipating, at the beginning of the project, unexpected situations that may arise that are beyond the project manager's control. These situations

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have the capacity to severely undermine the success of a project. Broadly speaking, for the manager, the process of risk management includes asking the following questions:

- What is likely to happen (the probability and impact)?
- What can be done to minimize the probability or impact of these events?
- What cues will signal the need for such action (i.e., what clues should I actively look for)?
- What are the likely outcomes of these problems and my anticipated reactions?

This chapter will explore the concept of project risk management in detail. We will address some of the principal sources of uncertainty, and hence risk, in projects. The chapter will also provide information on identifying the key steps to consider in formulating project risk management processes, methods for assessing risk impact, and processes for mitigating negative effects.

Project risk is based on a simple equation:

Event Risk = (Probability of Event) (Consequences of Event)

In other words, all risks must be evaluated in terms of two distinct elements: the likelihood that the event is going to occur as well as the consequences, or effect, of its occurrence. The risk of a project manager in your company being struck by lightning on the way to work would clearly constitute a high level of consequence to the project, but the probability of such an occurrence is sufficiently low to minimize your need to worry about it. On the other hand, people do change jobs, so an event such as the loss of a key project team member midway through the development phase may have both a potentially serious impact and a high degree of probability in some organizations. Hence, in those project environments, it would be appropriate to develop mitigation strategies to address this risk, given its high likelihood of occurring and the negative consequences it would engender. For example, the project manager could develop a bonus or other incentive program to reward personnel who remain on the project team as a useful response (risk mitigation) for the potential loss of key personnel during the project.

Risk and opportunity are mirror opposites of the same coin—opportunity emerges from favorable project uncertainties and negative consequences from unfavorable events. Figure 11.2 illustrates the dynamics of risk and opportunity over the project life cycle compared to the severity of negative consequences. Early in the life of a project, both risk and opportunity are high. The concept may be thought valuable, and the opportunities are strong, as are the negative risks. This result is due to the basic uncertainty early in a project's life cycle. Until we move forward into the development phases, many unanswered questions remain, adding to overall project uncertainty. On the other hand, the severity of negative consequences (the "amount at stake") is minimal early in the project's life. Few resources have yet been committed to the project, so the company's exposure level is still quite low. As the project progresses and more budget money is committed, the overall potential for negative consequences ramps up dramatically. At the same time, however, risk continues to diminish. The project takes on a more concrete form and many previously unanswered questions ("Will the technology work?" "Is the development time line feasible?") are finding answers. The result is a circumstance in which overall opportunity and risk (defined by their uncertainty) are dropping just as the amount the company has at stake in the project is rising.

The periods of greatest worry shown in Figure 11.2 are the execute and finish stages, at which point uncertainty is still relatively high and the amount at stake is rapidly increasing. The goal of a risk management strategy is to minimize the company's exposure to this unpleasant combination of uncertainty and potential for negative consequences.

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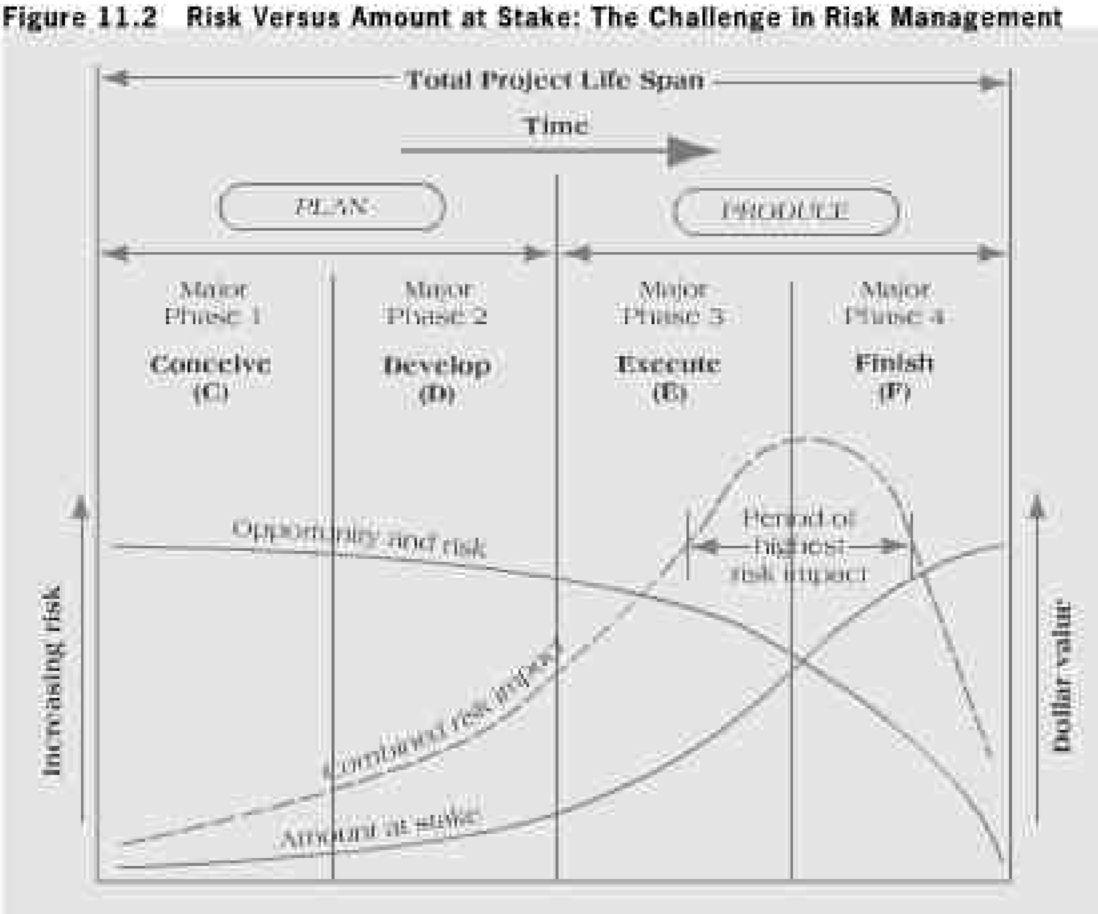
Figure 11.2 Risk Versus Amount at Stake: The Challenge in Risk Management



Source: R. Max Wideman. (2004). *A Management Framework for Project, Program and Portfolio Integration.* Victoria, BC, Canada, 2004. Copyright © 2004 by R. Max Wideman, AEW Services Vancouver, BC, Canada: Trafford Publishing. Figure from page 64. Reproduced with permission of R. Max Wideman.

BOX 11.1

Project Managers in Practice

Mathew Paul, General Electric Company

Mathew Paul is the Program Leader for Liquefied Natural Gas (LNG) Locomotives at GE Transportation in Erie, PA. He is currently responsible for leading the introduction of GE's natural gas locomotives for domestic markets from the Engineering function. Mathew completed his Bachelor's in Mechanical Engineering from The University of Kerala, India, in 1998. After a short stint at Cochin Port Trust and Lucent Technologies in India, he decided to pursue his Master's in Mechanical Engineering at The University of Alabama, Tuscaloosa. He also holds a Master's in Business Administration from Fogelman's College of Business at The University of Memphis, Tennessee. He is PMP certified and a Six Sigma Green Belt.

Mathew's career started as an Engineer at Cummins working on new internal combustion engine introduction projects to meet customer requirements and environmental regulations. His specific job was to identify combustion recipes and meet engine performance requirements. However, during the recession of 2008, he was given the responsibility of leading cost reductions as well as identifying profitable projects for the business.

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Identifying components that either need to be avoided in the engine or redesigned to gain economies of scale was not an easy task due to the wide application and customer base. Project management methodologies had to be implemented to execute the tasks and show the benefits to customers. It was in meeting these challenges that Mathew learned the art of project management and decided to switch careers to project management.

In 2010, Mathew led the introduction of a low-cost Cummins fuel injection system in China for the trucking market to capture market share and reduce dependence on other firms' products. It was the first of its kind for Cummins Fuel Systems and the team quickly realized that a different approach was required to be successful in China. His specific tasks included managing a project comprised of people from both China and the United States in designing, developing, testing, and manufacturing the fuel system. Due to the magnitude of the project, project management methodologies were introduced for the first time at Cummins Fuel Systems. In his words, "The main challenge was to use the data-based approach in communicating with customers, suppliers, and team members as the Chinese culture is mostly customer-centric and saying 'no' was never appreciated. The profit margin per unit was very low and business was based on volume. Maintaining risks—both in quality and cost—was critical for the success of the project."

After the successful implementation of the low-cost fuel system for Cummins, Mathew moved to GE Transportation to introduce PowerHaul™ locomotives in Australia and Korea. Paul recounts, "Even though the product was similar, the challenges were different—while meeting tight schedules was critical for Australia, maintaining customer relations and the highest quality were primary requirements for Korea." Mathew was also tasked to lead GE Transportation's first natural gas locomotive project for domestic markets. Due to the availability of shale gas in the United States, the move to natural gas as the predominant fuel for locomotives seemed a logical next step. However, being a new technology, the safety of personnel and environment was considered as the paramount cri-

Figure 11.3 An Example of the Next-Generation GE Locomotives That Mathew Paul Supports

Source: Sean Gallup/Getty Images

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teria. "The project was huge as part of my job involved coordinating the work of 250 people from five different countries with an initial investment of over $70 million dollars. We constructed and followed risk analysis and risk mitigation plans that had to be constantly updated—pretty much every day—due to the nature of the project. The project was capital intensive and eagerly awaited by customers, government, and competitors."

Mathew recollects that every project to date had been different and that makes it critical to follow a project management methodology for standard guidelines. He notes that planning is critical for the success of the project and executing the plan is essential; however, the key for any project manager is to have a "sixth" sense about potential risks and be able to respond to it at the earliest. Even with these challenges, the final outcome for any project manager is very fulfilling. "When the first natural gas locomotive was cranked and pulled the load at the desired speed, my eyes watered with joy. I got to experience several firsts in my life. When the first Cummins Tier 3 19L engine was rolled out of their Seymour engine plant, when the first fuel system rolled out of Cummins Wuhan plant, and when the first PowerHaul™ GE engine was unveiled at the customer property in Australia, to cite a few." As Paul has found, that is the moment when years of hard work, volumes of documentation, and hours of meeting converge and only a project manager can envision the final product and strive towards attaining the same on a daily basis.

11.2 Risk Management: A Four-Stage Process

Systematic risk management comprises four distinct steps:

- **Risk identification**—the process of determining the specific risk factors that can reasonably be expected to affect your project.
- **Analysis of probability and consequences**—the potential impact of these risk factors, determined by how likely they are to occur and the effect they would have on the project if they did occur.
- **Risk mitigation strategies**—steps taken to minimize the potential impact of those risk factors deemed sufficiently threatening to the project.
- **Control and documentation**—creating a knowledge base for future projects based on lessons learned.

11.2.1 Risk Identification

A useful method for developing a risk identification strategy begins by creating a classification scheme for likely risks. Remember that risk implies the potential for both positive and negative effects on the project. Risks commonly fall into one or more of the following classification clusters:[3]

- **Financial risk**—Financial risk refers to the financial exposure a firm opens itself to when developing a project. If there is a large up-front capital investment required, as in the case of Boeing or Airbus Industries' development of a new airframe, the company is voluntarily assuming a serious financial risk in the project. Construction companies building structures "on spec" provide another example. Without a contracted buyer prior to the construction, these companies agree to accept significant financial risk in the hopes of selling office space or the building itself after it is completed.
- **Technical risk**—When new projects contain unique technical elements or unproven technology, they are being developed under significant technical risk.

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Naturally, there are degrees of such risk; in some cases, the technical risk is minimal (modifications to an already-developed product), whereas in other situations the technical risk may be substantial. For example, Goodrich Corporation developed a modification to its electronic hoist system, used for cable hoists in rescue helicopters. Because the company had already developed the technology and was increasing the power of the lift hoist only marginally, the technical risk was considered minimal. On the other hand, the Spanish ship-builder Navantia is currently wrestling with serious performance problems in its newest generation of submarine, the S-80 class, because of the decision to include too many ground-breaking technical upgrades in one ship. The problems with the S-80 are so severe that the submarine itself is considered unsafe and not ready for sea trials (see Case Study 11.2 at the end of the chapter). The greater the level of technical risk, the greater the possibility of project underperformance in meeting specification requirements.

- **Commercial risk**—For projects that have been developed for a definite commercial intent (profitability), a constant unknown is their degree of commercial success once they have been introduced into the marketplace. Commercial risk is an uncertainty that companies may willingly accept, given that it is virtually impossible to accurately predict customer acceptance of a new product or service venture.
- **Execution risk**—What are the specific unknowns related to the execution of the project plan? For example, you may question whether geographical or physical conditions could play a role. For example, developing a power plant on the slopes of Mount Pinatubo (an active volcano) in the Philippines would involve serious execution risks! Likewise, poorly trained or insufficient project team personnel might constrain project execution. Execution risk is a broad category that seeks to assess any *unique* circumstances or uncertainties that could have a negative impact on execution of the plan.
- **Contractual or legal risk**—This form of risk is often consistent with projects in which strict terms and conditions are drawn up in advance. Many forms of contracted terms (e.g., cost-plus terms, fixed cost, liquidated damages) result in a significant degree of project risk. Companies naturally seek to limit their legal exposure through legal protection, but it is sometimes impossible to pass along contractual risk to other parties. For example, most U.S. railroads will not accept penalty clauses for late deliveries of components because they have an almost monopolistic control of the market. Therefore, organizations utilizing rail transportation must accept all delivery risk themselves.

After understanding the broad categories of risk, you want to anticipate some of the more common forms of risk in projects. The following list, though not inclusive, offers a short set of some of the more common types of risk to which most projects may be exposed:

- Absenteeism
- Resignation
- Staff being pulled away by management
- Additional staff/skills not available
- Training not as effective as desired
- Initial specifications poor or incomplete
- Work or change orders multiplying due to various problems
- Enhancements taking longer than expected

Although the broad categories and common types of risk in the preceding lists are both good starting points, you also need to consider common industry-specific risks that run across different types of projects in the specific field in which you are working. A num-

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ber of methods, both qualitative and quantitative, are available for conducting risk factor identification for industry-specific risks, including:

- ***Brainstorming meetings***—Bringing the members of the project team, top management, and even clients together for a brainstorming meeting can generate a good list of potential risk factors. Brainstorming is a qualitative idea-creation technique, not one focused on decision making. In order to be effective, brainstorming meetings must be free of judgments, criticism of others' viewpoints, and pressure to conform. A mini-scenario of risk management is at work. Think about it: Would you be willing to place your most creative ideas on the table in front of 10 other people if you were at risk of being immediately critiqued? Or might you be tempted to hold an idea for later if your boss required that you present it in a fully developed way? In short, the brainstorming environment needs to be made safe for the risk-averse.
- ***Expert opinion***—This technique can be used in two alternative ways in assessing project risks. The more quantifiable method, commonly referred to as the Delphi approach, collects and consolidates the judgments of isolated anonymous respondents. For Delphi to be used effectively, some preliminary screening of potential contributors is usually necessary. The collective "wisdom" of the set of experts is then used as the basis for decision making. The simpler, more intuitive method for using expert judgments is based on the principle that "experience counts." You simply identify and consult people within the organization who have had similar experiences in running projects in the past or who have been with the firm long enough to have a clear grasp of the mechanics of project risk analysis. As obvious as this may seem, this opportunity may not be clear to everyone, particularly if management shifts recently have taken place in a firm or if new employees are not aware of the firm's project history.
- ***History***—In many cases the best source of information on future risks is history. Has a firm encountered a consistent pattern of problems while pursuing projects over time? What "storm signals," or events that have preceded past problems, have been detected? Experience can be used to identify not only risk factors but their leading indicators as well. The problem with experience is that it is no guarantee of future events. The issues or conditions that contributed to project risk in the past decade, year, or even month may not be relevant to current market conditions or the state of project work as it is now being conducted. Hence, history can be useful for identifying key project risk factors provided all parties employ a reasonable degree of caution when evaluating current projects through the portal of past events. Rauma Corporation of Finland, for example, developed state-of-the-art logging equipment that worked well in locations with good infrastructure to allow for frequent servicing. When it attempted to use the equipment in remote rain forest regions of Indonesia, however, the company found it had not anticipated the problems involved in routine servicing, including having to fly the machinery hundreds of miles out of the forests to servicing centers. Experience had not prepared the company for new risks.
- ***Multiple (or team-based) assessments***—Using single-case sources to identify project risks is itself a risky proposition because of the potential bias in any one person's viewpoint.[4] It makes sense that no one individual, regardless of her perceived degree of expertise, can possibly discern all sources of threat and project risk. Although an engineer is likely to be more attuned to technical risks, a cost accountant to budgetary risks, and so forth, not even the most seasoned manager with experience in many fields is all-knowing. A team-based approach to risk

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factor identification encourages identification of a more comprehensive set of potential project risks. At the same time, a collaborative approach can help persuade the half-convinced or uncommitted members of the team to support project goals.[5]

PROJECT PROFILE

Bank of America Completely Misjudges Its Customers

When Bank of America (BofA) decided it would begin to charge customers $5 per month in 2012 just to gain access to their funds via their debit cards, it was unprepared for a response that was far more hostile than it could have imagined. After announcing the new fee in late September 2011, the giant bank anticipated some negative reaction from its customers but thought that after an initial angry response, most would fall in line and grudgingly accept the fee. Perhaps BofA felt secure due to the initial decision by some of its largest competitors, including Wells Fargo, SunTrust, and JPMorgan Chase, to mirror the fees. If BofA thought "might made right," it was in for a giant surprise.

The announcement of a pending new charge just to allow customers to use their debit cards led to massive consumer anger directed at the bank and a pledge that the new fees would not be accepted. These informal protests were galvanized and given a degree of organization by the creation of several viral Internet and Facebook sites to support two major dates in November 2011: "Bank Transfer Day" (November 5) and "Dump your Bank Day" (November 8). Wells Fargo, SunTrust, and JPMorgan Chase banks all dropped their fee-charging plan in the face of these gathering protests, leaving BofA standing alone and continuing to assert its intention of charging the debit card fee. By October 2011, a poll by *TheStreet* showed a whopping 83% of BofA customers said they would indeed take the time out of their busy schedules and dump BofA. Contributing to the poor timing of the BofA announcement was the continuation of the "Occupy Wall Street" protests against financial institutions. Seen in this light, the timing of BofA's decision could not have been worse.

Belatedly realizing its mistake, BofA announced on November 1, 2011, that it was cancelling the $5 debit card fee. Although it is uncertain how many customers BofA lost as a result of this misguided decision, there is no doubt that it sacrificed a huge amount of customer goodwill. In a recession, when Americans were carefully watching their spending, BofA's decisions made no sense. Charging $5 to be allowed to use your own money angered too many and the announcement to drop the charge came too late, causing people to bail on BofA.[6]

Once the process of risk factor analysis is complete and the variety of circumstances or sources of risk have been uncovered, an assessment of potential risk impact can be undertaken.

11.2.2 Risk Breakdown Structures

In identifying and categorizing various project risks, one useful tool is the **Risk Breakdown Structure** (RBS). An RBS is defined as "a source-oriented grouping of project risks that organizes and defines the total risk exposure of the project."[7] We developed the Work Breakdown Structure (WBS) as a means to hierarchically organize and define the various elements of the project scope by breaking up the deliverables into increasingly distinct elements, known as work packages. An RBS employs a similar approach; however, in this case, our goal is to create a hierarchical representation of the project's risks, starting at the higher, general level and breaking the risks down to more

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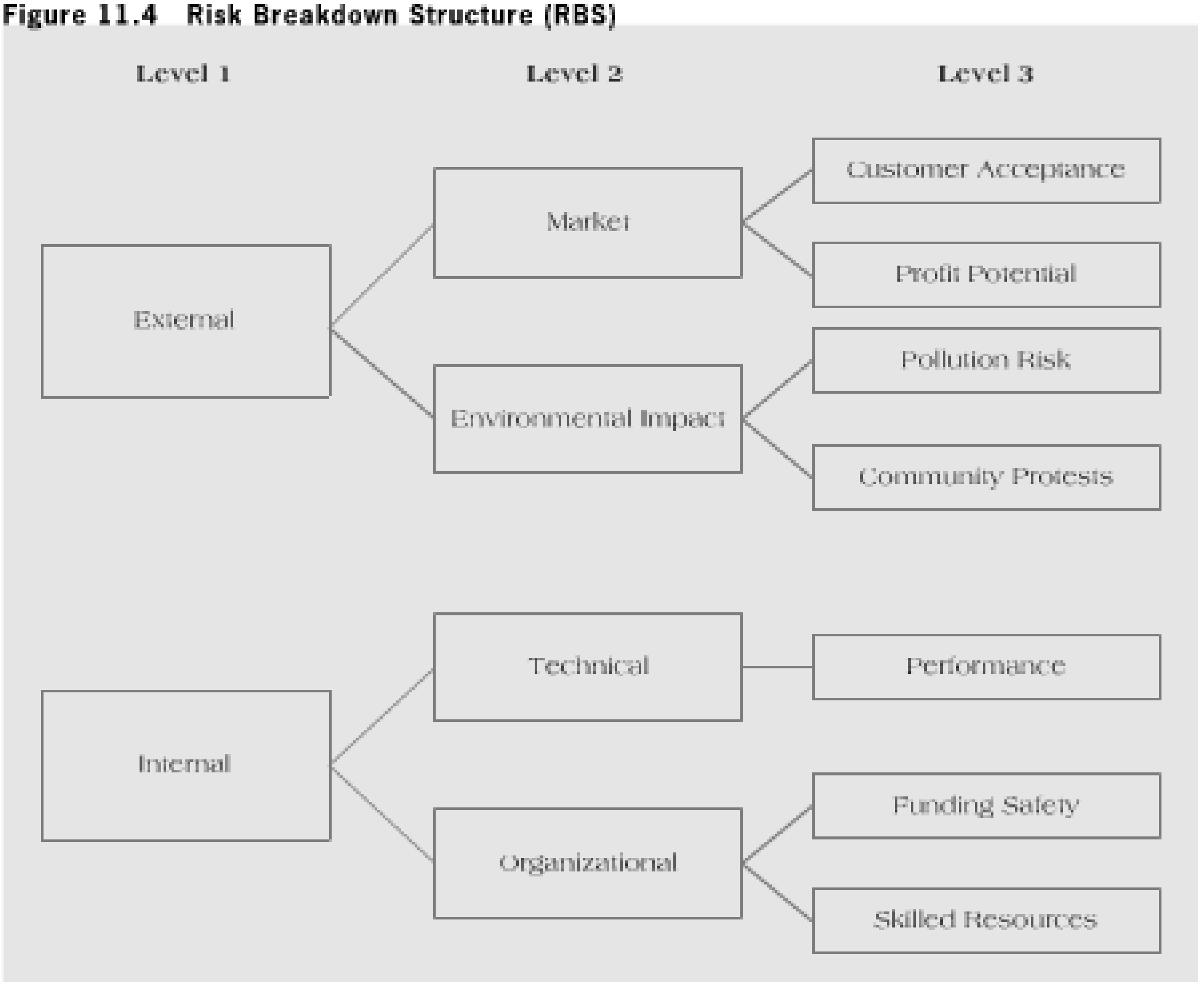
Figure 11.4 Risk Breakdown Structure (RBS)



specific risks at lower levels. For example, at the highest level, you have both external and internal risks. Specifying more closely, you may identify "Market risks," "Technical risks," "Environmental Impact risks," and "Quality risks" as second level categories. From this first level, your project team breaks out the specific types of risk associated with each of these broader concepts. Figure 11.4 gives an example of an RBS for this hypothetical project. Moving down to more specific risks, we can further classify "Market Risks" as consisting of customer acceptance and profit potential. Likewise, for "Environmental Impact," we have identified two specific risks: pollution risks and community protest potential. A similar de-classification can be conducted across each broader category of project risk. You can see that the advantage of the RBS is that it provides the project team with a visual representation of the critical risks for their project, as well as highlighting the specific components of these risks. This identification method helps with the next step in project risk management: the analysis of probability and consequences associated with each risk.[8]

11.2.3 Analysis of Probability and Consequences

The next step in the process consists of trying to attach a reasonable estimate of the likelihood of each of these risk events occurring. We can construct a risk impact matrix similar to the one shown in Figure 11.5.[9] The matrix reflects all identified project risks, each prioritized according to the probability of its occurrence, along with the potential consequences for the project, the project team, or the sponsoring organization should

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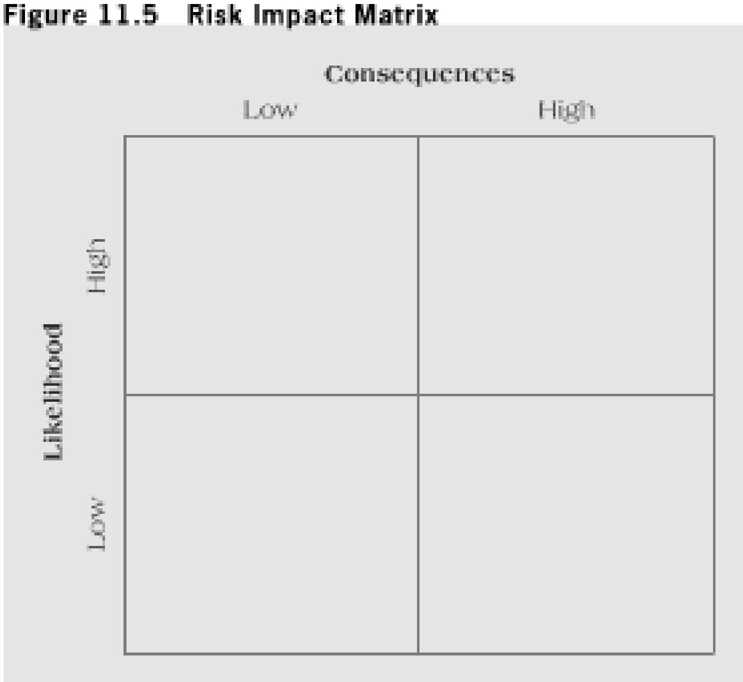
Figure 11.5 Risk Impact Matrix

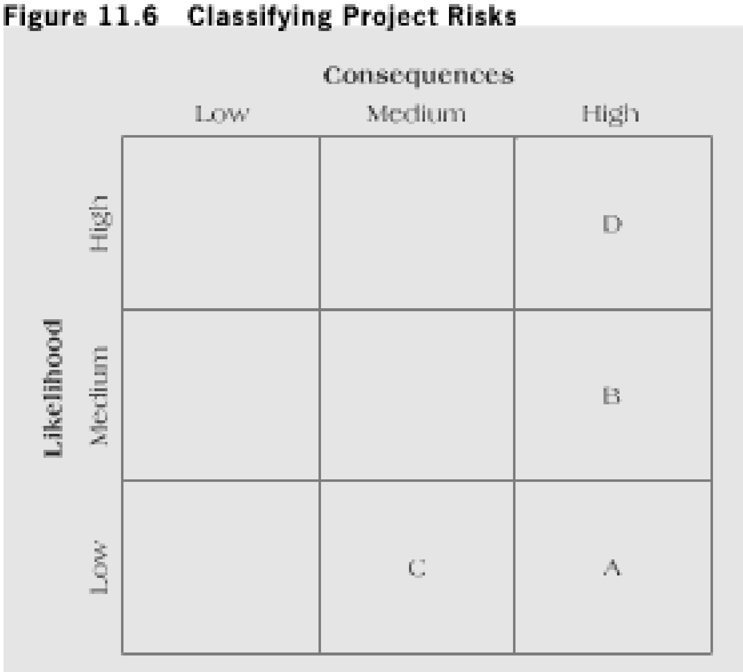


the worst come to pass. Probability combined with consequences provides a sense of overall risk impact. With such a prioritization scheme, the project team is better able to focus their attention where their energy can do the most good.

Figure 11.6 shows a risk impact matrix in use by several *Fortune* 500 companies. Note that instead of a high-low classification, this alternative one features three levels: high, medium, and low. This matrix is further refined by classifying risk impact as either serious, moderate, or minor. The fundamental reason for employing this more complete matrix is to develop a sense of priority in addressing the various risks.

After a project team has worked through and completed a detailed matrix, it is better equipped to recognize the sorts of risks to which the project is subject and the "critical-

Figure 11.6 Classifying Project Risks



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ity" of each of those risks in terms of their potential impact on project performance. Clearly, the types of risks that are most relevant to project planning are those that the team classifies as having both high likelihood of occurring (probability) and high potential for harming the project (impact). Risks that fall into this category require detailed contingency planning in order to adequately protect the project's development cycle. Figure 11.6 shows how projects might be classified on the basis of their potential risk impact. The team first identifies the risk factors and then evaluates their impact using the matrix. You can see how the high-low-moderate classification scheme plays out in this example.

It is also useful to revisit our earlier point about the potential opportunities that may emerge from the uncertainty of project risk. That is, when analyzing the probability and consequences of risk events, we should include, as part of our calculation, the ways in which these uncertainties can open up opportunities for the organization. For example, if our project team identifies several project risks (market, technical, political, etc.), brainstorming sessions can help us determine if these risks are distinctly negative or if they open up the possibility of finding innovative, win-win solutions by transforming them into opportunities. For example, a firm may have concern about the risk from possible governmental regulations regarding reducing greenhouse gases to slow man-made climate change. These concerns can lead a firm to adopt one of two actions: (1) defensive—employing lobbyists to try and derail the legislation to maintain business as usual, or (2) opportunistic—getting out ahead of the regulations by challenging business units to start employing nontraditional, sustainable solutions to technical challenges, leading to new products or processes that they can market to other firms facing similar challenges. As a result, part of our analysis of risk probability consequences should always take into consideration both negative and positive consequences.

Table 11.1 illustrates this quantitative method using the example of a firm developing a new software product for the retail market. The scenario considers both probability of failure and consequences of failure. In *probability of failure*, we are interested in identifying any factors that can significantly affect the probability that the new project can be successfully completed. Think of this category as requiring us to focus on the potential causes of failure. For the example in this section, let us assume that the issues identified as potential contributors are (1) maturity of the software design—is it a new product or based on an existing software platform? (2) complexity of the product—is the design relatively simple or is it highly complex in structure? and (3) dependency—can the product be developed independently of any system currently in place in the company or is it tied to current operating systems or practices? A number of factors can have an impact on the probability of a new project's successful completion. Although our example identifies three (maturity, complexity, and dependency), depending upon the project, a team may identify many unique issues or factors that will increase the probability of failure.

Under the dimension of *consequences of failure*, we are concerned with the issues that will highlight the *effects* of project failure. The consequences of failure require us to critically evaluate the results of a project's success or failure along a number of key dimensions. For this example, the organization has identified four elements that must be considered as critical effects of project failure: (1) cost—budget adherence versus overruns, (2) schedule—on time versus severe delays, (3) reliability—the usefulness and quality of the finished product, and (4) performance—how well the new software performs its designed functions. As with items shown under probability of failure, the set of issues related to the consequences of failure that should be clearly identified will be unique to each project.

Table 11.2 demonstrates the process of creating a project risk score. The scores for each individual dimension of probability and consequence are added and the sum is

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Table 11.1 Determining Likely Risks and Consequences

Probability of Failure (P_f)			
Score	**Maturity**	**Complexity**	**Dependency**
Low (0.1)	Existing software	Simple design	Not limited to existing system or clients. No external or uncontrollable events are likely to have an impact on the project.
Minor (0.3)	Minor redesign	Minor increase in complexity	Schedule or performance depends on an existing system. Effect on cost or schedule is minor.
Moderate (0.5)	Major change	Moderate increase	Moderate risk to schedule or performance due to dependence on existing system, facility, or processes. Effect on cost is moderate.
Significant (0.7)	Technology is available, but complex design	Significant increase	Schedule or performance depends on new system or process. Significant cost or schedule risk.
Major (0.9)	State of art, some research complete	Extremely complex	Schedule and performance depend on new system and process. Very high cost or schedule risk.

Consequence of Failure (C_f)				
Score	**Cost**	**Schedule**	**Reliability**	**Performance**
Low (0.1)	Budget estimate not exceeded	Negligible impact on program, no impact on critical path	Minimal or no reliability consequence	Minimal or no performance consequence.
Minor (0.3)	Cost estimate exceeds budget by < 5%	Minor slip in schedule (less than 5%)	Small reduction in reliability	Small reduction in system performance.
Moderate (0.5)	Cost estimate exceeds budget by < 15%	Small slip in schedule starting to impact critical path	Some reduction in reliability	Some reduction in system performance. May require moderate debugging.
Significant (0.7)	Cost estimate exceeds budget by < 30%	Development time slips in excess of 1 month, requires readjustment of critical path	Significant degradation in reliability	Significant degradation in system performance. Guarantees are at risk. Serious debugging required.
Major (0.9)	Cost estimate exceeds budget by > 50%	Large schedule slips ensure the system will miss client time frame	Reliability goals cannot be achieved under current plan	Performance goals cannot be achieved. Results may not be usable.

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Table 11.2 Calculating a Project Risk Factor

1. Use the project team's consensus to determine the scores for each Probability of Failure category: Maturity (P_m), Complexity (P_c), Dependency (P_d).
2. Calculate P_f by adding the three categories and dividing by 3:
$$P_f = (P_m + P_c + P_d)/3$$
3. Use the project team's consensus to determine the scores for each Consequence of Failure category: Cost (C_c), Schedule (C_s), Reliability (C_r), Performance (C_p).
4. Calculate C_f by adding the four categories and dividing by 4:
$$C_f = (C_c + C_s + C_r + C_p)/4$$
5. Calculate Overall Risk Factor for the project by using the formula:
$$RF = P_f + C_f - (P_f)(C_f)$$

Rule of Thumb:

Low risk	$RF < .30$
Medium risk	$RF = .30$ to $.70$
High risk	$RF > .70$

divided by the number of factors used to assess them. For example, under *probability of failure*, the scores of the three assessed elements (maturity, complexity, and dependency) are totaled to derive an overall score, and that number is divided by 3 to arrive at the probability score. This table shows the overall risk factor formula for the sample project, based on the quantitative assessment. A common rule of thumb assigns any project scoring below .30 as "low risk," projects scoring between .30 and .70 as "medium risk," and projects scoring over .70 as "high risk."

11.2.4 Risk Mitigation Strategies

The next stage in risk management is the development of effective risk mitigation strategies. In a general sense, there are four possible alternatives a project organization can adopt in deciding how to address risks: (1) accept risk, (2) minimize risk, (3) share risk, or (4) transfer risk.

Accept Risk

One option that a project team must always consider is whether the risk is sufficiently strong that any action is warranted. Any number of risks of a relatively minor nature may be present in a project as a matter of course. However, because the likelihood of their occurrence is so small or the consequences of their impact are so minor, they may be judged acceptable and ignored. In this case, the decision to "do nothing" is a reasoned calculation, not the result of inattention or incompetence. Likewise, for many types of projects, certain risks are simply part of the equation and must be factored in. For example, it has been estimated that the U.S. recording industry spends millions every year in developing, producing, and promoting new recording artists, knowing full well that of the thousands of albums produced every year, less than 5% are profitable.[10]

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We've seen the extraordinary lengths that pharmaceutical manufacturers must go to and the high percentage of failures they accept in order to get a small percentage of commercially successful drugs to the marketplace. Hence, a high degree of commercial risk is embedded in the systems themselves and must be accepted in order to operate in certain industries.

Minimize Risk

Strategies to minimize risk are the next option. Consider the challenges that Boeing Corporation faces in developing new airframes, such as the newly introduced 787 model. Each aircraft contains millions of individual parts, most of which must be acquired from vendors. Further, Boeing has been experimenting with the use of composite materials, instead of aluminum, throughout the airframe. The risks to Boeing in the event of faulty parts leading to a catastrophic failure are huge. For example, several early flights were plagued by meltdowns in the aircraft's lithium ion batteries, manufactured in Japan by GS Yuasa. Consequently, the process of selecting and ensuring quality performance from vendors is a challenge that Boeing takes extremely seriously. One method Boeing employs for minimizing risk in vendor quality is to insist that all significant vendors maintain continuous direct contact with Boeing quality assessment teams. Also, in considering a new potential vendor, Boeing insists upon the right to intervene in the vendor's production process in order to ensure that the resulting quality of all supplier parts meets its exacting standards. Because Boeing cannot produce all the myriad parts needed to fabricate an aircraft, it seeks to minimize the resultant risk by adopting strategies that allow it to directly affect the production processes of its suppliers.

Share Risk

Risk may be allocated proportionately among multiple members of the project. Two examples of risk sharing include the research and development done through the European Space Agency (ESA) and the Airbus consortium. Due to tremendous barriers to entry, no one country in the European Union has the capital resources and technical skills to undertake the development of the Ariane rocket for satellite delivery or the creation of a new airframe to compete with Boeing in the commercial aircraft industry. ESA and Airbus partners from a number of countries have jointly pooled their resources and, at the same time, agreed to jointly share the risk inherent in these ventures.

In addition to partnerships that pool project risk, ameliorating risk through sharing can be achieved contractually. Many project organizations create relationships with suppliers and customers that include legal requirements for risk to be shared among those involved in the project. Host countries of large industrial construction projects, such as petrochemical or power generation facilities, have begun insisting on contracts that enforce a "Build-Own-Operate-Transfer" provision for all project firms. The lead project organization is expected to build the plant and take initial ownership of it until its operating capacity has been proven and all debugging occurs before finally transferring ownership to the client. In this way, the project firm and the host country agree to jointly accept financial (risk) ownership of the project until such time as the project has been completed and its capabilities proven.

Transfer Risk

In some circumstances, when it is impossible to change the nature of the risk, either through elimination or minimization, it may be possible to shift the risks bound up in a

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project to another party. This option, transferring risk to other parties when feasible, acknowledges that even in the cases where a risk cannot be reduced, it may not have to be accepted by the project organization, provided that there is a reasonable means for passing the risk along. Companies use several methods to transfer risks, depending upon their power relative to the client organizations and the types of risks they face. For example, if our goal is to prevent excessive budget overruns, a good method for directly transferring risk lies in developing fixed-price contracts. **Fixed-price contracts** establish a firm, fixed price for the project upfront; should the project's budget begin to slip, the project organization must bear the full cost of these overruns. Alternatively, if our goal is to ensure project functionality (quality and performance), the concept of liquidated damages offers a way to transfer risk through contracts. **Liquidated damages** represent project penalty clauses that kick in at mutually agreed-on points in the project's development and implementation. A project organization installing a new information system in a large utility may, for example, agree to a liquidated damages clause should the system be inoperable after a certain date. Finally, insurance is a common option for some organizations, particularly in the construction industry. Used as a risk mitigation tool, insurance transfers the financial obligation to an insuring agency.

11.2.5 Use of Contingency Reserves

Contingency reserves in several forms, including financial and managerial, are among the most common methods to mitigate project risks. They are defined as the specific provision for unforeseen elements of cost within the defined project scope. Contingency reserves are viewed differently, however, depending upon the type of project undertaken and the organization that initiates it. In construction projects, it is common to set aside anywhere between 10% and 15% of the construction price in a contingency fund. A contract to construct a $5 million building will actually be built to the cost of approximately $4.5 million, with the balance retained for contingency. In other fields, however, project teams are much more reluctant to admit to the up-front need for establishing contingency reserves, fearing that customers or other project stakeholders will view this as a sign of poor planning or inadequate scope definition.

The best way to offset concerns about the use of contingency reserves is to offer documentation of past risk events—unforeseen or uncontrollable circumstances that required the need for such contingency planning. Some of the concerns that might be generated may also be offset if the project team has done its homework and demonstrated in a detailed plan how contingency funds will be released as they are needed. Since the goal of creating contingency funds is to ensure against unforeseen risks, the key to their effective use lies in proactive planning to establish reasonable triggers for their release.[11]

Task Contingency

Perhaps the most common form of contingency reserve is **task contingency,** which is used to offset budget cutbacks, schedule overruns, or other unforeseen circumstances accruing to individual tasks or project work packages. These budget reserves can be a valuable form of risk management because they provide the project team with a buttress in the face of task completion difficulties. It may be found, for example, that some components or work packages of the project are highly unique or innovative, suggesting that development estimates and their related costs cannot be estimated with anything less than a bound of ±20% or even greater. Hence, task contingency becomes extremely important as a method for offsetting the project team's inability to make an accurate budget estimate.

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EXAMPLE 11.1 CALCULATING CONTINGENCY EXPECTED COST

Suppose a project task is estimated to cost $10,000 to complete, but it is viewed as a high-risk operation. A task contingency multiplier would require our budget to reflect the following:

$$(\text{Task estimated cost})(\text{Task contingency multiplier}) = \text{Expected cost}$$

$$(\$10{,}000)(1.2) = \$12{,}000$$

Naturally, as the project moves forward, it may be possible to reduce budget reserve requirements for task contingency because the project's scope will have been made clearer and its development will have progressed; that is, many of the tasks for which the contingency fund was established will have been completed. As a result, it is quite common for project organizations to assign a budget reserve to a project that is diminished across the project's development cycle. ■

Managerial Contingency

While task contingency may involve the risk associated with the development of individual work packages or even tasks, managerial contingency is an additional safety buffer applied at the project level. **Managerial contingency** is budget safety measures that address higher-level risks. For example, suppose a project team has begun development of a new wireless communication device set to operate within guidelines established for technical performance. At some point in the midst of the development process, the primary client requests major scope changes that will dramatically alter the nature of the technology to be employed. Managerial contingency typically is used as a reserve against just such a problem. Another way managerial contingency may be used is to offset potentially disastrous "acts of God," which are natural disasters that, by definition, are unforeseeable and highly disruptive.

One final point about budget reserves at either the task or managerial level: It is extremely important that open channels of communication be maintained between top management and the project manager regarding the availability and use of contingency reserve funds. Project managers must be fully aware of the guidelines for requesting additional funding and how extra project budget is to be disbursed. If either the project manager or top management group uses contingency reserves as a political tool or method for maintaining control, the other party will quickly develop an attitude of gamesmanship toward acquiring those reserves. In this case, the atmosphere and communications between these key stakeholders will become characterized by distrust and secrecy—two factors guaranteed to ensure that a project is likely to fail.

Insurance

Insurance can be a useful means for risk mitigation, particularly in certain types of projects, such as construction. Risks in construction go beyond technical risks or monetary/commercial risks to include health and safety concerns. Not all organizations or countries enforce the same rules regarding occupational health and safety standards. For example, there are countries in the developing world that do not require (or enforce) the use of safety harnesses for workers on skyscrapers, even though a fall would be fatal. Contractors acquire insurance as a means to offset the risks from the project that are often covered under contractual terms. For example, a construction contractor will routinely acquire insurance against loss or theft of building materials, workers' compensation, and professional or general liability. One of the duties of project managers in these

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settings is to ensure that all certificates of compliance are up to date; that is, all necessary insurance has been acquired and is valid for the life of the project to mitigate against potential risks.

11.2.6 Other Mitigation Strategies

In addition to the set of mitigation strategies already discussed, many organizations adopt practical approaches to minimizing risk through creating systems for effectively training all members of their project teams. One successful method for dealing with project risks involves **mentoring** new project managers and team members. In a mentoring program, junior or inexperienced project personnel are paired with senior managers in order to help them learn best practices. The goal of mentoring is to help ease new project personnel into their duties by giving them a formal contact who can help clarify problems, suggest solutions, and monitor them as they develop project skills. Another method for mitigating risks involves **cross-training** project team personnel so that they are capable of filling in for each other in the case of unforeseen circumstances. Cross-training requires that members of the project team learn not only their own duties but also the roles that other team members are expected to perform. Thus, in the case where a team member may be pulled from the project team for an extended period, other team members can take up the slack, thereby minimizing the time lost to the project's schedule.

11.2.7 Control and Documentation

Once project risk analysis has been completed, it is important to begin developing a reporting and documentation system for cataloging and future reference. Control and documentation methods help managers classify and codify the various risks the firm faces, its responses to these risks, and the outcome of its response strategies. Table 11.3 gives an example of a simplified version of the risk management report form that is used in several organizations. Managers may keep a hard-copy file of all these analyses or convert the analyses to databases for better accessibility.

Having a repository of past risk analysis transactions is invaluable, particularly to novice project managers who may recognize the need to perform risk management duties but are not sure of the best way to do them or where to begin. The U.S. Army, for example, has invested significant budget and time in creating a comprehensive database of project risk factors and their mitigation strategies as part of project management training for their officers. Newly appointed officers to Army procurement and project management offices are required to access this information in order to begin establishing preliminary risk management strategies prior to initiating new programs. Figure 11.7 illustrates a contingency document for adjustments to the project plan.

Establishing **change management** as part of risk mitigation strategies also requires a useful documentation system that all partners in the project can access. Any strategy aimed at minimizing a project risk factor, along with the member of the project team responsible for any action, must be clearly identified. The sample risk management report form shown in Table 11.3 includes the important elements in such change management. In order to be effective, the report must offer a comprehensive analysis of the problem, the plan for its minimization, a target date, and the expected outcome once the mitigation strategy has been implemented. In short, as a useful control document, a report form has to coherently identify the key information: what, who, when, why, and how.

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Table 11.3 Sample Risk Management Report Form

Customer: ______________________________ Project Name: ____________________
Budget Number: _________________________ Project Team: ____________________
Date of Most Recent Evaluation: ____
Risk Description: ____
____
____
____
Risk Assessment: _________________________ Risk Factor: ______________________
Discussion: ____
____
____
____
Risk Reduction Plan: _____________________ Owner: ___________________________
____
Time Frame to Next Assessment: ____
Expected Outcome: ____
____
____

- ***What***—Identify clearly the source of risk that has been uncovered.
- ***Who***—Assign a project team member direct responsibility for following this issue and maintaining ownership regarding its resolution.
- ***When***—Establish a clear time frame, including milestones if necessary, that will determine when the expected mitigation is to occur. If it is impossible to identify a completion date in advance, then identify reasonable process goals en route to the final risk reduction point.
- ***Why***—Pinpoint the most likely reasons for the risk; that is, identify its cause to ensure that efforts toward its minimization will correspond appropriately with the reason the risk emerged.
- ***How***—Create a detailed plan for how the risk is to be abated. What steps has the project team member charted as a method for closing this particular project "risk window"? Do they seem reasonable or far-fetched? Too expensive in terms of money or time? The particular strategy for risk abatement should, preferably, be developed as a collaborative effort among team members, including those with technical and administrative expertise to ensure that the steps taken to solve the problem are technically logical and managerially possible.

Documentation of risk analysis such as is shown in Table 11.3 and Figure 11.7 represents a key final component in the overall risk management process.

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Figure 11.7 Contingency Document for Adjustments to Project Plan

Probable Event	Adjustment to Plans
Absenteeism	
Resignation	
Pull-aways	
Unavailable staff/skills	
Spec change	
Added work	
Need more training	
Vendors late	

PROJECT PROFILE

Collapse of Shanghai Apartment Building

The science and engineering principles surrounding the construction of simple apartment blocks are well known and have been practiced for centuries. And yet, even in the most basic of construction projects, events can sometimes transpire to produce shocking results. Just such a story occurred in late June of 2009 in China, when a Shanghai high-rise, 13-story apartment building literally toppled onto its side. The nearly completed structure was part of an 11-building apartment complex in a new development known as "Lotus Riverside." Because the 629-unit apartment building was not yet completed, it was virtually empty. Although one worker was killed in the accident, the tragedy could have been far worse had the building been fully occupied.

The demand for affordable housing in Chinese cities has never been greater. With the economy humming along and a high demand for workers in economic regions such as Shanghai, there is a critical shortage of available housing. Private and governmental organizations are working to rapidly install new apartment blocks to keep up with this huge demand. Unfortunately, one of the risks with rapid building is the temptation to cut corners or use slipshod methods. When speed is paramount, the obvious concern is whether acceptable standards of building are being maintained.

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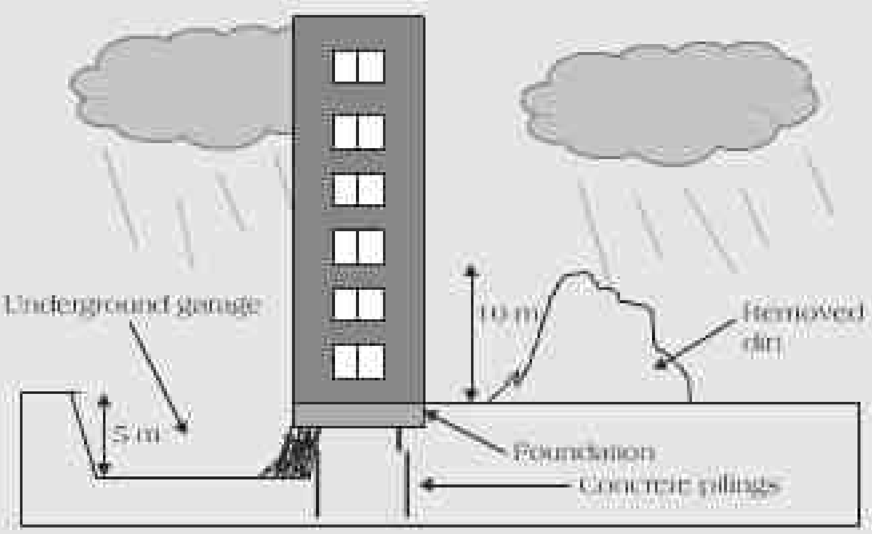
Figure 11.8 Shanghai Apartment Building Collapse

Source: Imago stock&people/Newscom

In the Lotus Riverside building project, unfortunately, the construction firm opted for a procedure that is generally frowned upon (indeed, the method is outlawed in Hong Kong due to its inherent riskiness). Under this system, rather than pour a deep concrete base on which to rest the structure, a series of prestressed, precast concrete pilings were used as a set of anchors to "pin" the building into the ground. Although this system can work effectively with shorter buildings, it has long been considered unsafe for larger, higher structures.

The problem was made critical when the construction crews began digging an underground garage on the south side of the building to a depth of nearly 5 meters. The excavated dirt was piled on the north side of the building to a height of 10 meters. The underground pilings began receiving severe lateral pressure from the excavation, which was further compromised by heavy rainstorms. The storms undermined the apartment building on the south side, causing more soil erosion and putting even greater lateral pressure (estimated at 3,000 tons) on the anchor piling system (see Figure 11.9). Suddenly, the pilings began snapping and the building toppled over on its side. Local officials noted that the only lucky result of the collapse was that the building fell into an empty space. Considering that all the buildings in the complex had been constructed in a similar manner, there was a very real possibility of creating a chain reaction of toppling buildings, much like a set of dominos falling over.

Figure 11.9 Schematic of Causes of Collapse



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The Chinese government immediately began to aggressively trace the cause of the collapse, questioning the private contractor's use of unskilled workers, questionable construction practices, and overall quality control. China's official news agency, Xinhua, said officials were taking "appropriate control measures" against nine people, including the developer, construction contractor, and supervisor of the project, after it was reported that the company's construction license had expired in 2004. Although it is certain that penalties will be imposed for the building failure, a less certain future awaits the tenants of the other buildings in the complex. After all, what more visible evidence could there be of the unsoundness of the construction in the complex than seeing a "sister building" lying on its side not far from the other structures? Hundreds of prospective tenants have besieged government offices, demanding refunds for apartments in the same complex that they purchased for upward of $60,000 but are now too frightened to live in.

Meanwhile, *China Daily*, the state-run newspaper, published an angry editorial blaming the collapse on the often corrupt relationship between Chinese property developers and local government officials who depend on property taxes and land sales for a significant proportion of their income. The paper raised fears—expressed by some construction industry insiders in China—that many buildings designed to have a 70-year life span "would not stand firm beyond 30 to 40 years" because of corner-cutting during China's rampant construction boom. "It is ironic that such an accident happened in Shanghai—one of the most advanced and international Chinese cities," the paper concluded. "The sheer fact that such a collapse occurred in the country's biggest metropolis should serve as warning to all developers and the authorities to ensure that construction projects do not cut corners and endanger people's lives."[12]

11.3 | Project Risk Management: An Integrated Approach

The European Association for Project Management has developed an integrated program of risk management, based on efforts to extend risk management to cover a project's entire life cycle. This program, known as **Project Risk Analysis and Management (PRAM),** presents a generic methodology that can be applied to multiple project environments and encompasses the key components of project risk management.[13] The ultimate benefit of models such as PRAM is that they present a systematic alternative to ad hoc approaches to risk assessment, and hence can help organizations that may not have a clearly developed, comprehensive process for risk management and are instead locked into one or two aspects (e.g., risk identification or analysis of probability and consequences). The PRAM model offers a step-by-step approach to creating a comprehensive and logically sequenced method for analyzing and addressing project risk.

Among the key features of the PRAM methodology are the following:

- ***The recognition that risk management follows its own life cycle, much as a project follows a life cycle.*** Risk management is integrated throughout the project's entire life cycle.
- ***The application of different risk management strategies at various points in the project life cycle.*** The PRAM approach tailors different strategies for different project life cycle stages.
- ***The integration of multiple approaches to risk management into a coherent, synthesized approach.*** PRAM recommends that all relevant risk management tools be applied as they are needed, rather than in a "pick-and-choose" approach.

Each of the nine phases in the PRAM approach is based on a specific purpose and requires the completion of a comprehensive set of targets (deliverables). Completing PRAM gives the project team a template for getting the most out of risk management and helps them sharpen their efforts in the most productive manner. It also creates a

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document for merging risk management with overall project planning, linking them in a collaborative sense.

The nine phases of a comprehensive project risk assessment include the following steps:

1. ***Define***—Make sure the project is well defined, including all deliverables, statement of work, and project scope.
2. ***Focus***—Begin to plan the risk management process as a project in its own right, as well as determining the best methods for addressing project risk, given the unique nature of the project being undertaken.
3. ***Identify***—Assess the specific sources of risk at the outset of the project, including the need to fashion appropriate responses. This step requires that we first search for all sources of risk and their responses and then classify these risks in some manner to prioritize or organize them.
4. ***Structure***—Review and refine the manner in which we have classified risks for the project, determine if there are commonalities across the various risks we have uncovered (suggesting common causes of the risks that can be addressed at a higher level), and create a prioritization scheme for addressing these risks.
5. ***Clarify ownership of risks***—Distinguish between risks that the project organization is willing to handle and those that the clients are expected to accept as well as allocate responsibility for managing risks and responses.
6. ***Estimate***—Develop a reasonable estimate of the impacts on the project of both the identified risks and the proposed solutions. What are the likely scenarios and their relative potential costs?
7. ***Evaluate***—Critically evaluate the results of the estimate phase to determine the most likely plan for mitigating potential risks. Begin to prioritize risks and the project team's responses.
8. ***Plan***—Produce a project risk management plan that proactively offers risk mitigation strategies for the project as needed.
9. ***Manage***—Monitor actual progress with the project and associated risk management plans, responding to any variances in these plans, with an eye toward developing these plans for the future.

Table 11.4 shows a generic risk management process following the PRAM methodology. At each of the risk management phases, specific project deliverables can be identified, allowing the project team to create comprehensive project risk management documentation while addressing specific steps along the way. These deliverables are important because they indicate to project managers exactly the types of information they should be collecting at different phases of the project and the materials they should make available to relevant stakeholders.

The PRAM model for risk management is extremely helpful because it offers project managers a systematic process for best employing risk assessment and mitigation strategies. Composed of nine interconnected steps that form a logical sequence, PRAM creates a unifying structure under which effective risk management can be conducted. Because it follows the logic of the project life cycle, PRAM should be conducted not as a "one-shot" activity but as an ongoing, progressive scheme that links project development directly to accurate risk assessment and management. Finally, in identifying the key deliverables at each step in the process, the PRAM model ensures a similarity of form that allows top management to make reasonable comparisons across all projects in an organization's portfolio.

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Table 11.4 A Generic Risk Management Process (RMP) Following the PRAM Methodology

Phases	Purposes	Deliverables
Define	Consolidate relevant existing information about the project.	A clear, unambiguous, shared understanding of all key aspects of the project documented, verified, and reported.
Focus	1. Identify scope and provide a strategic plan for the RMP. 2. Plan the RMP at an operational level.	A clear, unambiguous, shared understanding of all relevant key aspects of the RMP, documented, verified, and reported.
Identify	1. Identify where risk might arise. 2. Identify what we might do about this risk in proactive and reactive response terms. 3. Identify what might go wrong with our responses.	All key risks and responses identified; both threats and opportunities classified, characterized, documented, verified, and reported.
Structure	1. Test simplifying assumptions. 2. Provide more complex structure when appropriate.	A clear understanding of the implications of any important simplifying assumptions about relationships among risks, responses, and base plan activities.
Ownership	1. Client contractor allocation of ownership and management of risks and responses. 2. Allocation of client risks to named individuals. 3. Approval of contractor allocations.	Clear ownership and management allocations effectively and efficiently defined, legally enforceable in practice where appropriate.
Estimate	1. Identify areas of clear significant uncertainty. 2. Identify areas of possible significant uncertainty.	1. A basis for understanding which risks and responses are important. 2. Estimates of likelihood and impact on scenario or in numeric terms.
Evaluate	Synthesis and evaluation of the results of the estimate phase.	Diagnosis of all important difficulties and comparative analysis of the implications of responses to these difficulties, with specific deliverables like a prioritized list of risks.
Plan	Project plan ready for implementation and associated risk management plan.	1. Base plans in activity terms at the detailed level of implementation. 2. Risk assessment in terms of threats and opportunities prioritized, assessed in terms of impact. 3. Recommended proactive and reactive contingency plans in activity terms.
Manage	1. Monitoring. 2. Controlling. 3. Developing plans for immediate implementation.	1. Diagnosis of a need to revisit earlier plans and initiation of replanning as appropriate. 2. Exception reporting after significant events and associated replanning.

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Project risk management demonstrates the value of proactive planning for projects as a way to anticipate and, hopefully, mitigate serious problems that could adversely affect the project at some point in the future.[14] The value of this troubleshooting process is that it requires us to think critically, to be devil's advocates when examining how we are planning to develop a project. Research and common sense suggest, in the words of the adage, "An ounce of prevention is worth a pound of cure." The more sophisticated and systematic we are about conducting project risk management, the more confident we can be, as the project moves through planning and into its execution phase, that we have done everything possible to prepare the way for project success.

SUMMARY

1. **Define project risk.** Project risk is defined as any possible event that can negatively affect the viability of a project. We frequently use the equation: Risk event = (Probability of event)(Consequences of event). Effective risk management goes a long way toward influencing project development. To be effective, however, project risk management needs to be done early in the project's life. To quote Shakespeare's *Macbeth*: "If it were done, when 'tis done; then 'twere well it were done quickly."[15] As an important element in overall project planning, risk management identifies specific risks that can have a detrimental effect on project performance and quantifies the impact each risk may have. The impact of any one risk factor is defined as the product of the likelihood of the event's occurrence and the adverse consequences that would result. The tremendous number of unknowns in the early phases of a project makes this the time when risk is highest. As the project moves forward, the team continues to address risk with technical, administrative, and budgetary strategies.
2. **Recognize four key stages in project risk management and the steps necessary to manage risk.** There are four distinct phases of project risk management: (1) risk identification, (2) analysis of probability and consequences, (3) risk mitigation strategies, and (4) control and documentation. Risk identification focuses on determining a realistic set of risk factors that a project faces. In analysis of probability and consequences, the project team prioritizes its responses to these various risk factors by assessing the "impact factor" of each one. Impact factors are determined either in a qualitative manner, using a matrix approach and consensus decision making, or in more quantitative ways, in which all relevant probability and consequence parameters are laid out and used to assess overall project risk. The project team begins the process of developing risk mitigation strategies once a clear vision of risk factors is determined. The last step in the risk management process, control and documentation, is based on the knowledge that risk management strategies are most effective when they have been codified and introduced as part of standard operating procedures. The goal is to create systematic and repeatable strategies for project risk management.
3. **Understand five primary causes of project risk and four major approaches to risk identification.** The five primary causes of project risk are (1) financial risk, (2) technical risk, (3) commercial risk, (4) execution risk, and (5) contractual or legal risk. Among the most common methods for risk identification are (1) brainstorming meetings, (2) expert opinion, (3) past history, and (4) multiple or team-based assessments.

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4. **Recognize four primary risk mitigation strategies.** Risks can be mitigated through four primary approaches. First, we can simply accept the risk. We may choose to do this in a situation in which we either have no alternative or we consider the risk small enough to be acceptable. Second, we can seek to minimize risk, perhaps through entering partnerships or joint ventures in order to lower our company's exposure to the risk. Third, we can share risk with other organizations or project stakeholders. Finally, when appropriate, we may seek to transfer risk to other project stakeholders.

5. **Explain the Project Risk Analysis and Management (PRAM) process.** PRAM is a generic project risk management approach that offers a model for the life cycle steps a project team might adopt in developing a risk management methodology. Nine distinct steps in the PRAM model present each phase of the process and its associated deliverables.

KEY TERMS

Analysis of probability and consequences (p. 423)
Change management (p. 435)
Commercial risk (p. 424)
Contingency reserves (p. 433)
Contractual or legal risk (p. 424)
Control and documentation (p. 423)
Cross-training (p. 435)
Execution risk (p. 424)
Financial risk (p. 423)
Fixed-price contact (p. 433)
Insurance (p. 434)
Liquidated damages (p. 433)
Managerial contingency (p. 434)
Mentoring (p. 435)
Project risk (p. 419)
Project Risk Analysis and Management (PRAM) (p. 439)
Risk Breakdown Structure (p. 426)
Risk identification (p. 423)
Risk management (p. 419)
Risk mitigation strategies (p. 423)
Task contingency (p. 433)
Technical risk (p. 423)

SOLVED PROBLEM

11.1 Quantitative Risk Assessment

Refer to the risk factors shown in Table 11.1. Assume your project team has decided upon the following risk values:

$$
\begin{array}{ll}
P_m = .1 & C_c = .7 \\
P_c = .5 & C_s = .5 \\
P_d = .9 & C_r = .3 \\
 & C_p = .1
\end{array}
$$

You wish to determine the overall project risk using a quantitative method. Following the formulas shown in Table 11.2, we can calculate both the probability of project risk score and the consequences of project risk score, as follows:

$$
\begin{aligned}
P_f &= (.1 + .5 + .9)/3 = .5 \\
C_f &= (.7 + .5 + .3 + .1)/4 = .4 \\
RF &= .5 + .4 - (.5)(.4) = .70
\end{aligned}
$$

Conclusion: Medium risk to overall project.

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DISCUSSION QUESTIONS

11.1 Do you agree with the following statement: "With proper planning it is possible to eliminate most/all risks from a project"? Why or why not?

11.2 In evaluating projects across industries, it is sometimes possible to detect patterns in terms of the more common types of risks they routinely face. Consider the development of a new software product and compare it to coordinating an event, such as a school dance. What likely forms of risk would your project team face in either of these circumstances?

11.3 Analyze Figure 11.2 (degree of risk over the project life cycle). What is the practical significance of this model? What implications does it suggest for managing risk?

11.4 What are the benefits and drawbacks of using the various forms of risk identification mentioned in the chapter (e.g., brainstorming meetings, expert opinion, etc.)?

11.5 What are the benefits and drawbacks of using a qualitative risk impact matrix for classifying the types of project risk?

11.6 What are the benefits and drawbacks of using a quantitative risk assessment tool such as the one shown in the chapter?

11.7 Give some examples of projects using each of the risk mitigation strategies (accept, minimize, share, or transfer). How successful were these strategies? In hindsight, would another approach have been better?

11.8 Explain the difference between managerial contingency and task contingency.

11.9 What are the advantages of developing and using a systematic risk management approach such as the PRAM methodology? Do you perceive any disadvantages of the approach?

11.10 Consider the following observation: "The problem with risk analysis is that it is possible to imagine virtually anything going wrong on a project. Where do you draw the line? In other words, how far do you take risk analysis before it becomes overkill?" How would you respond?

PROBLEMS

11.1 **Assessing Risk Factors.** Consider the planned construction of a new office building in downtown Houston at a time when office space is in surplus demand (more office space than users). Construct a risk analysis that examines the various forms of risk (technical, commercial, financial, etc.) related to the creation of this office building. How would your analysis change if office space were in high demand?

11.2 **Qualitative Risk Assessment.** Imagine that you are a member of a project team that has been charged to develop a new product for the residential building industry. Using a qualitative risk analysis matrix, develop a risk assessment for a project based on the following information:

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Identified Risk Factors	Likelihood
1. Key team members pulled off project	1. High
2. Chance of economic downturn	2. Low
3. Project funding cut	3. Medium
4. Project scope changes	4. High
5. Poor spec. performance	5. Low

Based on this information, how would you rate the consequences of each of the identified risk factors? Why? Construct the risk matrix and classify each of the risk factors in the matrix.

11.3 Developing Risk Mitigation Strategies. Develop a preliminary risk mitigation strategy for each of the risk factors identified in Problem 11.2. If you were to prioritize your efforts, which risk factors would you address first? Why?

11.4 Quantitative Risk Assessment. Assume the following information:

Probability of Failure	Consequences of Failure
Maturity = .3	Cost = .1
Complexity = .3	Schedule = .7
Dependency = .5	Performance = .5

Calculate the overall risk factor for this project. Would you assess this level of risk as low, moderate, or high? Why?

11.5 Quantitative Risk Assessment. Assume the following information for an IT project.

Probability of Failure	Consequences of Failure
Maturity = .7	Cost = .9
Complexity = .7	Schedule = .7
Dependency = .5	Performance = .3
Client Concerns = .5	Future Business = .5
Programmer Skill = .3	

Calculate the overall risk factor for this project. Would you assess this level of risk as low, moderate, or high? Why?

11.6 Developing Risk Mitigation Strategies. Assume that you are a project team member for a highly complex project based on a new technology that has never been directly proven in the marketplace. Further, you require the services of a number of subcontractors to complete the design and development of this project. Because you are facing severe penalties in the event the project is late to market, your boss has asked you and your project team to develop risk mitigation strategies to minimize your company's exposure. Discuss the types of risk that you are likely to encounter. How should your company deal with them (accept them, share them, transfer them, or minimize them)? Justify your answers.

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11.7 **Assessing Risk and Benefits.** Suppose you are a member of a project team that is evaluating the bids of potential contractors for developing some subassemblies for your project. Your boss makes it clear that any successful bid must demonstrate a balance between risk and price. Explain how this is so; specifically, why are price and risk seen as equally important but opposite issues in determining the winner of the contract? Is a low-price/high-risk bid acceptable? Is a high-price/low-risk bid acceptable? Why or why not?

CASE STUDY 11.1

Classic Case: de Havilland's Falling Comet

The Development of the Comet

The de Havilland Aircraft Company of Great Britain had long been respected in the aircraft manufacturing industry for its innovative and high-performance designs. Coming off its excellent work during World War II, the company believed that it stood poised on the brink of success in the commercial airframe industry. The de Havilland designers and executives accurately perceived that the next generation of airplane would be jet-powered. Consequently, they decreed that their newest commercial airframe, tentatively called the Comet, would employ jet power and other leading-edge technology.

Jets offered a number of advantages over propeller-driven airplanes, the most obvious of which was speed. Jets could cruise at nearly 450 miles per hour compared with the 300 miles per hour a propeller could generate. For overseas flight, in particular, this advantage was important. It could reduce the length of long flights from a mind-numbing two to three days to mere hours, encouraging more and more businesspeople and tourists to use airplanes as their primary method for travel. Further, jets tended to be quieter than propeller-driven aircraft, giving a more comfortable interior sound level and ride to passengers.

Figure 11.10 The de Havilland Comet

Source: Heanly Mirrorpix/Newscom

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De Havilland engineers sought to create a streamlined airplane that could simultaneously carry up to 50 passengers in comfort, while maintaining aerodynamics and high speed. After working with a number of design alternatives, the Comet began to take shape. Its design was, indeed, distinctive: The four jet engines were embedded in pairs in the wing roots, at the point where they joined the fuselage. From the front, the aircraft looked as though its wings were literally held in place by the engines. The result of these innovative engineering designs was an aircraft that had remarkable stability in flight, was sleek in appearance, and was very fast.

Another distinctive feature of the aircraft was the pressurized cabin, intended to maintain passenger comfort at cruising altitudes of up to 30,000 feet. In its original testing for safety, de Havilland engineers had pressurized the airframe to more than five times the recommended air density to ensure that there was a clean seal. Consequently, they were confident that the pressurization system would perform well at its lower, standardized settings. Finally, in an effort to add some flair to the design, each window in the passenger cabin was square, rather than the small, round or oval shapes so commonly used.

Knowing that it was facing competition from Boeing Corporation to be first to market with a commercial jet, de Havilland's goal was to introduce its new aircraft as quickly as possible, in order to establish the standard for the commercial airline industry. At first, it appeared the company had succeeded: BOAC (British Overseas Airways Corporation) ordered several Comets, as did Air France and the British military. De Havilland also received some queries from interested American airline companies, notably Pan American Airlines. It looked as though de Havilland's strategy was working; the company was first to market with a radical new design, using a number of state-of-the-art technologies. BOAC's first nine Comet 1s entered service with the airline on May 2, 1952. The future looked bright.

Troubles

In early May of 1953, a brand new Comet operated by BOAC left Calcutta, India, and flew off into the afternoon sky. Six minutes later and only 22 miles from Calcutta's Dum Dum Airport, the aircraft exploded and plunged to earth, killing all 43 passengers and crew on board. There had been no indication of problems and no warning from the pilots of technical difficulties. Investigators from Great Britain and India tended to believe the crash came about due to pilot error coupled with weather conditions. Evidence from the wreckage, including the tail section, seemed to indicate that the aircraft had been struck by something heavy, but without any additional information forthcoming, both the authorities and de Havilland engineers laid the blame on external causes.

January 10, 1954, was a mild, clear day in Rome as passengers boarded their BOAC aircraft for the final leg of their flight from Singapore to London. When the airplane reached its cruising altitude and speed, it disintegrated over the Mediterranean Sea, near the island of Elba. Most of the airplane was lost at the bottom of the sea, but amid the flotsam 15 bodies of passengers and crew were recovered. A local physician who examined the remains noted: "They showed no look of terror. Death must have come without warning." As a safety precaution, BOAC instituted a ban on the use of Comets until the airplanes had been thoroughly checked over. Technicians could find nothing wrong with the new aircraft and, following recertification, the airplanes were again brought back into service.

Alas, it was too soon. On April 8, only 16 days after the Comet was reintroduced into service, a third aircraft, operated by South African Airways, departed from Rome's Ciampino airport for Cairo, one of the legs of its regular flight from London to Johannesburg. Under perfect flying weather, the airplane rapidly gained its cruising altitude of 26,000 feet and its airspeed of almost 500 miles an hour. Suddenly, the flight radio went silent and failed to answer repeated calls. A search of the ocean off the island of Stromboli, Italy, turned up an oil slick and some debris. Because of the depth of the water and the time necessary to arrive at

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the crash site, there was little to be found by search crews. Five bodies were all that were recovered this time, though with an eerie similarity to the victims of the second disaster: Facial expressions showed no fear, as though death had come upon them suddenly.

What Went Wrong?

Investigators swarmed over the recovered wreckage of the aircraft and reexamined the pieces from the first Calcutta accident while also conducting underwater searches at the sight of the second crash near the island of Elba. Guided by underwater cameras, investigators were able to collect sufficient aircraft fragments (in fact, they finally recovered nearly 70% of the airframe) to make some startling discoveries. The foremost finding, from the recovery of the entire, intact tail section, was that the fuselage of the aircraft had exploded. Second, it appeared that engine failure was not the cause of the accidents. Another finding was equally important: The wings and fuselage showed unmistakable signs of metal fatigue, later shown to be the cause of failure in all three aircraft. This point was important because it advanced the theory that the problem was one of structural design rather than simple part failure.

Britain's Civil Aviation Board immediately grounded the entire Comet fleet pending extensive reviews and airworthiness certification. For the next five months, the CAB set out on an extensive series of tests to isolate the exact causes of the mysterious crashes. Before testing was complete, one Comet had been tested literally to destruction, another had its fuel tanks ruptured, more than 70 complete test flights were made in a third, and between 50 and 100 test models were broken up. The results of the extensive tests indicated a number of structural and design flaws.

Although the aircraft's designers were convinced that the structure would remain sound for 10,000 flight hours before requiring major structural overhauling, simulations showed unmistakable signs of metal fatigue after the equivalent of only 3,000 flight hours. Experts argued that even when fatigue levels were revised downward to less than 3,000 hours, Comets would not be safe beyond 1,000 flying hours, a ludicrously low figure in terms of the amount of use a commercial airliner is expected to receive. In addition, testing of the fuselage offered disturbing indications of the cause of failure. Specifically, cracks began developing in the corners of the cabin windows, and these cracks were exacerbated by repeated pressurization and depressurization of the cabin. The investigators noted that this result was most pronounced along the rivet lines near the fuselage windows.

Testing also demonstrated that the wings had a low resistance to fatigue. At a number of stages in the tests, serious cracks appeared, starting at the rivet holes near the wheel wells and finally resulting in rivet heads in the top wing surface actually shearing off. Engineers and investigators were finding incontrovertible evidence in the pieces of recovered wreckage that the cause of the sudden disintegration of the aircraft could only have been due to cabin pressure blowout. Engineers suspected that the critical failure of the aircraft occurred following sudden depressurization, when one or more windows were literally blown out of the aircraft. This led to a sudden "gyroscopic moment" as the aircraft nosed down and began its plunge to earth.

Although at the time no one would admit it, the handwriting was on the wall. After two years, in which Comets carried more than 55,000 passengers over 7 million air miles, the Comet 1 was never to fly again. De Havilland had indeed won the race to be first to market with a commercial jet—a race that it would have been better to have never run at all.[16]

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Questions

1. How could risk management have aided in the development of the Comet?
2. Discuss the various types of risk (technical, financial, commercial, etc.) in relation to the Comet. Develop a qualitative risk matrix for these risk factors and assess them in terms of probability and consequences.
3. Given that a modified version of the Comet (the Comet IV) was used until recently by the British government as an antisubmarine warfare aircraft, it is clear that the design flaws could have been corrected given enough time. What, then, do you see as de Havilland's critical error in the development of the Comet?
4. Comment on this statement: "Failure is the price we pay for technological advancement."

CASE STUDY 11.2

The Spanish Navy Pays Nearly $3 Billion for a Submarine That Will Sink Like a Stone

In 2003, shipbuilders at Navantia, Spain's stateowner shipyard, welcomed a contract from their navy to construct four state-of-the-art submarines. The S-80 class was going to be an engineering marvel, filled with the latest and most cutting-edge technology, including a diesel-electric propulsion system that would be 20% lighter than other ships, while delivering 50% more power. As the list of upgrades and new technical gadgetry grew, the delivery date for the Isaac Peral—the lead ship in the S-80 class—continued to slip further behind schedule. Nevertheless, it wasn't the continuous upgrading and addition of new equipment that finally slammed the brakes on the project; it was the startling warning from Navantia's engineers that the Isaac Peral was not seaworthy. The submarine, named in honor of the Spanish man credited by some as the inventor of the underwater vessel, was 75–100 tons overweight, an excess that could make it difficult or impossible for the submarine to surface after submerging. As a result, the Spanish navy was faced with the challenge of fixing a submarine that ran the risk of disaster whenever it decided to submerge!

Navantia admitted the existence of "deviations related to the balance of weight" in the vessel and estimated it would take up to two years more to correct the problem, pushing the new delivery date to late 2018. The firm's engineers are trying to determine their best options at this point. It appears that two choices are most likely: Find a way to trim the design of the overall ship, which would be very difficult at this stage in construction, or lengthen the hull of the already 233-foot submarine to compensate for the extra weight. The problem with this option is that designers have estimated that for every meter the hull is lengthened, it will end up costing nearly 10 million additional euros (about $14 million dollars). Unfortunately for the Spaniards, independent agencies report that they have already sunk the equivalent of $680 million into the Isaac Peral, and a total of $3 billion into the entire quartet of S-80 class submarines.

The buoyancy problem is not the only difficulty facing the program; an analyst said that that submarine's air-independent propulsion (AIP) system reactor is also underperforming. A Strategic Studies Group spokesperson said that the AIP system has been designed to enable the submarine to operate underway for 28 days but is currently able to manage only one week. The Group's memo suggests, "The buoyancy problem alone could cost up to half a

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billion euros to cover redesign and extra construction, without considering the propulsion problem."

The submarine setback couldn't have come at a worse time for Prime Minister Mariano Rajoy, who was already caught up in a corruption scandal and saw his approval rating hit a record low in 2013. Because of the poor shape of Spain's economy, Rajoy's austerity cuts trimmed the Spanish military budget by 30 percent in 2012, leaving much less room for added ballast. With reports that the S-80 program will be delayed an estimated two years and another general election looming in 2015, Rajoy likely will not see the submarines through to successful launch.

How did such an expensive project get funded at a time when the Spanish military's entire special weapons program received a 98% cut? Sheer pride seems to have been a factor: Spain hoped the S-80 class would be a new homegrown breakthrough achieved without foreign help. Now that Navantia has entered into a $15 million contract with the Electric Boat Division of America's General Dynamics to help with the redesign, that dream seems dead in the water.[17]

Questions

1. Google "Spain's S-80 class submarine" and read some of the articles posted. In your opinion, how does technical risk cause problems with major defense projects?
2. Why do you think it is common for defense contractors to add new features and modifications to current programs? In other words, why do defense agencies contract for one project, only to see it often evolve into something new by the time it is launched?
3. If you were an advisor brought in by the Spanish government, what advice would you offer them in managing their defense projects?

CASE STUDY 11.3

Classic Case: Tacoma Narrows Suspension Bridge

The dramatic collapse of the Tacoma Narrows suspension bridge in 1940, barely four months after completion, was a severe blow to the design and construction of large span bridges. It serves as a landmark failure in engineering history and is, indeed, a featured lesson in most civil engineering programs. The story of the collapse serves as a fascinating account of one important aspect of project failure: engineering's misunderstanding of the effect that a variety of natural forces can have on projects, particularly in the construction industry.

Opening in July 1941, the Tacoma Narrows Bridge was built at a cost of $6.4 million and was largely funded by the federal government's Public Works Administration. The purpose of the bridge was essentially viewed as a defense measure to connect Seattle and Tacoma with the Puget Sound Navy Yard at Bremerton.[18] As the third-largest single suspension bridge in the world, it had a center span of 2,800 feet and 1,000-foot approaches at each end.

Even before its inauguration and opening, the bridge began exhibiting strange characteristics that were immediately noticeable. For example, the slightest wind could cause the bridge to develop a pronounced longitudinal roll. The bridge would quite literally begin to lift at one end and, in a wave action, the lift would "roll" the length of the bridge. Depending upon the severity of the wind, cameras were able to detect anywhere up to eight separate vertical nodes in its rolling action. Many motorists crossing the bridge complained of acute seasick-

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ness brought on by the bridge's rising and falling. So well-known to the locals did the strange weaving motion of the bridge become that they nicknamed the bridge "Galloping Gertie."

That the bridge was experiencing increasing and unexpected difficulties was clear to all involved in the project. In fact, the weaving motion of Galloping Gertie became so bad as the summer moved into fall that heavy steel cables were installed externally to the span in an attempt to reduce the wind-induced motion. The first attempt resulted in cables that snapped as they were being put into place. The second attempt, later in the fall, seemed to calm the swaying and oscillating motion of the bridge initially. Unfortunately, the cables would prove to be incapable of forestalling the effects of the dynamic forces (wind) playing on the bridge; they snapped just before the final critical torsional oscillations that led to the bridge's collapse.

On November 7, 1940, a bare four months after opening of the bridge, with winds of 42 miles per hour blowing steadily, the 280-foot main span that had already begun exhibiting a marked flex went into a series of violent vertical and torsional oscillations. Alarmingly, the amplitudes steadily increased, suspensions came loose, the support structures buckled, and the span began to break up. In effect, the bridge seemed to have come alive, struggling like a bound animal, and was literally shaking itself apart. Motorists caught on the bridge had to abandon their cars and crawl off the bridge, as the side-to-side roll had become so pronounced (by now, the roll had reached 45 degrees in either direction, causing the sides of the bridge to rise and fall more than 30 feet) that it was impossible to traverse the bridge on foot.

After a fairly short period of time in which the wave oscillations became incredibly violent, the suspension bridge simply could not resist the pounding and broke apart. Observers stood in shock on either side of the bridge and watched as first large pieces of the roadway and then entire lengths of the span rained down into the Tacoma Narrows below. Fortunately, no human lives were lost, since traffic had been closed in the nick of time.

The slender 12-meter-wide main deck had been supported by massive 130-meter-high steel towers comprised of 335-foot-long spans. These spans managed to remain intact despite the collapse of the main span. The second bridge (TNB II) would end up making use of these spans when it was rebuilt shortly thereafter, by a new span stiffened with a web truss.

Following the catastrophic failure, a three-person committee was immediately convened to determine the causes of the Tacoma Narrows Bridge collapse. The board consisted of some of the top scientists and engineers in the world at that time: Othmar Ammann, Theodore von Karman, and Glenn Woodruff. While satisfied that the basic design was sound and the suspension bridge had been constructed competently, these experts nevertheless were able to quickly uncover the underlying contributing causes to the bridge collapse:

- **Design features**—The physical construction of the bridge contributed directly to its failure and was a source of continual concern from the time of its completion. Unlike other suspension bridges, one distinguishing feature of the Tacoma Narrows Bridge was its small width-to-length ratio—smaller than any other suspension bridge of its type in the world (although almost one mile in length, the bridge was only constructed to carry a single traffic lane in each direction). That ratio means quite simply that the bridge was incredibly narrow for its long length, a fact that was to contribute hugely to its distinctive oscillating behavior.
- **Building materials**—Another feature of the construction that was to play an important role in its collapse was the substitution of key structural components. The original plans called for the use of open girders in the construction of the bridge's sides. Unfortunately, at some point, a local construction engineer substituted flat, solid girders that deflected the wind rather than allowing for its passage. The result was to cause the bridge to catch the wind "like a kite" and adopt a permanent sway. In engineering terms, the flat sides simply would not allow wind to pass through the sides of the bridge, reducing its wind drag. Instead, the solid, flat sides caught the wind that pushed

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the bridge sideways until it had swayed enough to "spill" the wind from the vertical plane, much as a sailboat catches and spills wind in its sails.

- **Bridge location—**A final problem with the initial plan lay in the actual location selected for the bridge's construction. Although the investigating committee did not view the physical location of the bridge as contributing to its collapse, the location did play an important secondary role through its effect on wind currents. The topography of the Tacoma Narrows over which the bridge was constructed was particularly prone to high winds due to the narrowing down of the land on either side of the river. The unique characteristics of the land on which the bridge was built virtually doubled the wind velocity and acted as a sort of wind tunnel.

Before this collapse, not much was known about the effects of dynamic loads on structures. Until then, it had always been taken for granted in bridge building that static load (downward forces) and the sheer bulk and mass of large trussed steel structures were enough to protect them against possible wind effects. It took this disaster to firmly establish in the minds of design engineers that dynamic, and not static, loads are really the critical factor in designing such structures.

The engineering profession took these lessons to heart and set about a radical rethinking of their conventional design practices. The stunning part of this failure was not so much the oscillations, but the spectacular way in which the wave motions along the main span turned into a destructive tossing and turning and led finally to the climax in which the deck was wrenched out of position. The support cables snapped one at a time, and the bridge began to shed its pieces in larger and larger chunks until the integrity was completely compromised.

Tacoma Narrows Bridge: The Postmortem

Immediately following the bridge's collapse, the investigating board's final report laid the blame squarely on the inadequacy of a design that did not anticipate the dynamic properties of the wind on what had been thought a purely static design problem. Although longitudinal oscillations were well understood and had been experienced early in the bridge's construction, it was not until the bridge experienced added torsional rolling movements that the bridge's failure became inevitable.

One member of the board investigating the accident, Dr. Theodore von Karman, faced the disbelief of the engineering profession as he pushed for the application of aerodynamics to the science of bridge building. It is in this context that he later wrote his memoirs in which he proclaimed his dilemma in this regard: "Bridge engineers, excellent though they were, couldn't see how a science applied to a small unstable thing like an airplane wing could also be applied to a huge, solid, nonflying structure like a bridge."

The lessons from the Tacoma Narrows Bridge collapse are primarily those of ensuring a general awareness of technical limitations in project design. Advances in technology often lead to a willingness to continually push out the edges of design envelopes, to try and achieve maximum efficiency in terms of design. The problem with radical designs or even with well-known designs used in unfamiliar ways is that their effect cannot be predicted using familiar formulae. In essence, a willingness to experiment requires that designers and engineers begin to work to simultaneously develop a new calculus for testing these designs. It is dangerous to assume that a technology, having worked well in one setting, will work equally well in another, particularly when other variables in the equation are subject to change.

The Tacoma Narrows Bridge collapse began in high drama and ended in farce. Following the bridge's destruction, the state of Washington discovered, when it attempted to collect the $6 million insurance refund on the bridge, that the insurance agent had simply pocketed the state's premium and never bothered obtaining a policy. After all, who ever heard of a bridge the size of the Tacoma Narrows span collapsing? As von Karman wryly noted, "He [the insurance agent] ended up in jail, one of the unluckiest men in the world."[19]

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Questions

1. In what ways were the project's planning and scope management appropriate? When did the planners begin taking unknowing or unnecessary risks? Discuss the issue of project constraints and other unique aspects of the bridge in the risk management process. Were these issues taken into consideration? Why or why not?
2. Conduct either a qualitative or quantitative risk assessment on this project. Identify the risk factors that you consider most important for the suspension bridge construction. How would you assess the riskiness of this project? Why?
3. What forms of risk mitigation would you consider appropriate for this project?

INTERNET EXERCISES

11.1 Go to www.informationweek.com/whitepaper/Management/ROI-TCO/managing-risk-an-integrated-approac-wp1229549889607?articleID=54000027 and access the article on "Managing Risk: An Integrated Approach." Consider the importance of proactive risk management in light of one of the cases at the end of this chapter. How were these guidelines violated by de Havilland or the Tacoma Narrows construction project organization? Support your arguments with information either from the case or from other Web sites.

11.2 FEMA, the Federal Emergency Management Agency, is responsible for mitigating or responding to natural disasters within the United States. Go to www.fema.gov/about/divisions/mitigation.shtm. Look around the site and scroll down to see examples of projects in which the agency is involved. How does FEMA apply the various mitigation strategies (e.g., accept, minimize, share, and transfer) in its approach to risk management?

11.3 Go to www.mindtools.com/pages/article/newTMC_07.htm and read the article on managing risks. What does the article say about creating a systematic methodology for managing project risks? How does this methodology compare with the qualitative risk assessment approach taken in this chapter? How does it diverge from our approach?

11.4 Using the keyword phrase "cases on project risk management," search the Internet to identify and report on a recent example of a project facing significant risks. What steps did the project organization take to first identify and then mitigate the risk factors in this case?

11.5 Go to www.project-management-podcast.com/index.php/podcast-episodes/episode-details/109-episode-063-how-do-risk-attitudes-affect-your-project to access the podcast on risk attitudes on projects. What does the speaker, Cornelius Fichtner, PMP, suggest about the causes of project failures as they relate to issues of risk management?

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PMP CERTIFICATION SAMPLE QUESTIONS

11.1 The project manager has just met with her team to brainstorm some of the problems that could occur on the upcoming project. Today's session was intended to generate possible issues that could arise and get everyone to start thinking in terms of what they should be looking for once the project kicks off. This meeting would be an example of what element in the risk management process?

(a) Risk mitigation

(b) Control and documentation

(c) Risk identification

(d) Analysis of probability and consequences

11.2 Todd is working on resource scheduling in preparation for the start of a project. There is a potential problem in the works, however, as the new collective bargaining agreement with the company's union has not been concluded. Todd decides to continue working on the resource schedule in anticipation of a satisfactory settlement. Todd's approach would be an example of which method for dealing with risk?

(a) Accept it

(b) Minimize it

(c) Transfer it

(d) Share it

11.3 A small manufacturer has won a major contract with the U.S. Army to develop a new generation of satellite phone for battlefield applications. Because of the significant technological challenges involved in this project and the company's own size limitations and lack of experience in dealing with the Army on these kinds of contracts, the company has decided to partner with another firm in order to collaborate on developing the technology. This decision would be an example of what kind of response to the risk?

(a) Accept it

(b) Minimize it

(c) Transfer it

(d) Share it

11.4 All of the following would be considered examples of significant project risks except:

(a) Financial risks

(b) Technical risks

(c) Commercial risks

(d) Legal risks

(e) All are examples of significant potential project risks

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11.5 Suppose your organization used a qualitative risk assessment matrix with three levels each of probability and consequences (high, medium, and low). In evaluating a project's risks, you determine that commercial risks pose a low probability of occurrence but high consequences. On the other hand, legal risks are evaluated as having a high probability of occurrence and medium consequences. If you are interested in prioritizing your risks, which of these should be considered first?

(a) Commercial risk

(b) Legal risk

(c) Both should be considered equally significant

(d) Neither is really much of a threat to this project, so it doesn't matter what order you assign them

Answers: 1. c—Brainstorming meetings are usually created as an effective means to get project team members to begin identifying potential risks; 2. a—Todd is choosing to accept the risk of potential future problems by continuing to work on his resource schedule in anticipation of positive contract talks; 3. d—The firm has decided to share the risk of the new project by partnering with another company; 4. e—All are examples of significant potential project risks; 5. b—Legal risks would be of higher overall significance (high probability, medium consequence) and so should probably be considered first in a prioritization scheme.

INTEGRATED PROJECT

Project Risk Assessment

Conduct a preliminary risk analysis of your project. Please use two techniques, one qualitative and one quantitative, in supporting your evaluation of project risk. In order to do this, you will need to:

- Generate a set of likely risk factors.
- Discuss them in terms of probability and consequences.
- Develop preliminary strategies for risk mitigation.

An effective risk analysis will demonstrate clear understanding of relevant project risks, their potential impact (probability and consequences), and preliminary plans for minimizing the negative effects.

Sample Risk Analysis—ABCups, Inc.

Among the potential threats or uncertainties contained in this project, the following have been identified:

1. Plant reorganization could take longer than anticipated. Process engineering may be more complicated or unexpected difficulties could arise while the process alterations are underway.
2. A key project team member could be reassigned or no longer able to work on the project. Due to other requirements or top management reshuffling of resources, the project could lose one of its key core team members.
3. The project budget could be cut because of budget cutbacks in other parts of the company. The project budget could be trimmed in the middle of the development cycle.

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4. Suppliers might be unable to fulfill contracts. After qualifying vendors and entering into contracts with them, it might be discovered that they cannot fulfill their contractual obligations, requiring the project team and organization to rebid contracts or accept lower-quality supplies.
5. New process designs could be found not to be technically feasible. The process engineers might determine midproject that the project's technical objectives cannot be achieved in the manner planned.
6. New products might not pass QA assessment testing. The project team might discover that the equipment purchased and/or the training that plant personnel received are insufficient to allow for proper quality levels of the output.
7. Vendors could discover our intentions and cut deliveries. Current vendors might determine our intent of eliminating their work and slow down or stop deliveries in anticipation of our company canceling contracts.
8. Marketing might not approve the prototype cups produced. The sales and marketing department might determine that the quality or "presence" of the products we produce are inferior and unlikely to sell in the market.
9. The new factory design might not be approved during government safety inspections. The factory might not meet OSHA requirements.

Qualitative Risk Assessment

Probability

Consequences	Low	Med	High
High	5		8
Med	3, 9	2	1
Low	4	6, 7	

Quantitative Risk Assessment

Probability of Failure

- Maturity (Moderate) = .50
- Complexity (Minor) = .30
- Dependency (Moderate) = .50

Consequences of Failure

- Cost (Significant) = .70
- Schedule (Moderate) = .50
- Reliability (Minor) = .30
- Performance (Moderate) = .50

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P_m	P_c	P_d		P_f
.50	.30	.50		.43
C_c	C_s	C_r	C_p	C_f
.70	.50	.30	.50	.50
Risk Factor = (.43) + (.50) − (.43) (.50) = .715 (High Risk)				

Risk Mitigation Strategies

High Risk	Mitigation Strategy
1. Plant reorganization takes longer than anticipated	1. Develop a comprehensive project tracking program to maintain schedule.
2. Marketing does not approve the prototype cups produced.	2. Maintain close ties to sales department—keep them in the loop throughout project development and quality control cycles.
Moderate Risk	
3. New process designs are found to not be technically feasible.	3. Assign sufficient time for quality assessment during prototype stage.
4. A key project team member could be reassigned or no longer able to work on the project	4. Develop a strategy for cross-training personnel on elements of one another's job or identity suitable replacement resources within the organization.
Low Risk	
5. The project budget could be cut.	5. Maintain close contact with top management regarding project status, including earned value and other control documentation.
6. Factory does not pass OSHA inspections.	6. Schedule preliminary inspection midway through project to defuse any concerns.
7. Suppliers are unable to fulfill contracts.	7. Qualify multiple suppliers at prototyping stage.
8. New products do not pass QA assessment testing.	8. Assign team member to work with QA department on interim inspection schedule.
9. Vendors discover our intentions and cut deliveries.	9. Maintain secrecy surrounding project development!

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CHAPTER 12

Change Management

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There are certain words which regularly crop up in management conversations, words that are used as if they are perfectly unambiguous. A classic example is the manager's favourite: *strategy*. Executives happily have conversations throwing the word *strategy* around without considering whether they are talking about the same concept. The topics of this book and those familiar mainstays of management discussion—*change* and *change management*—fall into this category. The literature on these subjects is voluminous: the clarity, for many managers, is not. This chapter provides clear and practical knowledge to face the challenges of change.

The reasons why we need to explore change in organisations are simple. Delivering change is central to senior managers and executives. Change is both inevitable and the path to future rewards. The benefits arise from seizing innovative opportunities, reducing competitive threats and removing operational problems. Occasionally a change may be essential to remain in business.

Managers have essentially two tasks. One is the business-as-usual work your role exists to achieve. The other is making changes to improve performance in that business-as-usual work. Put the right team in place and they will competently do the business-as-usual work. They need your help to identify and make changes. Executives cannot succeed without envisaging and delivering change. But change is risky and managers need to assess and manage that risk. Unfortunately, the track record of implementing change is not great. It should and can be better.

Change management has arisen to improve on this track record, and it is concerned with two dimensions of change: the human dimension and the organisational dimension. The human dimension is critical because change is made by people: it is not made by new systems, processes or tools. Change may require modified systems, processes and tools, but it is people's adoption of them that is the change and one of the key requirements for successful change is to gain and retain support from the various stakeholders involved. But even if change is experienced at an individual level, it is at the organisational level that change achieves business results. Organisations are complex entities, with unknown numbers of interdependencies and interrelationships. Cause people to work in a different way—to new processes, systems, tools or organisation structures—and without adequate thought the business can be seriously disrupted.

There are many aspects to change management, but essentially, it seeks to:

- understand changes and the associated implementation risks
- implement the desired changes
- achieve performance improvements
- ensure a rapid (or as rapid as practical) completion of the transition from current to future state
- minimise unplanned operational disruption during and following changes
- sustain changes over the longer term.

Is this the complete recipe book for change? No, because such a thing cannot exist. Claims for universal change management approaches that work in every situation should be regarded with scepticism. There is no model change, there is no standard organisation and there is no average context. Every situation is unique and each change is unique. This book gives you:

- models to help conceive and understand change
- tools and techniques that aid in planning and delivering change
- lessons from experience to avoid the pitfalls of change.

Implementing change successfully is not just about identifying changes and applying change management to make them happen. It is also concerned with choosing the right change management approach that is most relevant to the context. This book will help you take the models, tools, techniques and lessons, and apply them productively to *your* situation.

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12.1 What is Change Management?

12.1.1 Introduction

There are thousands of books and papers on change management. Many of them focus on answering two questions: 'Why change?' and 'How do we manage change?' Between the *why* and *how* questions is a logical step that is often missed out. This is answering the question 'what is change management?'

A large part of this book describes *how* to manage change and your role as an executive in this process. At one level, understanding *what* change management is, is the most valuable lesson for the executive. If you understand what change management is, then you are in a strong position to utilise, expand on or reject various parts of the assorted change management approaches. Executives constantly face the need to change and rarely require commentators telling them *why*. On the other hand, explanations of the mechanics of *how* to change can only provide so much guidance to your unique context. Optimal results will never be achieved by unthinkingly following a standard approach. Change is most successfully led by those who have a fundamental understanding of what change and change management are.

This chapter reflects the two central aspects of change. Change as experienced by the individuals in your organisation, and change as a period of risk the organisation's operations must pass through. Understand these aspects and you will understand what change management entails.

The Human Dimension to Change

Change is made by people. It is not made by new systems, processes or tools. Change may require modified systems, processes and tools, but it is people's adoption of them that is the change. Implementing change is simply getting people to work in a modified fashion. You may look at change from the organisation's perspective, but people experience change personally. If no one experiences it personally nothing has changed! There is a standard human response to change: resistance. Resistance occurs for a variety of practical and psychological reasons, including:

- fear of the unknown or uncontrolled
- loss of status
- feelings of loss of control
- laziness and unwillingness to break habits
- feelings of criticism
- lack of trust and poor previous experience of change
- a real or imagined threat to role and rewards.

There is no single level of response to change. The level of response depends on the individual and their interpretation of and perceived relationship to the change.

Recently, there has been considerable debate in the change management community arguing that people do not resist change. I think there is some merit in these arguments, as in real life people undertake change all the time. There is no evidence for a global rejection of all changes. What people do oppose is the risk of detrimental impact, real or imagined, of specific changes. What counts as a detrimental impact is individual and subjective. For shorthand, I will simply refer to this as *change resistance*.

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Resistance is a normal human defence mechanism; an inevitable part of change. If there is no resistance then there is no belief that the change will occur. Resistance may be a minor irritant or a serious risk to the delivery of a change. You should not underestimate it, nor should you assume it will always be immediately apparent. You can assess and prepare for resistance and attempt to reduce it, but you cannot eliminate it—and it is not your enemy. It is just a fact of life that must be managed. One major component of change management is concerned with dealing with this resistance.

The Organisational Dimension to Change

Even if change is experienced at an individual level, it is at the organisational level that it achieves business results. Organisations are complex entities, with unknown numbers of interdependencies and interrelationships. Cause people to work in a different way, to new processes, systems, tools or organisation structures, and without adequate thought the business can be seriously disrupted. Changing one part of an organisation can be like pulling a thread from a piece of clothing. A thread that you are not sure exactly what it connects to. The second component of change management manages change from the organisational or operational level. Change management ensures that whatever is changed will not disrupt the workings of the whole machine.

12.1.2 Types of Change

Essentially, change management enables the effective execution of the relevant change management activities required to make a change occur. An understanding of what this means develops from appreciating the context and types of change that exist. There are countless varieties of change in organisations. The phrase change management is used in different, but related ways, by various managers. Changes can be titled projects, programmes, strategic initiatives, task forces or a variety of other names. I will refer to all these as change initiatives. Very broadly, change initiatives can be categorised into three main types:

1. transformational change
2. bounded change
3. deliverable-led change.

Transformational Change

Change type 1 is typified by the policies of the visionary new CEO or in a company that finds itself in serious difficulty. The CEO's answer is a major change initiative. The goals of such initiatives usually revolve around objectives like becoming customer orientated, enhancing product quality, radically reducing the cost base, becoming more flexible, altering the strategic direction of the business, restructuring and re-engineering of the organisation, developing the workforce of the future, cultural change and so on. The overall vision paints a picture of doing things differently and making a step improvement in performance. The change is considered transformational because it is intended to result in large improvements in performance. This is achieved by altering many aspects of the business in parallel, often across the whole organisation. At times the organisation may become more focused on changing than on current daily operations. The improvements may be externally announced and even promised to shareholders. The change has numerous interdependent elements, and is highly risky. Such transformational change often takes years to fully accomplish, although some elements are completed more quickly.

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Bounded Change

The difference between change types 1 and 2 relates to scope and ambition. Type 2 changes are normally initiated by a divisional leader or departmental head, who wants to improve their part of the organisation. Type 2 changes may be driven by some pressing company need, by the vision of that manager, or to enhance personal career prospects. The scope of such changes is more limited with clear boundaries. A typical situation is when managers modify their departmental structure or processes. The change is often concerned with becoming more efficient. Such changes are normally implemented in months, but may take years. A significant proportion of change is type 2. Type 2 changes are significantly less risky than transformation, but typically the potential benefits are also lower.

Deliverable-Led Change

Type 3 changes are normally called projects. The projects are not usually defined in terms of a change, but in terms of some deliverable. By deliverable I mean the answer to the classic CFO question: 'If I invest in this project what do I get?' The focus tends to be on the deliverable and not the change, hence they are perceived as projects rather than changes. Such deliverables may be new products, enhanced IT systems, modified business processes, new buildings and so forth. Whilst such projects may not be thought of as a change, a change must always occur or else no benefits will be delivered. For instance, consider something as straightforward as buying a new building. The process of planning who sits where, preparing staff for the new location and the actual move is all a change. Projects may take anything from days to years to complete.

Creating Deliverables and Delivering Change

Whilst these three types of initiative are often thought of as different, they have much in common. The duration and structure of change initiatives vary significantly, but all have a degree of complexity and are outside of the normal daily workload. All are done for benefit or improvement above current performance. To gain this benefit there are activities relating to making change occur, and there are activities relating to the creation of deliverables. For instance, a new piece of machinery on a production line requires staff to adapt to it. Similarly, a cultural change project will have supporting deliverables such as presentations for communication and modified reward and recognition systems.

It is worth stressing the need both for deliverables and for change activities. The difference between deliverables from an initiative and change activities is shown in Table 12.1

Change management enables the effective execution of the relevant change management activities. Other disciplines, such as project management, are concerned with the design and creation of deliverables. However, there is no clear-cut boundary: change activities can be managed as part of the project; alternatively, projects may form part of a change initiative. Whatever management structure is chosen, change usually requires both deliverable development and change management action. If not, the following happens:

- *Creating deliverables without supporting change activities:* the result is investment is made in new assets which are not fully adopted and utilised by the organisation. For example, the development of an IT system which is never properly utilised.
- *Executing change activity without creating supporting deliverables:* the result is an environment which does not provide the supporting infrastructure for change. For example, cultural change programmes which fail because HR systems are not modified to reflect the desired new behaviours to be rewarded.

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Table 12.1 Change Initiative Deliverables and Change Activities

Example Deliverables	Example Change Management Activities
IT systems Business processes and procedures Organisational structures, roles and responsibility definition Performance management processes and reward and recognition systems Products and services Training materials Buildings and other infrastructure Communication and presentation materials	Communicating vision, direction, plans, etc. Assessing commitment to change Developing support and overcoming resistance Identifying and removing obstacles to change Assessing boundaries of change and integrating into other aspects of the organisation Assessing and mitigating change risk Preparing stakeholders for the implementation of the change

12.1.3 The Goals of Change Management

There are various ways of implementing change depending on the type of change, and a huge diversity of organisational forms and contexts. This is reflected in variations in change management approaches and terminology. Differences in approach and language also reflect management fads. However, irrespective of the type of change and the way change management is described, there are common features to all approaches. Essentially, change management seeks to:

- understand the change and the associated implementation risk for the organisation
- implement the desired change
- achieve performance improvements, whether tangible or intangible
- have a rapid (as practical) completion of the transition from current to future state
- minimise operational disruption whilst making change, and minimise the duration and depth of any decline in performance following the change
- sustain the change over the longer term (following any change initiative or project completion).

Whilst it is not solely an objective of change management, one extra should be added to this list, and that is learning from change. Change is an inherent and ever-present feature of most organisations, and those that deal with change best are the ones who continually enhance their change management skills.

12.1.4 Achieving Change

So far, I have shown the many interwoven themes defining *what* change management is, all of which need to be considered by the executive. This section consolidates all the themes into one short set of ideal outcomes from a change initiative. Change management attempts to ensure these ideal outcomes are achieved, and while such ideals are not always achieved they provide a good basis to aim for:

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1. Deliverables are designed so they are compatible with those parts of operations which are not changing. It is the right change, implemented in the right way, at the right time. Therefore the change works and does not have a negative effect on operational performance.
2. Every change is supported, or at least accepted, by sufficient stakeholders affected by the change. Therefore the change is adopted and is sustained after the change initiative is complete.
3. The risks from changes (or every component of changes) are understood and appropriate mitigating activities are put in place. Therefore risk is minimised, problems are rapidly resolved and the probability of success is increased.

Many approaches to change management focus on point 2. This is critically important, and needs ongoing focus and management action. However, designing the appropriate deliverables and managing change risk are also vital for avoiding operational disruption.

Achieving the three outcomes listed above depends on managing the two central aspects of change: people and operations. The first is concerned with the stakeholders involved in the change. Stakeholders can include anyone who is influenced by or can influence the change. The primary groups of stakeholders are your staff and managers. For some changes, other stakeholder groups have to be managed as well, such as customers, suppliers, shareholders or people living in the vicinity of a business. The second aspect that change management has to consider is the operation of the business. Businesses do not exist to change, but derive their value from daily operations. Operations include activities like buying supplies, manufacturing outputs, developing products, making sales, servicing customers, recruiting staff and so on. Changes are undertaken to improve performance, but every change also exhibits a degree of operational risk. At the point of implementing change, and sometimes earlier in a change initiative, there is a risk that operational performance can be compromised.

With regard to staff and other stakeholders, change management seeks to ensure that they:

- are willing to break or modify habits and existing ways of working
- understand the change and how it affects them personally: what do they need to do differently? how should they do it?
- are capable of performing in the new way
- are motivated to continue working in the new way until it becomes the accepted way of working.

For any major change the battle with resistance is not easily or quickly won. A change may apparently be successfully implemented, but unravel months or even years later. The unravelling can result from altering management attention or from a change in key personnel. This allows hidden resistance to resurface. One of the change management challenges is therefore determining when the change is over, and when management can focus elsewhere. Calling time too early on change initiatives has often led to changes failing after a major programme has been thought complete and success has been trumpeted.

Ask any operational manager about their experience of change and you will probably get a mixed response. Whilst change is often undertaken to derive operational improvements, there is an inherent tension. Stability is the operational manager's friend. It is far simpler to manage a stable operation. On the one hand, change must be made and the desire for operational stability cannot stop a business's evolution. On the other hand, there is little point in driving continuous change if the result is continually failing operations. A balance must be found—and it can be. Change does not have to be the enemy of

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operations. Changes can be well thought through, properly designed and executed. Hence, with regard to the operations of the business, change management seeks to:

- create deliverables that are fit for purpose
- ensure operations have sufficient, capably skilled human resource to utilise the deliverables appropriately
- plan changes to happen at the most appropriate time in the business cycle, minimising operational impacts and taking account of any that are unavoidable
- implement appropriate management processes to monitor and manage the operation in the new way.

12.1.5 The Eight Building Blocks of Successful Change

By now, you should have an appreciation of what change management is. But what is required to make change happen? There are eight building blocks to successful change, which are summarised in Figure 12.1.

1 Recognised Need

The first requirement for any change is that there is a recognised need. People and organisations do not change without some impetus. People develop habits and tend to stick to the status quo. Change will only occur if there is a recognised need for it. The need does not require universal recognition, but it has to be recognised by enough sufficiently powerful people in the organisation. If you are trying to pursue change, and there is no perceived need for it, then your effort should be spent in creating this recognition. Unless you do this, your change will be a battle.

2 Mandate

Even if there is a need to change, nothing will change unless someone has the mandate or power to make the change occur.

Figure 12.1 The Building Blocks of Change

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Usually, responsibility for managing change is delegated. This can work if the change takes place within a single function a change manager is responsible for. However, the most effective changes often require cross-functional modifications. The responsible manager has to encourage change in areas in which they have no line authority. Influencing skills help, but a formal allocation of mandate is usually essential.

3 Direction

There should always be some sense of direction for a change. Change may occur without a clear sense of direction—but the organisation may end up anywhere, and this is unlikely to be where you want! The direction may be clearly defined, or it may be evolving from experience. Often this direction exists in vision statements and strategy documents. Direction must be easy to communicate, and should be understandable, meaningful and relevant to the stakeholders. In the remainder of this book I talk about direction being encapsulated in a shared vision. Creating such a vision is a core responsibility of the executive.

4 Approach

Once there is a direction there needs to be an approach. The approach shows the organisation how to go about making the change. There are several aspects to approaches, including methods, tools and plans.

If you are unsure how to approach change, and do not have in-house expertise, this is an area where professional advice can be really helpful.

5 Complete Scope

Changes need a *complete* scope. Scope is a word favoured by project managers. It refers to the definition of the boundaries of a change initiative: what is included and what is not. Without a scope an initiative cannot be properly structured or planned. Grand ambition usually requires grand scope. However, one of the ongoing challenges of change is to make the scope narrow enough to be achievable. There are many benefits from rapid change, and speed is often achieved by limiting the scope. Yet the scope must be broad enough that all important interactions and interdependencies are considered. Also, in many change initiatives these interdependencies stretch beyond the boundaries of an organisation and may affect suppliers and customers as well.

6 Resources

A change initiative requires resources. There is work to be done and work requires resources (people, time, budget, etc.). There will be people who are dedicated to the change initiative, but also time will be required from others across the organisation. In terms of cumulative employee hours it is often the total time spent across the organisation, rather than the dedicated change team, that is one of the main costs of change. Successful change requires time from large numbers of people to consult, discuss, explain and train in new ways of working.

The change team will need the support of senior managers and executives to access all the resources they require.

7 Willingness to Change

Change requires a willingness to adapt. Without a willingness to change the change ini-

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that people have to be willing to change. Whether this willingness comes from an acceptance of a mandated management directive or from an individual alignment with the goals of the change depends on the change and your organisational culture.

8 Monitoring and Intervention

Finally, there must be a way to monitor changes and for management to intervene if necessary. Starting out on a change is not about following an infallible plan, but following an ever-evolving set of directions. Unless change is monitored and appropriate management interventions are made, it is unlikely to end up where and when you want it.

It is important to understand that these are the building blocks of change, not preconditions: some may exist prior to a change starting. A corporate strategy may exist which gives an adequate sense of direction to a change initiative. There may also be a willingness to change because of the state of a business. But such things are not givens in all change initiatives. The development of these building blocks can occur as an integral part of the change initiative. It is not uncommon, for example, for one of the earliest activities in a change initiative to be selecting and training the change team in a change management approach.

The components of change initiatives to be developed depend on what exists in your organisation. Most organisations have a range of disciplines, processes and experiences that can be leveraged to support a change. Core amongst these are strategy development, project management and specialist skills in the creation of deliverables. Such skills include IT, process and organisation design skills. So, for example, if your strategy department have defined a clear vision for the business and a roadmap for achieving it, then change initiatives can build on this vision. On the other hand, if there is no strategy or vision, one of the first things in a change initiative must be to build this sense of direction.

12.1.6 Finding a Balance

Like so many things that are difficult, a central problem with change management is finding the right balance between conflicting pressures. There are many aspects to balance, but let me describe the ones which are particularly useful to consider. The balance of these factors underlies much of the thinking in this book.

Personal Change Versus Organisational Change

At one level an organisation is simply an amalgamation of individuals. So, delivering change means managing change at an individual level. There is some truth to this, except it is not possible to manage deliberately the change each individual goes through in an organisation of 20,000 employees spread across the world. Additionally, the organisation at the start of the change may be made up of quite different individuals than at the end. The individuals may change, or the organisation may change the individuals it employs. Many models of change show the way individuals adopt or reject change, and this is important to understand. But in the end an executive will be measured by how the whole organisation's performance changes—not how individuals have or have not changed.

Project Managed Change Versus Evolving Change

Managers like to control activity and usually need to commit to timescales and results. The mechanism to control change is often project management and more specifically, the

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project plan. Project management has an important role in delivering change. But change, in such an unpredictable thing as an organisation made up of a large body of staff, cannot be controlled perfectly by a task-based project plan. There are predictable aspects to many changes, such as developing and implementing a new IT system, which can be managed as a project. There are also evolving aspects to change, such as modifying organisational culture, which cannot be managed as a project. Additionally, you can never control all the external forces that affect change results. This makes it a challenge for executives to commit to benefits at the outset of an initiative. The consequence is a tendency to keep promises conservative until the plan unfolds. Sometimes creating the plan and business case for change are nothing more than going through rituals of expected business behaviour. What happens in reality bears no resemblance to plan or business case.

Change as Management Directive Versus Change as Individual Choice

There is an emphasis in some business literature about the need to direct change. In contrast, other writers stress the individual's choice and journey to accepting change. In most cases both are important. An organisation must find the balance between working with staff until they willingly consent to change and leaders mandating change.

Change is rarely successful just because it is mandated by the senior managers in an organisation. In the end, it is not the leaders who need to make changes, but the ways that people work in an organisation need to change. In most situations, people will not change just because leaders tell them to. Managers should be particularly alert for superficial commitment from staff to following their commands. However, seeking commitment to change from every individual in an organisation is usually impractical, Without some level of directive, based on organisational power, many changes will never occur.

The Change Wanted, Versus the Status Quo to be Retained

However transformational a change initiative may claim to be, it is never appropriate to change everything in an organisation, otherwise why not just start a new organisation? Some things need to stay the same. Change can have collateral damage and may modify things that an organisation does not want to alter. The classic example is the cost reduction programme, which changes a company's cost base but also inadvertently lowers product or service standards and staff morale. Often there is too much focus on what to change whilst forgetting what needs to stay the same. On the other hand, too much concern about what needs to stay the same can lead to excessive caution and timid aspirations. Finding the balance between keeping hold of what is important in an organisation whilst achieving the aspirations of a change initiative is one of the great change challenges for executives.

Change Management as an Implementation Issue as Opposed to a Core Discipline

Change management tends to be looked at in two different ways. Some people see change management as an add-on discipline which is used to ensure the success of a project during its final implementation. For example, the IT developer analyses, designs and develops a new system and when it comes to implementation asks for some change management support to make sure the system is implemented smoothly and accepted by users. The alternative view positions change management as an over-arching discipline that controls the whole initiative. For instance, in a cultural change programme, the whole programme is about change—it is not merely something done at the end of the initiative. The appropriate choice depends on the situation. Whether to treat a whole

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initiative as a change, or to apply change management at an appropriate stage, is an important judgement in shaping successful changes.

The Change Versus Changing in General

There is a project view of a change: define a change, make it happen, achieve a result, end the project. There is also an evolutionary view of change: every change is just part of a process of a gradually evolving business—change never starts and never finishes. There is truth to both views. An organisation that only focuses on projects may optimise an individual change, but is unlikely to develop the flexible organisation that learns and can adapt to new situations. On the other hand, too little focus on the project can lead to a lack of specific results. (Six Sigma is an approach which can be implemented to achieve this balance. At one level it is a way to improve a business through ongoing change, yet it is implemented through specific targeted initiatives with measured results.)

Theoretical or Academic Approaches Versus Practical or Pragmatic Approaches

Change is a topic that has a significant history of academic research. There is a huge amount to learn from theoretical ideas on change, but executives are not faced with the challenge of understanding and debating change—but with delivering it. Most executives want leading-edge thinking and robust proven techniques. Such knowledge must be practical. Debates can be had on whether change is chosen by organisations or forced upon them, or whether there really is such a thing as a steady state 'as-is' organisation to change. Such ideas are intellectually interesting, but of little relevance to an executive facing the challenge of delivering a change today. No number of change lifecycle diagrams drawn on flip charts will actually make change happen. Most writing on change is experience-based opinion—it is not, and should not be treated as, proven scientific law. However, the pragmatist who pays no attention to useful theory is missing a powerful body of knowledge.

The focus of this book is on the practical. It takes account of models and theories of change, but it does not provide a compendium of them.

The central point is that successful change requires a balance between contending pressures. There is no one right balance, but only a balance that is right for an organisation at a point in time. Finding this balance and making the organisation work with the constraints it imposes is one of the key roles for the executive in change management. Different approaches to change management stress different balances.

Many of the most significant innovations in management thinking have been about change in one way or another. Look back over the past 20, 40 or 60 years, and topics like statistical process control, total quality management, software development and automation, business process re-engineering (BPR), restructuring, organisation design theories, balanced scorecards, ERP (enterprise resource planning) systems, Lean, Six Sigma, and many others are all essentially ways to identify, implement and sustain change in organisations. A skilled executive needs to be able to pick the most relevant tools from this ever-growing body of knowledge.

12.1.7 Key Terms and Concepts

There is, unfortunately, no standard or universal terminology for change. In this section I outline some of the key terms which are used in the book. The definitions are my own, but they are based on commonly accepted usage. If you are working with experienced change practitioners or consultants it is worth asking them to define any terminology

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they use to ensure there is no confusion. Don't feel embarrassed about asking. Even the most experienced practitioners use terms in different ways, and a shared understanding is essential for a successful change initiative.

CLOSE-UP 12.1 People Involved in Change

Stakeholder: anyone who can influence or is influenced by a change initiative. In practice, this is primarily the staff and managers in an organisation, but it can include others such as suppliers, customers, shareholders or people who live in the vicinity of an organisation.

Change sponsor: a senior manager or executive accountable for the delivery of the change. For any significant change this must be an executive and ideally a board member. This is usually a part-time role, but may be full-time on a major transformation programme.

Change manager: the individual tasked with directing the change initiative on a day-to-day basis. Typically, this is a full-time role for someone with some level of change and project management knowledge. If these skills are not available the individual may be supported by consultants.

Change team: a team of people working under the direction of the change manager who create change deliverables and undertake the necessary change management activities.

Change agent: individuals within operational functions who support the change initiative and who actively help to achieve the change. Such individuals may or may not have formal roles in a change initiative.

Another term in common usage is *change leader*. I have avoided it as I find it ambiguous. Sometimes it refers to the change sponsor, sometimes the change manager, and on other occasions it refers to change agents.

CLOSE-UP 12.2 The Process of Change

Change agenda: the complete set of initiatives an organisation would like to pursue at any point in time. The agenda contains actively pursued initiatives as well as those that have not yet been started. The totality of the agenda, if ever executed, is designed to achieve the organisation's overall vision.

Portfolio: the set of projects and initiatives under way in an organisation at any point in time.

Roadmap: a high-level milestone plan showing a path from one state to another in an organisation, usually involving multiple projects over a period of time.

Change initiative: a specific change that an organisation wants to undertake. This may be structured as a project, a programme, a Six Sigma initiative, etc.

Implementation: the stage in a change initiative when changes are actually made. Typically this follows a period of design and development of deliverables and gaining acceptance of the change from staff in the organisation.

Execution risk: operational risk that occurs at the point of implementation.

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Phase: a sub-part of a change initiative. Large initiatives are often broken into phases, with each phase delivering a part of the overall change.

Deliverable: something created in a change initiative which supports or facilitates the change. Deliverables are often new assets such as IT systems, new infrastructure or training materials but they may also be intangibles such as organisation designs or business processes.

Benefit: the tangible or intangible results from a change initiative. Usually a change initiative must be justified through a business case. The business case lists the benefits to be achieved. Typical measurable benefits are margin increases, cost reductions, increased customer engagement, staff satisfaction improvements, reduction in staff turnover, etc. There may be intangible and unmeasurable benefits as well, such as increased organisational flexibility. The benefits are the ultimate answer to the question, 'Why are you pursuing this change initiative?'

Change activity: activities within a change initiative to assist with managing and achieving a change.

Project: a formally structured approach for delivering a change, utilising project management.

Programme: a set of related projects, usually structured to deliver some common area of change. For example a cost reduction programme made up of several projects each delivering an element of the overall cost reduction.

CLOSE-UP 12.3 Supporting Concepts

Change capability: the level of capability within an organisation to pursue a change. This relates to factors such as the levels of experience, numbers of managers with change management experience, etc.

Change capacity: the ability of an organisation at a particular point in time to pursue a change. This is typically related to the period in the business cycle and the degree of other changes going on in parallel. At the busiest times of the year, and when there are many other initiatives under way, there is typically limited capacity to undertake other change.

BRIEFING LESSONS

- There are two main dimensions to every change: the human dimension dealing with the responses of individuals, and the organisational dimension ensuring the change is compatible with your operations.
- There are a variety of changes in terms of scope and approach. Change requires a combination of creating deliverables which enable the change and change management activities to encourage the change to occur.
- The ideal outcomes from a change are:
  - deliverables designed so they are compatible with those parts of operations which are not changing: the right change, implemented in the right way, at the right time
  - that the change is supported, or at least accepted, by sufficient stakeholders affected by the change
  - that the risks from change (or every component of change) are understood and appropriate mitigating activities are put in place.

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- There are eight building blocks to change: recognised need, mandate, direction, approach, complete scope, resources, willingness to change, and monitoring and intervention.
- Successful change requires a balance between contending pressures.

12.2 Why Change Management?

12.2.1 Introduction

For executives, before worrying about the details of selecting changes and performing change management, there are four fundamental questions that are worth answering:

1. Why bother with change?
2. What are the risks of change?
3. What are the costs of change?
4. What are the rewards of change?

12.2.2 Why Bother with Change?

Why do you need to change? The easy answer is that you have no choice, Change is an inherent feature of business and management. Whilst the pace of change may have increased, it has always been a facet of life: integral parts of society, organisations and businesses are not immune to the need to change for many reasons. Common drivers for change are:

- national and global economic shifts—as economies move from growth to recession, and back to growth again
- competitive threats
- globalisation—including outsourcing and offshoring
- technology enhancements—for example new IT systems and improved machinery
- modifications in legislation and regulation
- new product opportunities
- mergers and acquisitions
- environmental concerns
- alterations in customer demands.

Businesses are continually subject to evolving competition and increasing demands from shareholders. Even the most apparently cosseted public sector organisations are exposed to the results of varying tax revenues, evolution of social attitudes and political trends. It is not an overstatement to say that change is essential to organisational survival. Change is both inevitable and the path to future rewards. (The last section of this chapter looks at the rewards from change in a little more detail.)

Whether change is something an individual organisation chooses to do, or is forced to do, is a moot point. My view is that the drive for change comes from a combination of external pressures and internal management foresight. Given that change is both inevitable and the path to future rewards, executives have a responsibility to prepare organisations for change. Much of change management is concerned with the definition and implementation of specific changes. Executives should also be concerned with the

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development of a capability to change irrespective of the specific individual changes pursued. This is achieved by ensuring the organisation has the following:

- Human resources with the skills and experience of change: the availability of a cadre of managers and staff who can deliver change.
- Effective change tools and methodologies: this includes basics, such as reliable project management; supporting skills such as process, organisation and technology design skills; and specific change management techniques.
- Flexibility: if change is ongoing, then the organisation that has inherent flexibility in systems, processes, organisation, people and skills, infrastructure, etc. will be best placed to respond to change requirements as they arise. Flexibility is not a result of lucky circumstances, it is designed into organisations.

Accepting there is a need for change is a long way from accepting the need for a specific change—or a specific approach to implementing that change. Let's look at these points too.

Why This Change?

Whilst change is a general requirement of every organisation, most specific changes are choices. As an executive you are usually faced with options over both the nature of change and pace of change implementation. Even if your business is facing bankruptcy and only has a short time to make radical cuts or face shutdown, you usually have choice as to what specific cuts to make. At the other extreme, if your organisation has reliable revenues and limited competition you have time to pick and choose which changes to make. There are significant implications regarding which changes are made, and how those changes are undertaken.

This leads to two challenges for you as an executive:

- to identity the right set of changes to undertake at any time: it's easy to identify some possible changes, but are they really the best ones to implement now?
- to develop a compelling case for change.

How do you select the right changes to make? Partially, the choice is developed in the organisational strategy. Arguably, the key purpose of strategy is to identify and prioritise the changes required. But, whilst a strategy may be critically important, it will not identify all changes needed. Some aspects of change are concerned with the grand vision for an organisation and are achieved through strategic company-wide change programmes. On the other hand, much change is identified and implemented at the micro level in organisations—within individual departments and processes. Such micro change is often invisible to the executive. Usually, it is not individual changes which deliver the strategic agenda of the organisation, but the cumulative effect of many small changes. Additionally, there is an operational reality in most organisations. Change may have little to do with strategic vision, and simply be concerned with fixing current problems and hitting current targets. Executives are regularly faced with decisions about trading off resources allocated to fixing today's problems versus investment in strategic change.

Assuming you select the right changes, you then need to create a persuasive case for change. Even if change is unavoidable, the case for a specific change may not appear to be compelling to all stakeholders. Why does this matter? One of the main concerns of change management is gaining and retaining support for change from various stakeholders. The stakeholders can either help or hinder the change. Change initiatives succeed or fail depending on their level of adoption by stakeholders in an organisation. The primary stakeholders are the staff and managers of the business, but may also include others such as

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customers, suppliers and shareholders. In a strong command and control environment it may be possible to mandate change, but to some extent, and often a considerable extent, adopting a change is a choice people make. With increasingly distributed organisations with high levels of delegated decision making and empowered staff, successful change is built upon compelling stories that people believe. Hence one of the main activities in change management is developing a compelling case for change, and using this case to convince stakeholders to actively support the change.

What is a compelling case for change will vary between stakeholders. A board member will want to see a positive business case for any change. An operations director may ask, 'How will this increase operational performance?' More junior staff want to ascertain 'What's in it for me?' What is good for a business overall may not be good for every individual in the business. Change is often unwelcome, especially with the history of job losses over the past few decades. In most changes there will be some people who perceive themselves as winners and some as losers. You may not be able to convince everyone to accept a change, but you must convince sufficient people. For a large change this cannot be achieved by a single communication, but is done by a set of communications targeted at different stakeholder groups. For those who will never accept the change, communications are undertaken to minimise the disruption such groups may cause to a change initiative.

Change is usually portrayed as being undertaken to achieve a result. There is another approach, which I am personally sceptical of. This is change as an end in itself. The aim of this type of change is not to achieve some predefined business case or benefit, but simply to keep people on their toes. The theory is that the most flexible staff will be those who are used to changing most on a regular basis.

Why a Specific Approach to Change Management?

The term 'change management' brings a wide range of concepts and ideas into various practitioners' minds. There is no single universal body of knowledge for change management, and different change practitioners have their favoured approaches, usually depending on their experience to date. Bring half a dozen change consultants from the major consultancies into one room and there is much they would agree on, but there would also be much they would do in different ways or explain in different words. Even the term 'change management' is not liked by some practitioners. Look at the books on change management in any business bookshop—there will be tomes on leadership for change, communication for change, projectised approaches to change, people-focused methods and even fables, such as the hugely popular 'Who moved my cheese?'

Most senior managers accept the need for some form of change management, but often struggle with selecting what is right for their business. It would of course be so much easier if there was one approach to change, but I do not think this is possible. There is no model change, there is no standard organisation and there is no average context. Every situation is unique and each change is unique, To some extent your approach to managing change must reflect these unique situations. This book will help you select the right approach.

There are human-centric forms of change management that consider the process of learning, acceptance and adoption of change by individuals in an organisation. There are more global visions of change management that look at an organisation as an organism in dynamic balance. There are management fads over the past few decades relating to change, from programme management, total quality management (TQM), business process reengineering (BPR), organisational design models, Six Sigma and Lean, to complex project management and so on. This book cannot encompass the richness of all of

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these methodologies—but it will show a path through them and explain your role with regard to them.

Current fashions in management thinking rapidly evolve, but each wave of thinking has its longer-term impact. For instance, BPR may no longer be an everyday term in regular use when it comes to change initiatives, but the concept of designing organisations around processes and the reflection on business processes of any change are now universally accepted. Few organisations see TQM as a central plank of driving their organisation forward, but the principle of building quality into every aspect of work has been widely taken on board.

The vast array of different approaches can make change management seem overly and unnecessarily complex. There are commercial reasons why change practitioners, consultants and authors come up with new approaches and present them as the answers to all your ills. The truth is generally simpler, There is no need for well-managed change to be complex-managed change. Most of the change management approaches have many common aspects. Those parts that are novel or different have specific applications that may or may not be relevant to your situation. Why a specific approach to change management? Because your situation is unique and you must choose the approach that is best for your current situation.

Whatever approach to change management is taken there is universal agreement on the importance of the executive and senior management with regard to successful change implementation. As an executive, you will rarely need to know every aspect of a specific change management approach, but there is significant value in having some level of understanding of a wide range of tools. If nothing else, you have an important role in ensuring the organisation has access to the right set of capabilities to deliver the necessary changes.

12.2.3 What are the Risks of Change?

Assuming you accept the need for change, you may be thinking, 'So what's the catch?' One catch is that change is risky (the other is the costs which are described in the next section). In this section I explore these risks and explain how you can use change management to overcome them.

Changes cost money and use up valuable resources. Often, an important change will take up the time of your most highly skilled and valuable staff. Individual changes may be optional, but change over time is essential to survival. Activities that are both resource hungry and essential to survival should not be left to ad hoc management. It is too easy to manage change poorly and there are many risks in implementing change. Without the right management approaches, these risks will derail even the most essential changes. To understand these risks let's explore that track record of change in business.

There are four classic outcomes from change, which reflect the risks and the ways to avoid them. The outcomes are shown in Figure 12.2. In summary they are:

- the disaster
- the lost investment
- the partial success
- the ideal.

Figure 12.2 is made up of four graphs, each describing an organisation's performance against time both before and after a change is implemented. Each graph represents a different possible change outcome. By understanding these outcomes, you will be able to understand the risks of change, and the need for and objectives of change management.

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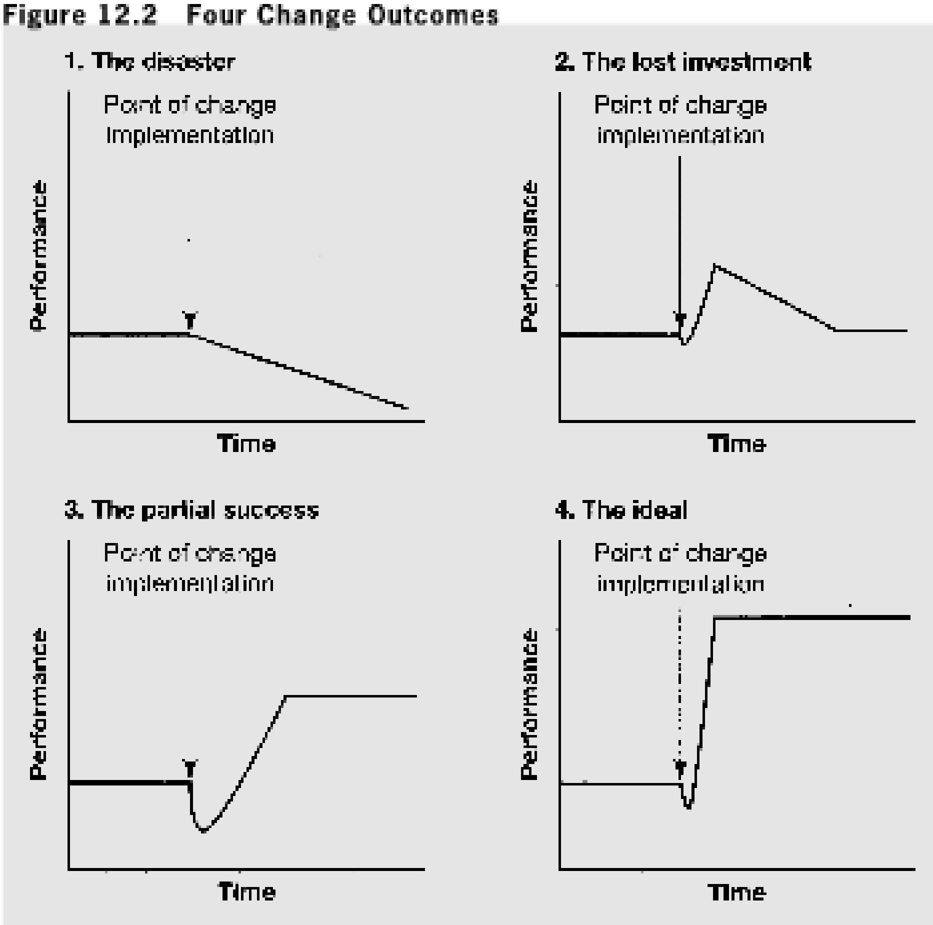
Figure 12.2 Four Change Outcomes



In the first situation, 'the disaster', an organisation has undertaken an irreversible change. You may think that all changes are reversible, but they are not. For instance, many IT and production line changes cannot, in practice, be reversed once undertaken. Similarly, redundancy programmes cannot be undone. You can recruit again, but that will not deliver the same pool of talent and skills. The first graph describes a change which is incompatible with the wider business operations—but it cannot now be undone. The change was probably not fully tested prior to implementation. The result is a devastating reduction in performance, leading possibly to bankruptcy or failure. Such outcomes are rare, but not unknown. Business history has plenty of examples of the hasty executive, whose schemes turned out to be disastrous for the client organisation. More common than complete business failure is a period of painful adjustment as ways have to be found to overcome the unforeseen damage the change has done.

In the second example, 'the lost investment', the change is implemented, usually to great fanfare. Initially, there is a significant improvement in performance. Over time performance declines. Old ways of working reassert themselves and the change is gradually abandoned. The initial implementation of a change is often far easier than sustaining it for the longer term. Sometimes, the reversing out of changes happens bit-by-bit, and so slowly and subtly that it is not even noticed. It only becomes apparent when a board member asks why, given the huge investment in change over the past few years, business performance has stubbornly stayed at the historic levels.

The third outcome is happier for the client organisation. The change is implemented, and over time there is a sustained improvement in performance. This 'partial success' may not realise the change's full potential, and the business case is never achieved. This outcome is very common. The result is a positive improvement, but less than was originally

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planned. In time, the original business case is usually forgotten and left lying deep in the company archives.

Before I explain the fourth graph let's look at one feature of all of these change outcomes. In all cases, following change implementation there is a drop in performance. This may seem counter-intuitive, but experience shows that at the point of implementing a change there is almost always a drop in performance. This is due to a number of reasons. One reason is that at the point of implementation key resources are focused on the change and not daily operations. Another reason is that it takes some time to learn the new ways and reach the change's potential. For example, think of your own experience of adopting a new piece of technology—it may eventually make you more productive, but the minute you get it you are usually unproductive as you grapple with how to use it and how its features work.

The 'ideal' outcome (number 4) takes account of these facts. The change leads to a rapid, significant and sustained improvement in business performance. Additionally, the drop in performance immediately following change implementation is shallow and short—ideally so shallow and so short that it never shows up in the performance figures. Many executives may deny it, but achieving this optimal result is rare, yet possible.

It's easy to criticise such models. They never truly represent reality. Most organisations are implementing multiple changes at once and there is no neat performance graph like these. Even individual changes do not lead to a single result, but can show aspects of all of these graphs. Some changes do not have a hard go-live date, but are implemented over a period of time and evolve as the implementation takes place. Irrespective of this, the principles and lessons these models display hold. The answer to the question 'Why change management?' is straightforward: to avoid outcomes 1, 2 or 3 and to get as close to outcome 4 as possible.

Another way of answering the 'Why change management?' question is to consider the risks that arise in managing individual or multiple change initiatives poorly and show how change management avoids them. The main risks you face in undertaking change are:

- failure to achieve a business case
- repeatedly making the same mistakes and failing to learn
- short-term disruption to operational performance
- long-term unexpected outcomes from the change

Let's look at each one of these in turn.

Your first risk of managing change poorly is that the change initiative does not achieve its justifying business case. Just because a change should deliver certain business benefits does not mean it will. A change initiative may fail completely or partially, as seen in the models above. The initiative may be late, cost too much or deliver too little. Either way, the disciplines of change management increase the probability that your change will succeed as desired.

Your second risk is that your organisation repeatedly makes the same mistakes every time you try to change. Because organisations change regularly there is the opportunity to learn and improve on the way change is handled. But too often changes are implemented without organisations learning from the experience. This may be perceived as a trivial issue, but in the long run it becomes a significant problem. Successful organisations are organisations that learn. Individuals learn from their experiences, and will learn from both poorly and well-executed change, But organisations that learn the most do not rely on their staff to learn in an ad hoc fashion. Such organisations deliberately capture knowledge and have formal reviews of experiences to aid learning. Good change management will build in this learning as a normal part of change execution.

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Wasting resources on unsuccessful initiatives and failing to learn are ways to short executive careers. They also result in sub-optimally performing businesses. But you face greater risks from change. The most significant risk from a poorly executed change is that it detrimentally disrupts your current business operations. There are thousands of examples of poorly managed changes that have led to problems such as production lines stopping, staff going on strike, customers leaving or computer systems malfunctioning. Large organisations are complex entities with numerous interactions and interdependencies which are not easy to understand. Change one part of the machine and another can easily stop working. Change management prepares for *execution* or *implementation risk*—that is the risk that something may go wrong in an organisation as a change is implemented. Preparing for implementation, testing and trialling changes and choosing the best implementation approach are all critical parts of change management.

Changes pose long-term operational risk as well. There may be a sigh of relief the day a change is implemented if nothing goes wrong. But problems from change may not be initially apparent. Businesses have cycles—and for example it may only be when a peak workload is reached that problems with a change become apparent. There is little point in being pleased about a change to enhance staff working patterns, if over the following six months there is a significant upswing in staff turnover. Similarly, cost reductions in operations may be seized, but lead, in time, to lower product quality. If this in turn causes reduced customer satisfaction and, in time, to losses in market share then nothing has been gained. Such risks show the need for the executive to take the long-term as well as the immediate view of change.

One way to view change management is as a method for assessing and dealing with risk. There are many sources of this risk, but two are critical:

1. The complexity of operations and supporting infrastructure—whether this relates to business processes, computer systems or some other aspect of a business. How a change works in the real live organisation is often different from that predicted in the high-minded visioning of an executive workshop or project planning session.
2. People—the individuals affected by the change. How people learn about, react, accept or reject change, and how these responses should be dealt with. Human beings are neither predictable nor homogeneous, and this leads to significant risk with change.

But managing change is not just about managing risk. To change, an organisation has to have to the capability to change. Change management is a set of disciplines that aims to ensure an organisation is capable of making a change (i.e. it has the right skills and resources), and has the capacity to execute the change at the designated point in time.

In summary: why change management? Change is too important and too risky not to be managed in a controlled way. Change management provides a set of tools and techniques to enable organisations to change whilst managing the risk that arises from the process of changing.

12.2.4 What are the Costs of Change?

Change is a complex activity. It costs money and uses up valuable resources. What initiatives cost varies hugely, but what is certain is that change cannot be done for free. You may never account for the cost, as it may be hidden as part of your business-as-usual activity, but it is there. There are five main areas of cost to consider:

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1. the direct cost of the change team
2. consultants and advisers
3. the time from the rest of the organisation
4. investments to facilitate change
5. longer-term costs.

The Change Team

The most apparent costs are those associated with a change team. This team may be full- or part-time, but for any significant change it is likely that there will be a core team that will be dedicated to the change initiative. The temptation can be to reduce this cost by using the time of the most easily available staff. Perhaps their work has naturally come to an end, they have been sidelined for one reason or another, or were working on a project that is complete. The problem is that the most easily available staff are often not your most highly skilled. A high-risk change initiative needs skilled people. If you are accountable for the change initiative and you really want it to be a success, it is usually your most highly skilled and valuable staff who should be allocated.

Consultants and Advisers

Realising there is a need to change is a common trigger for executives to think about using consultants and advisers. Such helpers, if well chosen, can provide access to a wide range of tools, techniques and experiences which can significantly reduce the risks your business faces in undertaking change can also simply increase your capacity. Increasing capacity is a common, if expensive, reason for using consultants. However, good advisers do not come cheaply and a large team of consultants can soon consume even the most generous budget. Hundreds of thousands of pounds on consultants is normal, and millions and even tens of millions is not that uncommon for large initiatives. Before you assume you are going to make use of consultants, check you have the budget!

Some organisations successfully reduce these costs by building their own in-house centres of expertise in change.

Time From the Rest of the Organisation

One significant cost that is often forgotten is the effect on the time of everyone affected by a change. Whilst you may allocate a change team to act as the central resource to design and manage a change, they are not the only people who will work on the change. Many people in the organisation will need to give up time to:

- explain how things work to those involved in designing changes
- provide ideas for improvements
- be consulted on the effectiveness and realism of planned change
- have changes explained to them
- be trained and prepared for change.

These costs are often hard to quantify as they may be in the form of odd hours here and there rather than identifiable contiguous chunks of time. The most complex change may require days of training and workshops for everyone in an organisation. This obviously has a direct cost, but often more significant is the indirect cost of reduced productivity whilst employees are supporting the change.

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Investments

Another factor you must consider is any investments made as part of a change initiative, or to support the change initiative. Such costs can include anything from buying new facilities, to investing in enhanced IT systems, spending on process and organisational designs, through-to more intangible costs. Such costs are often thought of in terms of project budgets to create deliverables required to facilitate the change.

Longer-Term Costs

The final set of costs are often the most difficult to quantify, and the ones that tend to be ignored. These are the long-term costs of a change. Of course changes are done for benefits and rewards, but there are almost always side effects. The classic situation is when you choose to make people redundant. This will tend to reduce staff morale amongst those who remain, resulting in reduced productivity and increased staff turnover.

This final set of costs is often ignored because of the challenge of quantification or sometimes because of naivety. Unfortunately, these costs are sometimes deliberately ignored by less scrupulous managers, especially those with a short-term involvement in a business, to ensure a business case for a change initiative looks positive. If you are presented with a very positive business case for an initiative, always challenge for the longer-term implications and costs.

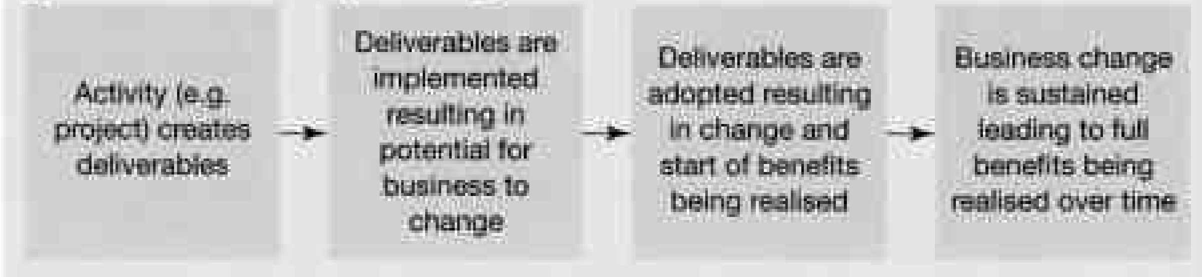
12.2.5 What are the Rewards of Change?

If change is risky and it costs money—why should you undertake it? Quite simply, because change provides the potential for significant rewards. This potential for rewards is the reason for change, and the real measure of success. If there are no rewards, the change is not worth investing in. Typically, these rewards are thought of in terms of financial returns, but change can improve organisations in many ways, not all of which are linked to a financial benefit. The process of reaping these rewards is shown in Figure 12.3.

The general name for such rewards is *benefits*. The benefits arise from seizing innovative opportunities, reducing competitive threats and removing operational problems. Occasionally a change may be essential to remain in business.

Change starts with activity to create something. Examples include creating a change plan, developing tangible deliverables like new facilities, machinery, IT systems or process designs, or it may be more intangible, such as designing an improved culture or identifying preferred behaviours in an organisation. Irrespective of what it is, this adds no value to the organisation unless it is adopted and used. This may seem obvious, but it is often forgotten.

Figure 12.3 From Activity to Change Rewards



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Business history is full of well-intentioned projects and activity which never achieve anything because no change has taken place.

Like most things in business, to be optimised rewards need measurement and management. The process of managing and measuring the rewards from a change initiative is called *benefits realisation*. As well as capturing rewards, benefits realisation leads you to consider factors such as:

- the timing of the change
- the phasing of benefits (i.e. the rate at which rewards are achieved from a change)
- the types of rewards possible.

The Timing of a Change

The impact of timing upon benefits is often relative to what your competitors are doing. Generally, making an innovative change early is risky, but the rewards are potentially high. Make it late relative to your competitors and some of the risk will be reduced, as the idea is proven. However, the benefits are often lower, and the change may be necessary to remain competitive rather than giving you any measurable advantage. Of course, this is a very simplistic analysis and the reality will depend on the nature of the change and the trends in your industry. However, it does point to the advantages of understanding the trends in your industry or sector.

For most executives, the need for change in business is a given, but it is worth understanding the general pressures and trends in your sector. The reason is practical. Much of the time spent in change will be convincing others of the need for change. The clearer you are about the trends and pressures in your industry, the more informed and convincing your arguments will be.

Phasing of Benefits

When you consider the benefits from a change initiative you should not forget the phasing of benefits across time. The flow of benefits from a change initiative is known as the *benefits stream*. Two change initiatives, with the very same financial total of benefits, can have significantly different values to an organisation depending on the phasing of benefits. When you are designing your change initiatives, you should consider the phasing of benefits and try to maximise both the benefits and when they occur, optimally in as short a time as possible. In reality, these are often conflicting pressures. One of the key decisions for you will be the pace of change: balancing the opportunity to seize the maximum rewards most quickly, versus the implications which are often extra costs and risks of moving too quickly.

Benefits may arise during the change initiative, at completion or accrue over time after completion.

Types of Rewards

Change initiatives can result in improvements to any metric in a business. There is usually a focus on financial returns. Financial returns are obviously important in many situations, especially given the business case process in place in many organisations. However, too great a focus on financial returns can lead to missing out on many opportunities. Non-financial benefits may be both tangible and intangible. Often the most important improvements in the longer run are intangible.

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Newton* provides detailed descriptions of the risks and costs of change as well as the processes for benefits realisation.

BRIEFING LESSONS

In reviewing *why* change and change management this chapter has started to develop a picture of the activities the executive should be involved with regarding change management. This is not a complete list but contains the most important activities. They are:

- ensuring the organisation has the appropriate capability to manage and deliver change
- selecting and prioritising the optimal change(s) to undertake at any time, balancing short-term operational needs with longer-term strategic vision
- developing a compelling case for change(s), and championing the change until it is complete. (This case should be supported by the business case considering the costs, rewards and risks of the change)
- selecting the right approach to delivering the changes
- assessing the key risks from change, and ensuring action is taken to manage these risks, including the longer-term execution risks.

These items will be expanded on in the following chapters.

12.3 Who is Changing?

12.3.1 Introduction

If you ask the question 'Which organisations are changing?', the most probable answer is—every organisation. I doubt that there is any significant enterprise that has never changed and which will not change again in the future. Yet organisations do not have a shared experience of, attitude or approach to change. There are huge varieties of changes, approaches to change and outcomes from change. Some organisations manage change smoothly whilst others struggle. There are businesses that use the phrase *change management* all the time and apply a defined approach. Others manage change more informally, and the words *change management* are rarely if ever used. Some companies regard change as part of their everyday management. In others it is an infrequent process. Most organisations sit somewhere between these two extremes.

This chapter starts with four case studies of real organisations who have successfully overcome the challenge of change management in very different ways. These are not descriptions of specific change initiatives, but accounts of the general approach to managing change each organisation has taken. They have been included because each has a different approach to change. The case studies offer lessons to other organisations, and together they show how varied the approach to change can be. They give perspective and context to the rest of the book and you will find themes from them in later chapters.

The remaining section of this chapter describes both change success and failure in general terms. Answering the questions *what is success?* and *what is failure?* with regards to change is helpful, but more difficult than may be expected.

* Newton, Richard (2008) *The Practice and Theory of Project Management: delivering value through change*, Palgrave MacMillan.

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12.3.2 Four change case studies

CASE STUDY 12.1

Kazakhmys

Kazakhmys PLC is an international natural resources company, listed in the UK, with its principal operations in Kazakhstan and the surrounding region. The core business is the production and sale of copper. Kazakhmys is fully integrated from mining ore through to the production of finished metal. The copper division also produces significant volumes of other metals as by-products, including zinc, silver and gold.

Kazakhmys can trace its history back to the 1930s with an initial copper mining and smelting complex. Since then the company has gone through many modifications, including changes brought about by the disintegration of the Soviet Union and the company's gradual privatisation by the government of Kazakhstan between 1992 and 2002. Throughout these changes Kazakhmys has expanded in terms of the number of mines and the volumes of copper produced. Recently it has set up separate gold, power and petroleum divisions.

Change is therefore nothing new to the organisation. Over the decades the company's directors have steered the organisation through a number of significant alterations. In 2008 the company's management team determined that it was time to enhance change skills within the organisation. Kazakhmys wants to be ready for whatever challenges the future business environment throws up. To facilitate this change, the Corporate Development Centre (CDC) was set up. The CDC is a central team tasked with delivering beneficial change in the company.

In setting up such a function the company wanted to achieve a number of objectives. Four aspects of the approach Kazkahmys has chosen to change are worth learning from. Firstly, the company appreciated that there was modern expertise in change management and associated disciplines outside of the organisation. So a range of external experts were engaged. However, it was also recognised that the company has a successful history managing its own development. Any approach to change had to take the best external experiences and merge them with the strengths of the company. So, the CDC team has been staffed with a combination of external and long-term Kazakhmys employees.

Secondly, in engaging people from different backgrounds in the CDC, Kazakhmys wanted to build a sustainable capability to develop and deliver change. As important as any one change is the lasting capability to drive change in future. Any external experts are expected to share their skills with Kazakhmys staff. Sharing knowledge, coaching and training Kazakhmys staff are requirements placed upon all consultants engaged in the CDC. Any new approaches are tailored to fit the Kazakhmys culture.

Thirdly, Kazakhmys is a complex and busy organisation. As with any large company there are ongoing business-as-usual management tasks to be fulfilled. Without sufficient focus, change team members are likely to become involved in daily operational issues. This could delay ongoing change initiatives. Hence a decision was made to set up the CDC as a separate division of the business. The CDC can therefore focus on identifying and delivering beneficial change.

Finally, the CDC has direct involvement from the most senior levels in the organisation. This level of sponsorship and direction is critical to success and overcoming any issues inhibiting change.

The CDC has been set a number of challenging goals. Providing the right level of resource, focusing on change using the best of in-house and external experiences, and gaining senior sponsorship are important in ensuring these goals can be met.

For more information on Kazakhmys see *www.kazakhmys.com*

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CASE STUDY 12.2

Map Group

MAP Group (uk) is a privately owned company, based in the North East of England. It is one of the leading independent providers of professional technology services to the UK communications sector, including network operators, service providers, equipment vendors, utility providers, government and public bodies and private enterprises. MAP Group employs over 600 engineers providing a wide range of knowledge and technical expertise, operating across the UK.

Map Group has thrived by focusing on customer needs and being willing to adapt and change as those needs change. The company has constantly transformed itself. Having started by providing one line of service, it has continually transitioned to others. New markets have been selected due to the foresight of the managing team, but the company also moves quickly to seize opportunities as they arise. The rate of change is significant. People who knew the business as it was a few years ago might not recognise the organisation of today—except for its ongoing focus on customer service and its entrepreneurial culture.

Although change is nothing new, few staff at Map would use the term *change management.* This is because change is not regarded as anything special, but it is part of normal business. The organisation constantly seeks to innovate. How is this achieved?

There are a number of features that enable change in Map. The leadership team is closely involved in the business. Decisions are made by a small group of executive directors who meet regularly. When decisions are made they are rapidly cascaded throughout the organisation. Management chains are short, and therefore strategic decisions are quickly communicated from the centre to the periphery of the organisation. Staff are empowered to improve continually the areas of work they are involved in. Teams interact and sort out problems without waiting for management directions. The organisation is inherently flexible. This means that whole lines of business can be quickly established, and if necessary closed down.

Another important feature that enables Map to continue to change is the organisation's culture. Although the business has ambitious plans to continue to grow, it wants to retain the culture of a smaller entrepreneurial company. Many staff know the founder and main shareholder, whose vision pervades the company. As important as what it wants to be, is what Map does not want to be. Irrespective of the size it grows to, the leadership team want to avoid the culture and working methods of larger corporations.

Bureaucracy is frowned on. Nimbleness and rapid ability to respond to new opportunities are valued. Many of Map's clients are corporate organisations but, typically, what they like about dealing with Map is the way it adapts quickly to their situation. Speed is one of its competitive differentiators. It is the ability to assess situations rapidly, seize opportunities, and the flexibility built into the organisation that enable Map to adapt continually to market needs.

For more information on Map Group (uk) see *www.mapgroupuk.com.*

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CASE STUDY 12.3

TDA

The Training and Development Agency for Schools (TDA) is the national agency and recognised sector body responsible for the training and development of the school workforce in England. The objectives of the TDA are summarised in its guiding vision: developing people, improving young lives. The TDA provides an interesting case study for change management. It is involved in many activities, but from the perspective of a change practitioner, the TDA is as an organisation that achieves its guiding vision through a series of change projects.

To appreciate how the TDA delivers change it is helpful to start by understanding the organisation's workload. The TDA's remit and funding are provided by the Department for Children, Schools and Families (DCSF). The TDA works to implement a wide variety of initiatives based on DCSF policy. These initiatives vary in scope and timescale significantly. Some are relatively short, others run for several years. Each initiative is structured into a project, controlled through the TDA's project management process.

The TDA's organisation is designed to work around an annual planning cycle, which commences with the development of an annual business plan based on a remit letter from the DCSF. The remit has a broad scope and will result in the TDA pursuing a range of policy-based projects. The business plan defines the projects the TDA will pursue in the following year. Some projects continue across years, others will be new that year. There will be additional projects started during a year, and the TDA has a specific process called the new work protocol to handle such additions.

The TDA makes use of a wide variety of tools and approaches to implement its initiatives. There are two specific lessons which are interesting case studies for change management. The first is the way the whole organisation is structured around delivery of change projects. The second is how the TDA extends its ability to achieve its goals by working closely with a range of partner organisations.

TDA policy specialists analyse DCSF policy and convert it into a set of projects grouped into a few key programmes. All the projects are part of the annual business plan or a new work protocol. This provides a structure for all the work in the organisation. Each project requires engagement with a host of stakeholders. These stakeholders include local authorities, schools, government offices, initial teacher training providers, children's trusts and a number of other stakeholders. The whole process and nature of each change project is highly interactive and constantly evolving, and there are significant regional variations in the school workforce's needs. To achieve the most beneficial change the TDA has to be responsive to local requirements. The TDA-wide business plan is converted into a series of regional delivery plans, which control how projects are implemented within a specific region. In addition, there are well-established measurement and governance procedures to monitor and ensure projects are achieving desired results.

As with any organisation, the TDA has a limited resource base. What is interesting is the way it works with partner organisations to leverage a wider resource pool. Much of the work of the TDA is about influencing and encouraging action in these partners in line with the needs of the TDA projects. The TDA has developed the mechanisms and relationships to enable this partner working. Compared to many organisations, the TDA is more successful at creating change teams which are not constrained by its organisational boundaries.

For more information on the TDA see *www.tda.gov.uk*

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CASE STUDY 12.4

A European Utility Company

My fourth case study is anonymous as the company did not wish to be named, but it is a utility company with tens of thousands of employees based in various countries in Europe. There are some minor operations outside of Europe which are growing rapidly. The national subsidiaries are operated fairly independently, and the market conditions vary from country to country. This case study focuses on the UK subsidiary.

The UK subsidiary operates in a market in which it has traditionally achieved good financial returns and there were high barriers to entry. However, new forms of competition have arisen with advances in technology, and there is an increasing regulatory burden and greater regulatory intervention. This has had a number of impacts on the organisation, but two are most relevant. The first is a desire for greater cost efficiency to maintain margins. Initially, there was no pressing need to cut costs, but it was perceived that over time the cost base must be reduced. This perception continues. Secondly, there was a desire to become more innovative, requiring a shift in organisational culture. The culture is typically relatively conservative and sluggish in the uptake of novel approaches. These two pressures have led to an ongoing series of change initiatives over the past few years. At the start of these change initiatives employees' experience of, and skills in, change management were limited.

The first major change initiative was the reorganisation of the IT department. IT was restructured and many functions were outsourced, including a significant proportion of offshoring. As part of this initiative about 15% of the IT community, that is all the line managers and influential experts, were trained in change management skills. A two-day workshop was designed with the help of external consultants. In this workshop the attendees were given a deeper understanding of change, the role of the manager in change was explored, and specific skills such as communicating about change were practised. As many of these managers themselves were part of the functions outsourced, the course was presented both as beneficial in helping the IT change to occur, and also as beneficial to anyone's career, irrespective of future job roles and employer.

As the workshop was delivered to these managers, it was refined and in-house staff were trained in its running. The result is a workshop which is now a standard part of all managers' training and development. The organisation is moving from one in which there were very limited change management skills to one with a large pool of managers both familiar with and competent in change management.

In addition to training all managers in change management, it was realised that there was a need for a central pool of expert change managers. This team has two roles—to directly manage the largest initiatives in the business and to act as coaches to other managers in the business tasked with delivering change. The pool was initially staffed by two experts recruited from consultancies, but over time it has grown to approximately a dozen staff. All the additional members of this team have been recruited internally. This means the team not only has change management skills, but has in-depth knowledge of the business. The organization still uses change management consultants, but all are selected and managed via this central team.

By building both an expert central team and a general level of competence in all managers in the organisation, this business has significantly improved its capability to successfully execute change quickly.

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12.3.3 What Does Change Success (or Failure) Look Like?

A good way to start analysing any management discipline is to ask 'What does success look like?' and correspondingly, 'How does failure appear?' You might think that it is easy to spot whether a change is a success or failure, but this is often harder than expected. Managers are always eager to claim victory and frequently this is justified, sometimes it is not. I have seen several very dubious accomplishments being presented as triumphs, and on occasions these unjustified claims have not been disputed. This occurs because the success or failure of a change initiative is not always clear cut. I start this section by briefly explaining the main difficulties in assessing the degree of change success, followed by a table describing typical examples of change success and failure. Finally, I list some of the most common factors which contribute to success or failure. This discussion is closely tied to measurement.

Let's start with change failures. Occasionally, there are total change disasters, which can be spotted easily. For a commercial enterprise a total disaster results in bankruptcy. For non-commercial organisations total disaster results in unplanned closure of the enterprise. These situations are relatively rare. A more common problem with change activity, and the one that is harder to spot, is the large number of intermediate levels of performance. Such intermediate performance levels are not always even noticed by the organisation in which the change is occurring. There are three typical patterns. Initiatives which are started are gradually abandoned and forgotten as momentum is lost. No one is ever asked to explain what has happened. Alternatively, the initiative is completed, and success is taken for granted. However, if the situation is assessed some time later it is found that no one in the organisation is doing anything differently. If no one is doing anything differently, then the initiative has achieved no benefit. Another pattern is the change initiative that is constantly modified or tweaked, which by the time it is complete bears no resemblance to the original objectives.

One difficulty in assessing success is developing the baseline case for change. Without a baseline how can you justify that a change initiative was successful? It becomes purely a subjective judgement. Where the measurement of benefits and outcomes is possible, it always provides a more informational and less subjective basis for assessment.

It is often difficult to estimate the benefits that will arise from an initiative. Answering a question like *what will the quantifiable benefit from a changed organisational culture be?* is almost impossible. Even where benefits are theoretically easier to identify and quantify, the level of understanding before an initiative starts is usually limited. With limited understanding, estimating benefits accurately is not possible. Finally, change initiatives evolve. They are learning experiences, and the understanding of benefits modifies as the initiative progresses. This means what you end up with does not always represent what you wanted to start with. This is not a bad thing from the perspective of making a change. But it does mean that the traditional way of measuring investment success—comparing an initial estimate of benefits with a final result—may be of limited effectiveness or significance.

Another problem is the relevance of what is achieved in an initiative to the current environment an organisation operates in. The world moves on and what may have been a great idea one day may not be so great by the time the end of the initiative is reached. To avoid this problem there has to be a willingness to modify or shut down initiatives that lose their relevance. Closing down irrelevant activities should be a sign of success, but managers are often reluctant to do this. Perhaps they are afraid of losing face or being seen to have wasted time and money. Too many initiatives which should have been killed off are relentlessly pursued. Never be afraid to close down poorly performing initiatives, or those that lose their relevance.

Organisations often forget one of the key benefits from change initiatives—learning.

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strong financial return, but not all. Some experiments have to be made, and as long as the organisation learns then this may be as good an outcome as is possible. Even those with a strong financial case should be seen as opportunities to learn. Arguably an initiative resulting in limited learning is at least a partial failure because a great opportunity has been missed. Learning can be claimed as a positive outcome from a change initiative, but I am not aware of any practical and direct ways of measuring how much learning has been achieved by the initiative.

Another point to consider is the difference between the outcome from an initiative and success across initiatives in an organisation. What is most important with multiple change initiatives is that *overall* you achieve your vision and reach your success. The outcome from individual initiatives is less important. With a strong enough portfolio the occasional failure can be seen as a sign of innovation and experimentation—as long as they are balanced by more successes.

So what are the typical characteristics of a successful versus a failed change initiative? In Table 12.2 I compare some typical examples of success and failure. In Table 12.3 I summarise some of the most common factors that contribute to failure.

The contributory causes to change success and failure are discussed throughout this book. Some of the most significant are listed in Table 12.2 None of the success factors alone will lead to triumph, and none of the failure factors spell a definite catastrophe. The success factors listed here are complementary to each other. The failure factors are not a single coherent set, as there are different ways to fail in change!

Table 12.2 Comparing Change Success and Failure

Typical Characteristics and Examples of Successful Change Initiatives	Typical Characteristics and Examples of Failed Change Initiatives
A worthy vision that is still relevant to the organisation is achieved. Operational disruption during the initiative is minimal. Change is achieved and sustained in the longer run. Long-term benefits or positive outcomes are realised. The change results in organizational learning and development. There is an expansion in the change capability. Stakeholders are positive about the outcomes from the initiative.	A vision is created but no initiative is mobilised. The vision may be compelling, but it is not converted into achievements (all talk and no action). The initiative starts and a few quick wins are delivered. Over time the initiative is forgotten and stalls. The initiative stalls because unforeseen operational problems occur. The cost of the change in terms of business disruption is higher than expected. The initiative completes to a fanfare—but there is limited long-term benefit and the change is not maintained. Changes are never embedded (e.g. new IT systems or processes that are implemented but which no one uses). The cost of the initiative is underestimated, meaning that the business case does not stack up. The initiative may be completed, but the benefits never justify the true costs. Often the true costs are never assessed or known.

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Table 12.3 Contributory Causes to Success or Failure

Sample Factors Contributing to Change Success	Sample Factors Contributing to Change Failure
The initiative starts with a clear and compelling vision.	There is no vision. Change is embarked on as a response to problems without understanding where it will lead.
The vision is supported by a strong group of senior managers.	There is an imbalance of ambitions. Too small an ambition leads to conservatism. Too large an ambition causes unrealistic initiatives,
The change team is adequately resourced and its work is explicitly given a high priority.	There is no powerful coalition or support for the initiative. There may be an agenda, but without support it will never be achieved.
The change willingness of the organisation is regularly monitored—and resistance is constructively dealt with.	There is a vision for the future with insufficient understanding of the organisation and insufficient listening.
The change team and sponsor persevere with the change in light of resistance. However, the change team are responsive to feedback and the nature and approach to the change evolves as team members learn.	Feedback is all taken as resistance. The change is pushed on at all costs.
The team have access to sufficient change management skills.	The change team members tend to avoid confrontation and are unwilling to take on vested interests. This leads to stagnation, too slow a progress and too limited change.
The change is planned taking account of both short- and long-term considerations.	Progress focuses on completing the activity without enough focus on the outcomes or benefits. The result is a completed initiative, but no lasting change.
There is a sufficient level of valid and timely data to monitor progress and understand outcomes.	Progress focuses on creating deliverables rather than change. Project products are mistaken for change completion.
There is a significant emphasis on sharing information, listening and communicating.	There is a lack of perseverance or loss of drive part way through an initiative, particularly for longer-term initiatives. This may be because there is a change of senior management during the initiative.
Ongoing, proactive risk management is undertaken for the life of the initiative.	There is insufficient data to measure progress or outcomes. If success is claimed, it may or may not be real.
The focus is on change outcomes, not merely activity or deliverable creation.	There is a lack of active risk management.
	There is insufficient understanding of how to manage change.
	Success is claimed without considering the longer-term detrimental effects of the change.

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BRIEFING LESSONS

There are many different ways to approach change. The examples in this chapter describe organisations which encourage change by:

- Building skilled change teams mixing internal (permanent) and external (consultants) staff, and using such teams to develop a sustainable capability to deliver change.
- Ensuring that change teams are not interrupted with operational work.
- Supporting change initiatives with explicit senior executive sponsorship.
- Forming a leadership team that is closely involved in the business and rapidly cascades decisions through the organisation.
- Empowered staff working in a flexible organisation.
- A culture in which nimbleness and rapid ability to respond to new opportunities are valued and bureaucracy is frowned on.
- Structuring the organisation around delivery of change projects and extending the organisation's ability to achieve its goals by working closely with a range of partner organisations.
- Setting competency in change management as a basic skill of all managers in the business and developing suitable training and development to achieve this.
- Supporting these managers with a small team of expert change practitioners.

Although every change is unique there are some common characteristics in change initiatives which indicate whether the initiative is more likely to be a success or a failure; these are summarised in Table 12.3.

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CHAPTER 13

Recognizing *Opportunities* and Generating Ideas

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OPENING PROFILE

iCRACKED

Solving a Problem and Building a Business in an Exploding Industry

In mid-2009, AJ Forsythe had a problem. While a student at California-Poly San Luis Obispo, he broke his iPhone twice within two days. The first time occurred when he was exiting his car. He dropped his iPhone and cracked the screen. That accident cost him $200 and an hour's trip to the Apple store. A few days later the same phone broke again, when his roommate casually tossed it to him and it hit a ceiling fan. Determined to fix the phone himself this time, Forsythe got help from some engineering students and used a small screwdriver and dental pick to replace the phone's shattered screen. Incredibly, shortly after these two incidents, Forsythe's roommate broke his iPhone. At that point, Forsythe realized that repairing iPhones was a promising idea for pursuing a business opportunity.

To start, Forsythe gave a friend $20 to design a flyer, and began putting the flyers up around campus. Within two weeks, he had his first customer. Forsythe set up a Facebook page and a Twitter account to generate additional awareness and sales, and the business—which he named iCracked—started to take shape. Profit margins were good. At $75 a phone, Forsythe was making about $40 for less than an hour's work.

From the outset, Forsythe saw iCracked as a business that could be replicated on other college campuses. He spent the summer of 2010 in Dallas, his hometown, pitching the idea to local campuses. Forsythe brought on a partner in the fall of 2010, Anthony Martin. The two met through a mutual friend. Martin's best friend in high school was Forsythe's best friend in college. At the time, Martin was running a textbook exchange platform at UC Santa Barbara. Martin and Forsythe were both college entrepreneurs and enjoyed talking to each other about business. Martin liked the opportunity Forsythe was pursuing, particularly given Apple's growing market share in the smartphone industry. Martin put the first investment into iCracked to buy inventory and set up a website. The two began putting job listings on college campuses across the United States. Within 30 days, they had their first website up and 23 repair technicians on college campuses across the country. They called their repair technicians "iTechs." In the nearby photo, Anthony Martin appears on the left while AJ Forsythe is on the right.

Since that time, iCracked has continued to expand, and the company now has over 500 iTechs spread over most of the United States and eight foreign countries. Initially, a customer would be put in touch with an iTech technician, and they agree on a place to meet. Starting in late 2013, the service improved, and the iTechs now travel directly to the customer. They repair broken screens, LCDs, bad batteries and all other small parts problems, as well as water damage for Apple iPhone, iPad, and iPod models. As long as the logic board is intact, which it usually is, the repair can be made. The repairs typically take between 10 and 30 minutes and cost between $70 and $170. They also purchase used iPhone, iPad, and iPod devices. The iTechs aren't full-time employees of iCracked. The firm makes money by selling parts to the iTechs and connecting them to customers. iCracked is extremely diligent about who becomes an iTech. Every applicant is subject to a five-step interview process and a background check. Thousands apply, but only 2 percent of applicants are accepted. The firm adds 50–70 new iTechs each month. Over time, iCracked technicians have seen all manner of iPhone catastrophes, from pet pigs stomping on them, to iPhones being run over by trucks, to phones falling out of the hands of skydivers. Often badly damaged, the phones can usually be repaired and restored. Offering insurance on iPhones is a new product line iCracked is considering. The insurance is expected to cost around $6 a month, with a $20 deductible. For people in areas where iTech technicians aren't yet available, iCracked offers the option of sending the broken phone to the company's headquarters, where it will be fixed and sent back the same day. iCracked also continues to sell its do-it-yourself iPhone Screen Repair Kit.

iCracked believes it is just getting started. The company had sales of around $2 million in 2012 and $10 million in 2013. It sees additional opportunities in its core business and in other areas. In regard to its core business, it's estimated that within the next five years, there will be five billion smartphones in the world. About 30 percent of smartphones are damaged and at some point need repairs. iCracked has already positioned itself as

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the world's largest and most efficient iPhone repair and buyback service. It plans to soon extend its service to Android-equipped phones. As a result, iCracked is positioned to dramatically increase its revenue in smartphone repairs, buybacks, and additional services. Its smartphone insurance service is also expected to significantly add to the firm's sales revenue.

In regard to other areas, in early 2012, Forsythe and Martin were admitted to Y Combinator, based on the strength of their company's early traction. Y Combinator is a business accelerator that provides seed money, mentoring and connections to promising technology startups. The three-month Y Combinator experience challenged Forsythe and Martin to see iCracked in a new light and as a much bigger potential opportunity. Forsythe and Martin believe their network of iTech technicians is the company's most valuable asset. They foresee the technicians eventually providing repairs, installations, and additional service across a variety of industries for a wide range of clientele.

In this chapter, we discuss the importance of understanding the difference between ideas and opportunities. While ideas are interesting and can intrigue us as possibilities, not every idea is in fact the source of an opportunity for an entrepreneur to pursue. In addition to describing the differences between ideas and opportunities, this chapter also discusses approaches entrepreneurs use to spot opportunities, as well as factors or conditions in the external environment that may result in opportunities. As you will see, too, certain characteristics seem to be associated with individuals who are adept at spotting viable business opportunities.

13.1 The Differences Between Opportunities and Ideas

Essentially, entrepreneurs recognize an opportunity and turn it into a successful business.[1] An **opportunity** is a favorable set of circumstances that creates a need for a new product, service, or business. Most entrepreneurial ventures are started in one of two ways. Some ventures are externally stimulated. In this instance, an entrepreneur decides to launch a firm, searches for and recognizes an opportunity, and then starts a business, as Jeff Bezos did when he created Amazon.com. In 1994, Bezos quit his lucrative job at a New York City investment firm and headed for Seattle with a plan to find an attractive opportunity and launch an e-commerce company. Other firms are internally stimulated, like iCracked. An entrepreneur recognizes a problem or an **opportunity gap** and creates a business to address the problem or fill the identified gap.

Regardless of which of these two ways an entrepreneur starts a new business, opportunities are tough to spot. Identifying a product, service, or business opportunity that isn't merely a different version of something already available is difficult. A common mistake entrepreneurs make in the opportunity recognition process is picking a currently available product or service that they like or are passionate about and then trying to build a business around a slightly better version of it. Although this approach seems sensible, such is usually not the case. The key to opportunity recognition is to identify a product or service that people need and are willing to buy, not one that an entrepreneur wants to make and sell.

As shown in Figure 13.1, an opportunity has four essential qualities: It is (1) attractive, (2) timely, (3) durable, and (4) anchored in a product, service, or business that creates or adds value for its buyer or end-user. For an entrepreneur to capitalize on an opportunity, its **window of opportunity** must be open. The term *window of opportunity* is a metaphor describing the time period in which a firm can realistically enter a new market. Once the

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Figure 13.1 Four Essential Qualities of an Opportunity

market for a new product is established, its window of opportunity opens. As the market grows, firms enter and try to establish a profitable position. At some point, the market matures, and the window of opportunity closes. This is the case with Internet search engines. Yahoo, the first search engine, appeared in 1995, and the market grew quickly, with the addition of Lycos, Excite, and several others. Google entered the market in 1998, sporting advanced search technology. Since then, the search engine market has matured, and the window of opportunity is less prominent. Today, it would be very difficult for a new start-up search engine firm to be successful unless it offered compelling advantages over already established competitors or targeted a niche market in an exemplary manner. Bing, Microsoft's search engine, is gaining ground with approximately 18 percent market share (compared to 67 percent for Google), but only after Microsoft has exerted an enormous amount of effort in head-to-head competition with Google.[2]

It is important to understand that there is a difference between an opportunity and an idea. An **idea** is a thought, an impression, or a notion. An idea may or may not meet the criteria of an opportunity. This is a critical point because many entrepreneurial ventures fail not because the entrepreneurs that launched them didn't work hard, but rather because there was no real opportunity to begin with. Before getting excited about a business idea, it is crucial to understand whether the idea fills a need and meets the criteria for an opportunity.

13.2 Three Ways to Identify Opportunities

There are three approaches entrepreneurs use to identify an opportunity their new venture can choose to pursue (see Figure 13.2). Once an entrepreneur understands the importance of each approach, s/he will be much more likely to look for opportunities and ideas that fit each profile. We discuss the three approaches in the next three sections.

13.2.1 Observing Trends

The first approach to identifying opportunities is to observe trends and study how they create opportunities for entrepreneurs to pursue. The most important trends to follow are

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Figure 13.2 Three Ways to Identify an Opportunity

economic trends, social trends, technological advances, and political action and regulatory changes. As an entrepreneur or potential entrepreneur, it's important to remain aware of changes in these areas. This sentiment is affirmed by Michael Yang, the founder of Become.com, a comparison shopping site, who believes that keen observation skills and a willingness to stay on top of changing environmental trends are key attributes of successful entrepreneurs:

> One of the most important attributes of a good entrepreneur is having a keen observation ability. Basically seeing what's needed in people's everyday lives and coming up with innovative new ideas and services that meet those needs . . . I always believe the entrepreneurs that anticipate trends and maintain observations of what's needed . . . to solve those needs will have a higher chance of succeeding in the marketplace.[3]

When looking at environmental trends to discern new business ideas, there are two caveats to keep in mind. First, it's important to distinguish between trends and fads. New businesses typically do not have the resources to ramp up fast enough to take advantage of a fad. Second, even though we discuss each trend individually, they are interconnected and should be considered simultaneously when brainstorming new business ideas. For

As baby boomers age, opportunities will grow for firms that provide unique services to the age group. Look for the resulting expansion in organic foods, specialty wines, insurance, and travel.

Rick Gomez/Comet/Corbis

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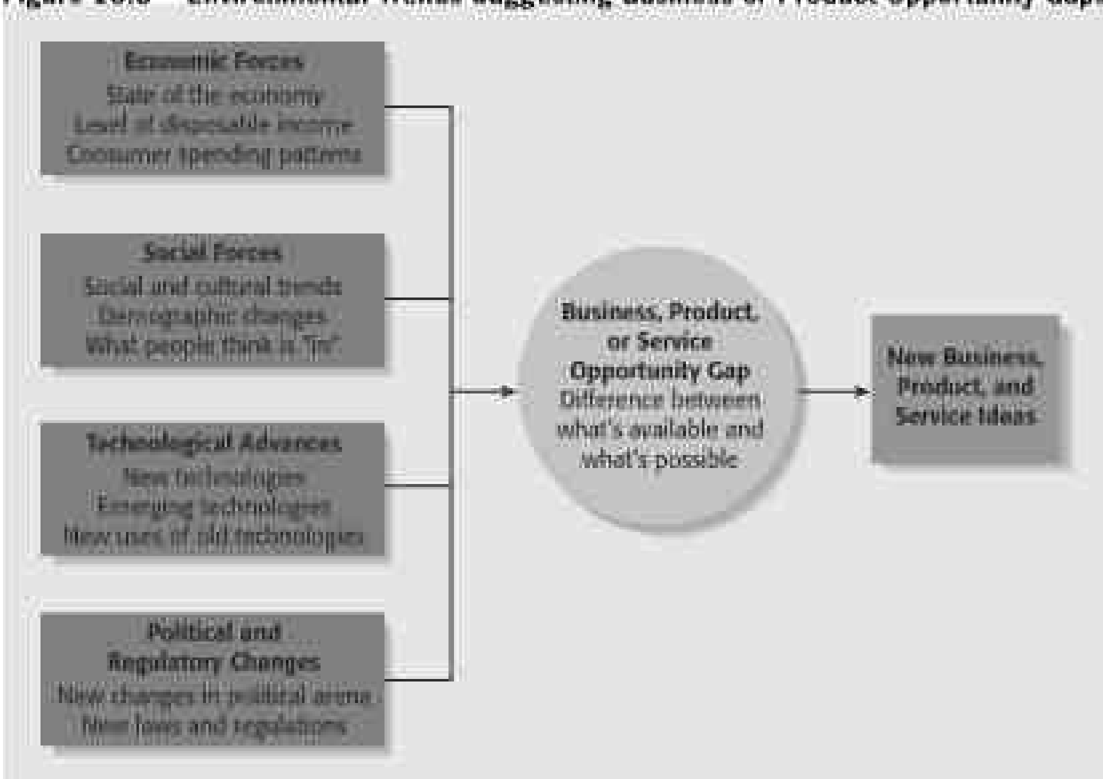
example, one reason that smartphones are so popular is because they benefit from several trends converging at the same time, including an increasingly mobile population (social trend), the continual miniaturization of electronics (technological trend), and their ability to help users better manage their money via online banking and comparison shopping (economic trend). If any of these trends weren't present, smartphones wouldn't be as successful as they are and wouldn't hold as much continuing promise to be even more successful in the future.

Figure 13.3 provides a summary of the relationship between the environmental factors just mentioned and identifying opportunity gaps. Next, let's look at how entrepreneurs can study each of these factors to help them spot business, product, and service opportunity gaps.

Economic Forces

Understanding economic trends is helpful in determining areas that are ripe for new business ideas, as well as areas to avoid.[4] When the economy is strong, people have more money to spend and are willing to buy discretionary products and services that enhance their lives. In contrast, when the economy is weak, not only do people have less money to spend, they are typically more reluctant to spend the money they have, fearing the economy may become even worse, and that in turn, they might lose their jobs because of a weakening economy. Paradoxically, a weak economy provides business opportunities for start-ups that help consumers and businesses save money. Examples include GasBuddy and GasPriceWatch.com, two companies started to help consumers save money on gasoline. A similar example is WaterSmart Software, a 2009 start-up. WaterSmart Software sells software to water utilities that makes it easier for their customers to save water and money.

Figure 13.3 Environmental Trends Suggesting Business or Product Opportunity Gaps



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When studying how economic forces affect business opportunities, it is important to evaluate who has money to spend and what they spend it on. For example, an increase in the number of women in the workforce and their related increase in disposable income is largely responsible for the number of online retailers and boutique clothing stores targeting professional women that have opened the past several years. Similarly, the increased buying power of minority populations has resulted in an upswing of ethnic restaurants and ethnic supermarkets in the United States. Baby boomers are another potential group to examine. These individuals, who were born between 1946 and 1964, are retiring in large numbers and will be retiring in even larger numbers over the next five years or so. The expectation is that these people will redirect a sizeable portion of their assets to products and services that facilitate their retirement. This trend will invariably spawn new businesses in many areas, largely because baby boomers have greater disposable income relative to previous generations. For example, baby boomers tend to take pride in their homes and lawns. Recent data indicates that baby boomers who own homes are 21 percent more likely than all American adults to have spent $10,000 or more on home improvements.[5] Other areas that baby boomers spend heavily on include health care, travel, and consumer packaged goods. The high cost of energy, coupled with a desire to be socially responsible, has also spawned a growing number of startups that are developing products and services that help business and consumers become more energy efficient. An example is Nest Labs (www.nest.com), a 2010 startup. Nest Labs—which was acquired by Google in 2014—makes the world's first learning thermostat. The thermostat, which can be used in homes or businesses, learns from your temperature adjustments and programs itself to optimize a building's comfort and energy efficiency.[6]

An understanding of economic trends also helps identify areas to avoid. For example, a decision to launch a company that sells products or services to public schools was not a wise one during the recent economic downturn. In the United States—and other countries, as well—public schools have been hit hard by budget cuts from governmental funding agencies. The cuts have significantly reduced the ability of schools to purchase new products and services.

Social Forces

An understanding of the impact of social forces on trends and how they affect new product, service, and business ideas is a fundamental piece of the opportunity recognition puzzle. Often, the reason that a product or service exists has more to do with satisfying a social need than the more transparent need the product fills. The proliferation of fast-food restaurants, for example, isn't primarily because of people's love of fast food, but rather because of the fact that people are busy and often don't have time to cook their own meals. Similarly, social networking sites like Facebook, Twitter, and Instagram aren't popular because they can be used to post information and photos on a website. They're popular because they allow people to connect and communicate with each other, which is a natural human tendency.

Changes in social trends alter how people and businesses behave and how they set their priorities. These changes affect how products and services are built and sold. Here is a sample of the social trends that are currently affecting how individuals behave and set their priorities:

- Aging of the population
- The increasing diversity of the workforce
- Increased participation in social networks
- Growth in the use of mobile devices

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- An increasing focus on health and wellness
- Emphasis on clean forms of energy, including wind, solar, biofuels, and others
- Continual migration of people from small towns and rural areas to cities
- Desire for personalization (which creates a need for products and services that people can tailor to their own tastes and needs)

Each of these trends is providing the impetus for new business ideas. The continual migration of people from small towns and rural areas to cities, for example, is creating more congestion in cities. Businesses like Zipcar, a carsharing service, and Alta Bicycle Share, a bicycle-sharing service, were started in part to address this problem. Similarly, the aging of the population is creating business opportunities from vision care to home health care to senior dating sites. An example is Glaukos, a company that's developing a new approach for treating glaucoma, which is an age-related eye disorder.

The proliferation of smartphones is a social trend that's opening business opportunities for entrepreneurs across the globe. More than 1.75 billion people worldwide owned mobile phones in 2014, and that number is expected grow to 2.5 billion by 2017. By 2017, nearly 50 percent of mobile phones will be smartphones, like the Apple iPhone and Android-equipped devices. The proliferation of smartphones will spawn new businesses both in the United States and throughout the world. Sometimes social trends converge to create a particularly compelling business idea. For example, CareZone, a 2012 startup, was launched by Johathan Schwartz, who was looking for ways to better manage the care of five aging parents and in-laws. CareZone is an app for smartphones, tablets, or computers that allows those involved in a person's care to share and save information in a secure, online setting. CareZone's potential is bolstered by two societal trends: the aging of the population and the growth in the use of smartphone apps and other connected devices.

The increasing interest in social networking sites such as Facebook, Twitter, and LinkedIn is a highly visible social trend. A total of 69 percent of men and 78 percent of women use one or more social networking sites.[7] In addition to providing people new ways to communicate and interact with each other, social networks also act as platforms for other businesses to build on. Zynga, for example, the maker of popular online games like FarmVille and Scramble, became popular by making browser-based games that worked as application widgets on Facebook. Similarly, entrepreneurs have launched businesses for the purpose of starting social networks that cater to specific niches. An example is PatientsLikeMe, which is a social networking site for people with serious diseases.

Technological Advances

Advances in technology frequently dovetail with economic and social changes to create opportunities. For example, there are many overlaps between an increased focus on health and wellness and technology. Wearable devices, like the Fitbit Flex and the Jawbone Up, help people maintain a healthy lifestyle by monitoring their movements and sleep. In fact, ABI Research projects that 90 million wearable computing devices will be shipped in 2014.[8] There are a growing number of mobile apps and activity trackers that beam the data they collect to their health care providers so they can keep tabs on their activities and inform treatments. Insurance companies and corporations are increasingly partnering with technology companies like RedBrick Health and Audax Health, which establish programs to help encourage healthy lifestyles.

Technological advances also provide opportunities to help people perform everyday tasks in better or more convenient ways. For example, OpenTable. com is a website that allows users to make restaurant reservations online and now covers most of the United States. If you're planning a trip to Boston, for example, you can access OpenTable.com,

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select the area of the city you'll be visiting, and view descriptions, reviews, customer ratings, and in most cases the menus of the restaurants in the area. You can then make a reservation at the restaurant and print a map and the directions to it. The basic tasks that OpenTable.com helps people perform have always been done: looking for a restaurant, comparing prices and menus, soliciting advice from people who are familiar with competing restaurants, and getting directions. What OpenTable.com does is help people perform these tasks in a more convenient and expedient manner.

Another aspect of technological advances is that once a technology is created, products often emerge to advance it. For example, the creation of the Apple iPod, iPhone, iPad, and similar devices has in turned spawned entire industries that produce compatible devices. For example, Rokit is a high-end mobile accessories company that makes smartphone cases, headphones, portable USB device chargers and Bluetooth speakers. Rokit wouldn't exist if it weren't for the advent of the smartphone industry. Similarly, there are a growing number of start-ups working on smartphone apps. An example is Ubersense, the subject of the You Be the VC 5.2 feature. Ubersense has made a smartphone and tablet app that allows athletes, coaches, and parents to shoot video of an athlete's move or competition, and then analyze the video in a variety of ways.

Political Action and Regulatory Changes

Political and regulatory changes also provide the basis for business ideas. For example, new laws often spur start-ups that are launched to take advantage of their specifications. This is currently happening as a result of the passage of the Affordable Care Act (Obamacare). The combination of new regulations, incentives for doctors and hospitals to shift to electronic records, and the release of mountains of data held by the Department of Health and Human Services (on topics such as hospital quality and nursing home patient satisfaction), is motivating entrepreneurs to launch electronic medical records start-ups, apps to help patients monitor their medications, and similar companies.[9]

On some occasions, entire industries hinge on whether certain government regulations evolve in a manner that is favorable to the industry. For example, there are several start-ups poised to commercialize the use of drones, or Aerial UAV's. Drones can be used for a number of domestic purposes, such as helping farmers determine the optimal level of fertilizer to place on crops or helping filmmakers shoot overhead scenes. Amazon.com created quite a bit of buzz in late 2013 when it suggested it would like to use drones for package delivery. As of spring 2014, the FAA permitted drones to be used for personal use, and restricted their use to below 400 feet, within eyesight of the controller and away from airports and populated areas. Drone start-ups, like 3D Robotics, are waiting for the FAA to develop more liberal rules and standards that will allow drones to be used for expanded purposes.[10]

Political change also engenders new business and product opportunities. For example, global political instability and the threat of terrorism have resulted in many firms becoming more security-conscious. These companies need new products and services to protect their physical assets and intellectual property, as well as to protect their customers and employees. The backup data storage industry, for example, is expanding because of this new trend in the tendency to feel the need for data to be more protected than in the past. An example of a start-up in this area is Box.net, which was funded by Mark Cuban, the owner of the Dallas Mavericks. Box.net allows its customers to store data "offsite" on Box.net servers, and access it via any Internet connection.

Table 13.1 offers additional examples of changes in environmental trends that provided fertile soil for opportunities and subsequent concepts to take advantage of them.

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Table 13.1 Examples of How Changes in Environmental Trends Provide Openings for New Business and Product Opportunities

Changing Environmental Trend	Resulting New Business, Product, and Service Opportunities	Companies That Resulted
Economic Trends		
Search for alternatives to traditional fossil fuels like gasoline	Ethanol, biodiesel, solar power, wind-generated power	Noesis Energy, Effortless Energy, eMeter, Nest Labs
Aging of the population	In-home care, health and wellness apps, financial services for older people, travel-related services for older people	CareLinx, Mango Health, Elder Life Financial Services, Senior Travel Services, Inc.
Social Trends		
Increased interest in different, tastier, and healthier food	Healthy-fare restaurants, ethnic packaged foods, craft beer, functional beverages	Naked Pizza, Brooklyn Brewery, Hint (bottled water), Popchips
Increased interest in fitness as the result of new medical information warning of the hazards of being overweight	Fitness centers, pilates and yogo studios, exercise apps, weight-loss programs and apps	Snap Fitness, Wello, Yogaview (Chicago), Fitbit, Noom Weight Loss Coach
Technological Advances		
Smartphones	Smartphone operating systems, smartphone apps, smartphone accessories	Android, Instagram, Mango Health, iSkin, OnTrion
Wearable technology	Wearable fitness devices, wearable lifesytle devices (like Google Glasses), and wearable tech gadgets.	Fitbit, Pebble Technologies, Oculus Rift, Recon Jet, Sensoria
Political and Regulatory Changes		
Increased EPA and OSHA standards	Consulting companies, software to monitor compliance	PrimeTech, Compliance Consulting Services, SafeSoft
Affordable Care Act (Obamacare)	Electronic medical records, doctor-patient matching services, physician social networks	CareCloud, One Touch EMR, ZocDoc, PracticeFusion, Sermo

One thing entrepreneurs invariably do when a changing environmental trend prompts them to think about a business opportunity is to learn more about the trend in an effort to shape and mold their idea. The "Savvy Entrepreneurial Firm" feature in this chapter focuses on how to learn more about specific environmental trends through the effective use of social media.

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SAVVY ENTREPRENEURIAL FIRM

How to Learn About Emerging Trends Through the Effective Use of Social Media

Often, as a result of a changing environmental trend, individuals have the seeds of a business idea, but need to know more about the trend before their idea can fully take shape. For example, one environmental trend, the continual migration of people from small towns and rural areas to cities, has resulted in cities becoming more congested. To help relieve congestion, many large cities are implementing bike-sharing programs. The programs typically allow a person to pick up a bike at Point A and then drop it off at Point B. The idea is that if someone has a short commute to work, or plans to make a short trip, s/he might opt to ride a bike rather than drive their car. The fewer cars there are on the street, the less congestion there will be.

Say you had the idea to start a for-profit company to manage bike-sharing programs for mid-sized cities. This potentially could be a viable idea, given that to date, most of the programs are in large cities. A mid-sized city would be a city like Tulsa, OK, or Little Rock, AR. You have the idea, but you now need to learn as much as you can about the migration of people from small towns and rural areas to cities, as well as how bike-sharing programs work. You're just in the idea stage here, collecting information and looking for insights. Many people try to use social media to learn about emerging trends, but go about it in a haphazard manner. Here are some suggestions for effectively using social media to study environmental trends and business ideas associated with those trends.

- Facebook Groups. Look for Facebook Groups that pertain to the topics in which you have an interest. You can find Facebook groups by simply accessing Facebook's main page and typing the appropriate keywords in the search bar. Once you start typing for a term like "bike sharing," you'll see a list of suggestions pop up beneath the search bar. You can then look at the groups in which you have an interest. Simply "like" the groups that you want to follow, and you'll start getting notifications of new posts. Most groups will ask you to join (by clicking the join button) if you want to post information or make comments on others' posts.
- LinkedIn Groups. LinkedIn also has groups. To find a group, simply go to LinkedIn's homepage, and to the left of the search bar, access the dropdown menu and select Groups. You can then search to see if groups exist that match your topic. When writing this feature, there were several LinkedIn groups on bike-sharing. There were also groups that dealt with urban congestion. By typing "urban congestion" into the search bar, LinkedIn suggested the group "Creating Healthy, Liveable Cities," among others. Similar to Facebook, most LinkedIn groups will want you to join to participate in the discussions.
- Twitter. You can search for topics on Twitter, along with people, businesses, and organizations. You simply place the hashtag (#) in front of the topic. For example, for the business idea proposed above, you might want to search for the following topics: #bikesharing, #urbancongestion, #urbanqualityoflife, #healthycities, etc. Your searches will result in the most current tweets of people talking about those topics. This is a good way to both consume content on a topic in which you are interested and to identify people or organizations that you might want to follow on a consistent basis. Twitter does not support groups. Some third-party Twitter tools, like Tweetdeck, do allow you to form or join groups of Twitter followers that are interested in a specific topic.
- Blogs. To check to see if there is a blog on a topic of interest, search Google Blogs at www.google.com/blogsearch. A quick search identified a blog named The Bike-Sharing Blog at www.bike-sharing.blogspot.com. It also identified a website on Healthy Cities at www.healthycities.org.

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- Tumblr. Tumblr is a popular microblogging platform and social networking website owned by Yahoo. Simply go to Tumblr (www.tumblr.com) and type your query into the search bar. You'll see what Tumblr has to offer. You can try many different combinations of terms, such as "bike sharing," "healthy cities," "migrations to cities," etc. You can then periodically view or follow the Tumblr microblogs that interest you the most.

13.2.2 Solving a Problem

The second approach to identifying opportunities is to recognize problems and find ways to solve them. Problems can be recognized by observing the challenges that people encounter in their daily lives and through more simple means, such as intuition, serendipity, or chance. There are many problems that have yet to be solved. Commenting on this issue and how noticing problems can lead to recognizing business ideas, Philip Kotler, a marketing expert, said:

> Look for problems. People complain about it being hard to sleep through the night, get rid of clutter in their homes, find an affordable vacation, trace their family origins, get rid of garden weeds, and so on. As the late John Gardner, founder of Common Cause, observed: "Every problem is a brilliantly disguised opportunity."[11]

Consistent with this observation, many companies have been started by people who have experienced a problem in their own lives, and then realized that the solution to the problem represented a business opportunity. For example, in 1991, Jay Sorensen dropped a cup of coffee in his lap because the paper cup was too hot. This experience led Sorensen to invent an insulating cup sleeve and to start a company to sell it. Since launching his venture, the company, Java Jacket, has sold over four billion cup sleeves. Similarly, after watching countless women walk home barefoot after a long night in heels, New York University finance students Katie Shea and Susie Levitt started a company named CitySlips to make easily portable, comfortable shoes. They created a pair of flats that fold up to fit into a pocket-size zip pouch, which easily fits into most women's purses. When a woman pops on the shoes, the pouch unfurles into a tote bag to carry the high heels. The two began selling CitySlips in 2009; today, their product is carried in over 500 stores.[12]

Advances in technology often result in problems for people who can't use the technology in the way it is sold to the masses. For example, some older people find traditional cell phones hard to use: the buttons are small, the text is hard to read, and it's often difficult to hear someone on a cell phone in a noisy room. To solve these problems, GreatCall, Inc. is producing a cell phone called the Jitterbug, which is designed specifically for older users. The Jitterbug features a large keypad that makes dialing easy, powerful speakers that deliver clear sound, easy-to-read text, and simple text-messaging capability. Another company, Firefly Mobile, has created a cell phone designed specifically for kids and tweens. The phone weighs only 2 ounces, and is designed to fit in a kid's hand. The phone includes a full-color screen, built-in games, built-in parental controls that allow parents to restrict incoming and outgoing calls as well as limit or restrict texting, and special speed dials for mom and dad.

If you're having difficulty solving a particular problem, one technique that is useful is to find an instance where a similar problem was solved and then apply that solution to your problem. For example, Yogitoes, a company that makes nonslip rugs for yoga enthusiasts, was started in this manner. Several yoga positions require participants to strike poses

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One of the most pressing problems facing the United States and other countries is finding alternatives to fossil fuels. A large number of entrepreneurial firms are being launched to take on this challenge. Among potential solutions is wind-generated energy.

Winslow Productions/Tetra Images/Corbis

where they balance their weight on their feet at an angle. In this position, it is easy to slip when using a regular yoga mat. The company's founder, Susan Nicols, looked for a yoga mat that would prevent her from slipping, but found that no one knew how to make one. So she started looking for an example of a product that was designed specifically to prevent it from slipping on a hard floor, to study how it functioned. Eventually, she came across a dog bowl with rubber nubs on the bottom to prevent it from sliding when a large dog ate or drank from it. Using the dog bowl as a model, Nichols found a manufacturer who helped her develop a rug with small PVC nubs that prevents yoga participants from slipping when they perform yoga moves. Nichols started Yogitoes to sell the rugs, patented her solution, and has now been in business for more than 10 years.[13]

Some business ideas are gleaned by recognizing problems that are associated with emerging trends. For example, SafetyWeb has created a Web-based service that helps parents protect their children's online reputation, privacy, and safety. The social trend toward more online activity by children resulted in the need for this service. Similarly, the proliferation of smartphones enables people to stay better connected, but results in problems when people aren't able to access electricity to recharge their phones for a period of time. A number of companies have solved this problem in innovative ways. Examples include BioLite, which is a stove for campers that uses wood to create energy to recharge smartphones, and BikeCharge, which is a set of devices that are placed near the rear wheels of your bike and on your handlebars that charges your smartphone while you ride.

Additional examples of people who launched businesses to solve problems are included in Table 13.2.

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Table 13.2 Businesses Created to Solve a Problem

Entrepreneur(s)	Year	Problem	Solution	Name of Business That Resulted
Alison Johnson Rue and Dan Johnson	2012	There is no easy way for a student to connect with an online tutor.	Create an online platform that makes it possible for any student to connect with a tutor at any time.	InstaEdu (www.instaedu.com)
Greg Goff and Hesky Kutscher	2010	People traveling do not have ready access to their children's medical records, which may be needed if the child gets injured or sick.	Create an online platform that can be pulled up from any Web browser or on a smartphone that provides access to a child's full medical history.	MotherKnows (www.motherknows.com)
Jason Kiesel	2009	There is no easy way for residents of a city to report quality-of-life issues, such as graffiti or an abandoned car.	Create a mobile app that allows a resident to take a photo of the problem, send it to a central clearinghouse in city government, who will alert the appropriate city agency to fix the problem.	CitySourced (www.citysourced.com)
Roger Marsh	2009	Concrete block construction takes time and requires water; a building built with concrete blocks cannot be occupied immediately because the building's mortar needs time to cure.	Alter traditional methods of concrete block construction to enable the assembly of the block to be completed in a manner that requires no water, has immediate occupancy, and is faster than current procedures.	Bolt-A-Blok Systems
Perry Chen, Yancey Strickler, and Charles Adler	2009	No easy-to-access platform for funding creative projects, like indie films, record albums, or food-related projects.	Create a Web-based "crowdfunding" platform that helps artists, musicians, and people involved in other creative projects raise money from the public.	Kickstarter

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13.2.3 Finding Gaps in the Marketplace

Gaps in the marketplace are the third source of business opportunities. There are many examples of products that consumers need or want that aren't available in a particular location or aren't available at all. Part of the problem is created by large retailers, like Wal-Mart and Costco, that compete primarily on price and offer the most popular items targeted toward mainstream consumers. While this approach allows the large retailers to achieve economies of scale, it leaves gaps in the marketplace. This is the reason that clothing boutiques, specialty shops, and e-commerce websites exist. These businesses are willing to carry merchandise that doesn't sell in large enough quantities for Wal-Mart and Costco to carry.

Product gaps in the marketplace represent potentially viable business opportunities. For example, Tish Cirovolo realized that there were no guitars on the market made specifically for women. To fill this gap, she started Daisy Rock guitars, a company that makes guitars just for women. Daisy Rock guitars are stylish, come in feminine colors, and incorporate design features that accommodate a woman's smaller hand and build. In a related manner, Southpaw Guitars located in Houston, Texas, carries only guitars that are designed and produced for left-handed players. Another company that is filling a gap in the marketplace is ModCloth, a firm selling vintage and vintage-inspired clothing for 18- to 32-year-old women, which is a surprisingly large market. A start-up in a completely different industry is GreenJob Spider. GreenJob Spider fills a gap in the online recruiting industry by supporting a job site for employers and prospective employees in "green" industries such as solar, wind, recycling, green buildings, and LED lighting.

Additional examples of companies started to fill gaps in the marketplace are provided in Table 13.3.

A common way that gaps in the marketplace are recognized is when people become frustrated because they can't find a product or service that they need and recognize that other people feel the same way. This scenario played out for Lorna Ketler and Barb Wilkins, who became frustrated when they couldn't find stylish "plus-sized" clothing that fit. In response to their frustration, they started Bodacious, a store that sells fun and stylish "plus-size" clothing that fits. Ketler and Wilkins's experience illustrates how compelling a business idea can be when it strikes just the right chord by filling a gap that deeply resonates with a specific clientele. Reflecting on the success of Bodacious, Wilkins said:

> It's so rewarding when you take a risk and it pays off for you and people are telling you every single day, "I am so glad you are here." We've had people cry in our store. It happens a lot. They're crying because they're so happy (that they're finding clothes that fit). One woman put on a pair of jeans that fit her, and she called me an hour later and said, "They still look good, even at home!" Sometimes people have a body change that happens, whether they have been ill or had a baby, and there's lots of emotion involved in it. If you can go and buy clothes that fit, that helps people feel good about themselves.[14]

A related technique for generating new business opportunities is to take an existing product or service and create a new category by targeting a completely different target market. This approach essentially involves creating a gap and filling it. An example is PopCap Games, a company that was started to create a new category in the electronic games industry called "casual games." The games are casual and relaxing rather than flashy and action-packed, and are made for people who want to wind down after a busy day.

One thing that entrepreneurs must remain mindful of in pursuing business opportunities, regardless of whether the opportunity results from changing environmental trends, solving a problem, or finding gaps in the marketplace, is that the opportunity must ultimately be fashioned into a successful business. The nearby "What Went Wrong?" feature

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Table 13.3 Businesses Created to Fill a Gap in the Marketplace

Gap in the Marketplace	Resulting New Business Opportunity	Name of Businesses That Resulted
No fitness centers that are open 24 hours a day	24-hour fitness centers to accommodate people who work odd hours	Anytime Fitness, 24 Hour Fitness
Lack of toys and toy stores that focus on a child's intellectual development	Toy stores, toy manufacturers, websites that sell educational toys, and toy and smartphone app combinations	Launchpad Toys, Little Bits, Modular Robotics, Ubolly
Too few women pursuing careers in engineering	For-profit and non-profit organizations that teach older girls to code, after-school programs that engage school-age girls in engineering-related projects, interactive books and games that interest young girls in engineering	Girls Who Code, Engineering for Kids, GoldieBlox, Roominate
Shortage of clothing stores that sell fashionable clothing for hard-to-fit people	Boutiques and retail stores that sell fashionable clothing for hard-to-fit people, including plus-sized clothing, maternity clothes, or clothing for tall or short people	Casual Male, Fashions to Figure, Motherhood Maternity

focuses on Everpix, a company that resulted from its founders' frustration regarding the lack of a good service to store and organize photos. Regrettably, the founder spent too much time focused on the opportunity at the expenses of the business, as you'll see in the feature.

13.3 Personal Characteristics of the Entrepreneur

How did Michael Dell come up with the idea of a "build it yourself" computer company? How did Dave Roberts, the founder of PopCap Games, figure out that there is a large and growing market for "casual" electronic games?

Researchers have identified several characteristics that tend to make some people better at recognizing opportunities than others. We've already defined an opportunity as a favorable set of circumstances that create the need for a new product, service, or business, but the term **opportunity recognition** refers to the process of *perceiving* the possibility of a profitable new business or a new product or service. That is, an opportunity cannot be pursued until it's *recognized*. Now let's look at some specific characteristics shared by those who excel at recognizing an opportunity.

13.3.1 Prior Experience

Several studies show that prior experience in an industry helps entrepreneurs recognize business opportunities. For example, evidence over time about the founders of firms appearing on the *Inc.* 500 list shows that well over 40 percent of those studied got the idea for their new businesses while working as employees for companies in the same industries.[15] This finding is consistent with those reported by scholars studying the relationship between industry experience and being able to recognize opportunities.[16] There

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WHAT WENT WRONG?

Why a Company That Solved a Problem with a Great Product Went Out of Business

In 2009, Pierre-Olivier Latour spent some time traveling through Asia with a friend. He became frustrated with how difficult it was to store and organize all the photos he was taking. When he returned to the United States, he discussed his frustration with Kevin Quennesson, a fellow French engineer. Quennesson had a different frustration with photos, noting that the more photos he took, the less likely he was to go back and look at them. Quennesson saw this likelihood as a paradox. The more he documented his life, the less likely he was to enjoy what he had created.

Latour and Quennesson saw the combination of their frustrations as a problem. There wasn't a good solution on the market to store and organize photos in a manner that would encourage people to go back and look at them. The two decided to start a business and build a prototype of a photo storing and organizing service that potentially solved the problem. In June 2011 they met Wayne Fan, who was working at a San Francisco firm doing interaction and visual design, and brought him in as a co-founder. The three spent the next several months building a prototype of their service, which they named Everpix. The service seamlessly found and uploaded photos from your desktop and from online services, then organized them to highlight the best ones. The service was fast, the design was clean, and it was simple to use.

Everpix raised a total of $1.8 million from angel investors and continued to work on the product. The first version of Everpix 1.0 rolled out in March 2013. A free option let you see all your photos from the past year or longer if you connected to Everpix's app. For $4.99 a month or $49 a year, the service would let you store an unlimited amount of photos. One cool feature, called Flashbacks, sent users daily email messages of their photos from the same day in prior years. The overall service got rave reviews, and its users seemed to love it. The Everpix app had a 4.5-star average rating (on a scale of 1–5) out of more than 1,000 reviews. It seemed as though the founders were solving the problem they had set out to solve, with an attractive and solid product. Then, in the summer of 2013, Everpix closed. What went wrong?

In a nutshell, Everpix's founders spent too much time and energy perfecting their service at the expense of building a business. The service wasn't viral, meaning it wasn't easy for Everpix subscribers to share photos with friends and encourage them to become Everpix members. The Everpix team realized this was a problem and kicked around ways to make the service more viral. One idea was to require a subscriber's friends to create an account to download any photos that the subscriber shared with them, but the idea was killed as just the type of self-serving design choice that the team prided itself in avoiding. It also spent almost nothing on advertising or promotions. It had spent the $1.8 million it raised building the service. So at the time when other photo apps were attracting millions of users, Everpix had fewer than 19,000 sign-ups.

In the weeks prior to closing, Everpix's founders scrambled to raise additional funding. Because they were well-connected in the angel investing and venture capital world, they got a number of meetings. They were consistently praised on the quality of their product and the quality of the team they had assembled, but the business was the problem. Investors were getting spooked, in part, by the sheer number of apps that were being created and the ease with which consumers could switch between them. In addition, a number of Everpix's competitors were giving their services away for free, while Everpix's business model relied on paid subscriptions. One by one, the investors turned them down. Several overtures were made to potential acquirers, but none panned out. Eventually, Everpix ran out of money and didn't have the capacity to continue.

Questions for Critical Thinking

1. In the context of this chapter, make a list of three "takeaways" from this feature that you can learn from and try to avoid if you set out to solve a problem by launching a business.

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2. To what degree is there a difference between pursuing an opportunity to solve a problem and building a business? In what ways did Everpix fail to do both?
3. According to the feature, Everpix spent almost nothing on advertising and promotions. How large of a role do you think that decision played in Everpix's failure?
4. Venture capitalists are often accused of swinging for the fences—in other words, they don't invest in firms that are hitting signals, doubles, or triples. They want home runs. In hindsight, do you think Everpix was building a business that had the potential to hit singles, doubles, or triples, or a business that had the potential to be a home run? Explain your answer.

Sources: C. Newton, "Out of the Picture: Why the World's Best Photo Startup is Going Out of Business," The Verge, originally posted on November 5, 2013, Available at http://www.theverge.com/2013/11/5/5039216/everpix-life-and-death-inside-the-worlds-best-photo-startup, accessed March 19, 2014; The Sublog, "Everpix, Snapchat, and The Startup Life," November 7, 2013, Available at http://subimage.com/blog/2013/11/07/everpix-snapchat-and-the-startup-lie/#.Uym15qMo670, accessed March 19, 2014.

are several explanations for these findings. By working in an industry, an individual may spot a market niche that is underserved. It is also possible that while working in a particular area, an individual builds a network of social contacts in that industry that may provide insights that lead to opportunities.[17]

Although prior experience is important in an industry in most instances, there is anecdotal evidence suggesting that people outside an industry can sometimes enter it with a new set of eyes, and as a result innovate in ways that people with prior experience might find difficult. An example is provided by Sam Calagione, the founder of Dogfish Head Craft Brewery, a very successful brewery based in Milton, Delaware. As indicated in the following quote, Milton set aside current industry best practices to craft some of his most popular products:

> In the mid-'90s, some beer enthusiasts and experts called us heretics for brewing beers with ingredients outside of the "traditional" water, yeast, hops, and barley. So, I started researching ancient brewing cultures and learned that long ago, brewers in every corner of the world made beer with whatever was beautiful and natural and grew beneath the ground they lived on. We (Dogfish Brewery) now make a whole series of Ancient Ales inspired by historic and molecular evidence found in tombs and dig sites.[18]

13.3.2 Cognitive Factors

Opportunity recognition may be an innate skill or a cognitive process.[19] There are some who think that entrepreneurs have a "sixth sense" that allows them to see opportunities that others miss. This sixth sense is called **entrepreneurial alertness,** which is formally defined as the ability to notice things without engaging in deliberate search.[20] Most entrepreneurs see themselves in this light, believing they are more "alert" than others. Alertness is largely a learned skill, and people who have more knowledge of an area tend to be more alert to opportunities in that area than others. A computer engineer, for example, would be more alert to needs and opportunities within the computer industry than a lawyer would be.

The research findings on entrepreneurial alertness are mixed. Some researchers conclude that alertness goes beyond noticing things and involves a more purposeful effort. For example, one scholar believes that the crucial difference between opportunity finders (i.e., entrepreneurs) and nonfinders is their relative assessments of the marketplace.[21] In other

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words, entrepreneurs may be better than others at sizing up the marketplace and inferring the likely implications.

13.3.3 Social Networks

The extent and depth of an individual's social network affects opportunity recognition.[22] People who build a substantial network of social and professional contacts will be exposed to more opportunities and ideas than people with sparse networks. This exposure can lead to new business starts. Research results over time consistently suggest that somewhere between 40 percent and 50 percent of those who start businesses got their ideas through social contacts.[23] In a related study, the differences between **solo entrepreneurs** (those who identified their business ideas on their own) and **network entrepreneurs** (those who identified their ideas through social contacts) were examined. The researchers found that network entrepreneurs identified significantly more opportunities than solo entrepreneurs, but were less likely to describe themselves as being particularly alert or creative.[24]

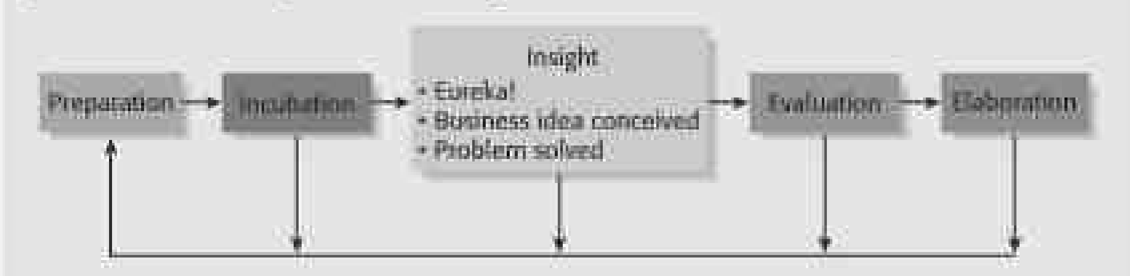
An important concept that sheds light on the importance of social networks to opportunity recognition is the differential impact of strong-tie versus weak-tie relationships. Relationships with other people are called "ties." We all have ties. **Strong-tie relationships** are characterized by frequent interaction, such as ties between coworkers, friends, and spouses. **Weak-tie relationships** are characterized by infrequent interaction, like ties between casual acquaintances. According to research in this area, it is more likely that an entrepreneur will get a new business idea through a weak-tie than a strong-tie relationship, because strong-tie relationships—which typically form between like-minded individuals—tend to reinforce insights and ideas the individuals already have.[25] Weak-tie relationships, on the other hand, which form between casual acquaintances, are not as apt to be between like-minded individuals, so one person may say something to another that sparks a completely new idea. An example might be an electrician explaining to a restaurant owner how he solved a business problem. After hearing the solution, the restaurant owner might say, "I would never have heard that solution from someone in my company or industry. That insight is completely new to me and just might help me solve my problem."

13.3.4 Creativity

Creativity is the process of generating a novel or useful idea. Opportunity recognition may be, at least in part, a creative process. On an anecdotal basis, it is easy to see the creativity involved in forming many products, services, and businesses. Increasingly, teams of entrepreneurs working within a company are sources of creativity for their firm.[26]

For an individual, the creative process can be broken into five stages, as shown in Figure 13.4.[27] Let's examine how these stages relate to the opportunity recognition

Figure 13.4 Five Steps to Generating Creative Ideas



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process. In the figure, the horizontal arrows that point from box to box suggest that the creative process progresses through five stages. The vertical arrows suggest that if at any stage an individual (such as an entrepreneur) gets "stuck" or doesn't have enough information or insight to continue, the best choice is to return to the preparation stage—to obtain more knowledge or experience before continuing to move forward.

Preparation. Preparation is the background, experience, and knowledge that an entrepreneur brings to the opportunity recognition process. Just as an athlete must practice to excel, an entrepreneur needs experience to spot opportunities. Over time, the results of research suggest that as much as 50 to 90 percent of start-up ideas emerge from a person's prior work experience.

Incubation. Incubation is the stage during which a person considers an idea or thinks about a problem; it is the "mulling things over" phase. Sometimes incubation is a conscious activity, and sometimes it is unconscious and occurs while a person is engaged in another activity. One writer characterized this phenomenon by saying that "ideas churn around below the threshold of consciousness."

Insight. Insight is the flash of recognition when the solution to a problem is seen or an idea is born. It is sometimes called the "eureka" experience. In a business context, this is the moment an entrepreneur recognizes an opportunity. Sometimes this experience pushes the process forward, and sometimes it prompts an individual to return to the preparation stage. For example, an entrepreneur may recognize the potential for an opportunity, but may feel that more knowledge and thought is required before pursuing it.

Evaluation. Evaluation is the stage of the creative process during which an idea is subjected to scrutiny and analyzed for its viability. Many entrepreneurs mistakenly skip this step and try to implement an idea before they've made sure it is viable. Evaluation is a particularly challenging stage of the creative process because it requires an entrepreneur to take a candid look at the viability of an idea. We discuss how to evaluate the feasibility of new business ideas in Chapter 14.

Elaboration. Elaboration is the stage during which the creative idea is put into a final form: The details are worked out and the idea is transformed into something of value, such as a new product, service, or business concept. In the case of a new business, this is the point at which a business plan is written.

Figure 13.5 illustrates the opportunity recognition process. As shown in the figure, there is a connection between an awareness of emerging trends and the personal characteristics of the entrepreneur because the two facets of opportunity recognition are interdependent. For example, an entrepreneur with a well-established social network may be in a better position to recognize emerging technological trends than an entrepreneur with a poorly established social network. Or the awareness of an emerging technology trend, such as digitization, may prompt an entrepreneur to attend conferences or workshops to learn more about the topic, expanding the social network.

13.4 Techniques for Generating Ideas

In general, entrepreneurs identify more ideas than opportunities because many ideas are typically generated to find the best way to capitalize on an opportunity.[28] Several techniques can be used to stimulate and facilitate the generation of new ideas for products, services, and businesses. Let's take a look at some of them.

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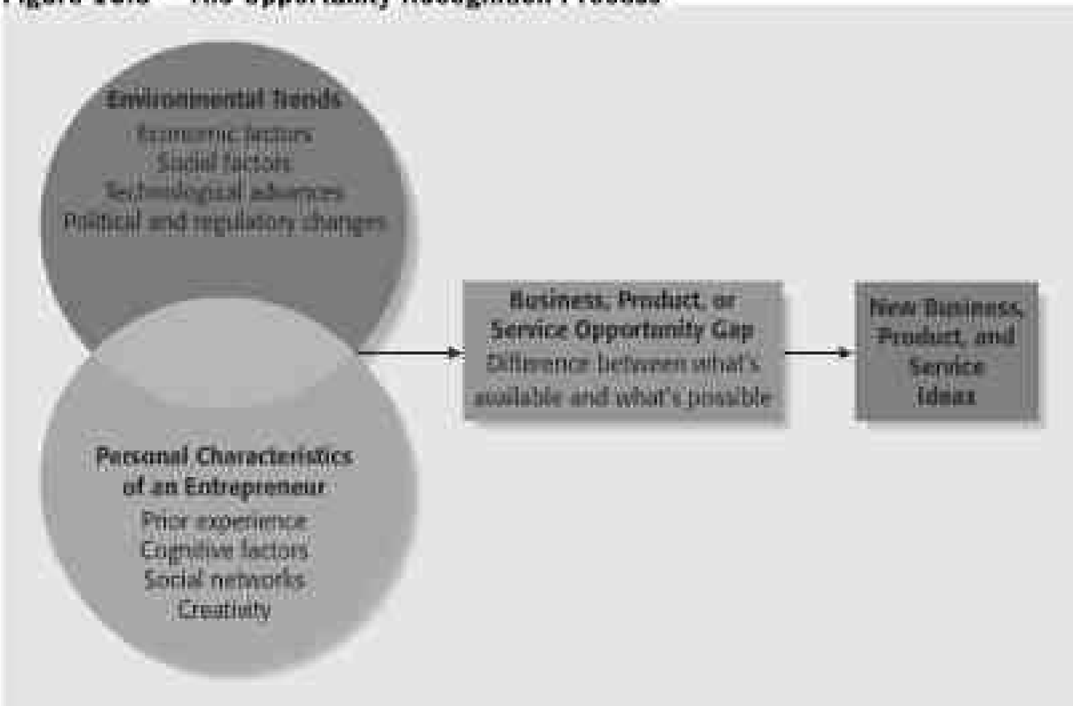
Figure 13.5 The Opportunity Recognition Process



13.4.1 Brainstorming

A common way to generate new business ideas is through **brainstorming**. In general, brainstorming is simply the process of generating several ideas about a specific topic. The approaches range from a person sitting down with a yellow legal pad and jotting down interesting business ideas to formal "brainstorming sessions" led by moderators that involve a group of people.

In a formal brainstorming session, the leader of the group asks the participants to share their ideas. One person shares an idea, another person reacts to it, another person reacts to the reaction, and so on. A flip chart or an electronic whiteboard is typically used to record all the ideas. A productive session is freewheeling and lively. The session is not used for analysis or decision making—the ideas generated during a brainstorming session need to be filtered and analyzed, but this is done later. We show the four strict rules for conducting a formal brainstorming session in Table 13.4. As you'll see, the number one rule for a brainstorming session is that no criticism is allowed, including chuckles, raised eyebrows, or facial expressions that express skepticism or doubt. Criticism stymies creativity and inhibits the free flow of ideas.

Brainstorming sessions dedicated to generating new business ideas are often less formal. For example, while creating Proactiv, a popular acne treatment product, Dr. Katie Rodan, one of the company's founders, hosted dinner parties at her house and conducted brainstorming sessions with guests. The guests included business executives, market researchers, marketing consultants, an FDA regulatory attorney, and others. Rodan credits this group with helping her and her co-founder brainstorm a number of ideas that helped shape Proactiv and move the process of starting the company forward.[29] Similarly, Sharelle Klaus—the founder of Dry Soda, a company that makes an all-natural soda that's paired with food the way wine is in upscale restaurants—tested her idea by first talking to her husband's colleagues, who were in the food industry, and then tapped into the professional network of a friend who owned a bottled water company. Through the process, she met a chemist, who was instrumental in helping her develop the initial recipes for her beverage.

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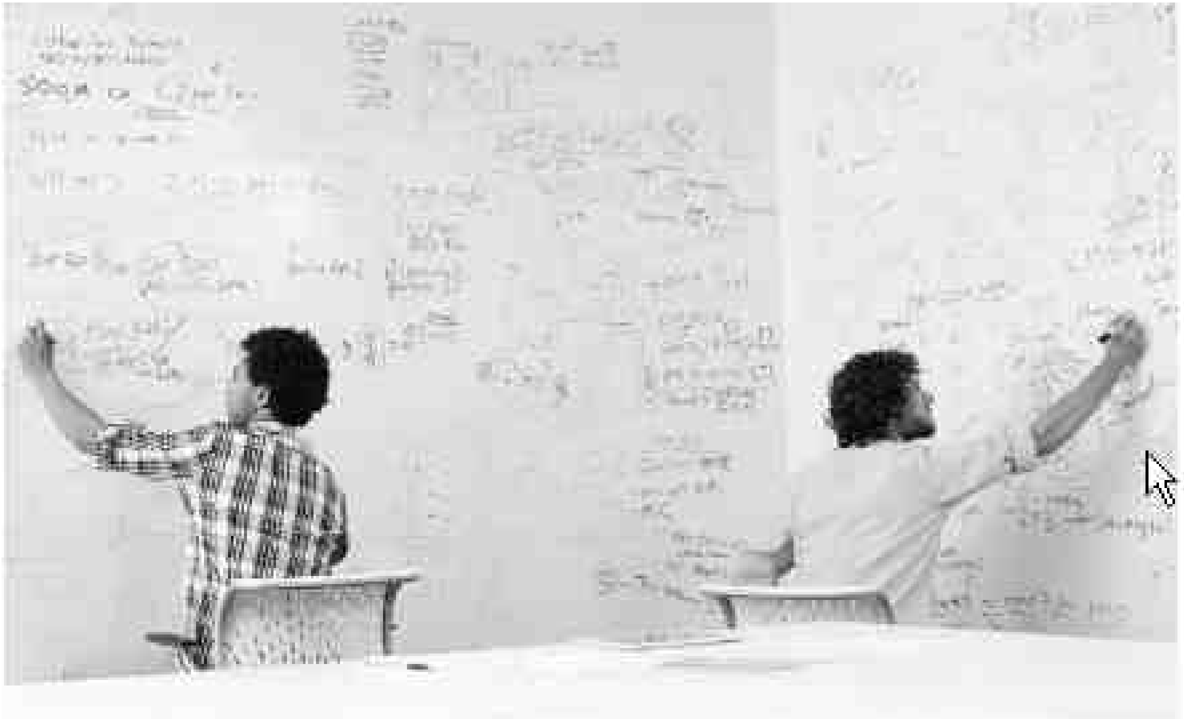
Some organizations use "brainstorming walls" for people to jot down ideas. By putting ideas on walls, people can stand back and view multiple ideas simultaneously, and make connections that they otherwise would not have made.



Hiya Images/Fancy/Corbis

Klaus also went directly to restaurant owners and chefs to ask them to sample early versions of her product.[30] While this approach only loosely fits the definition of brainstorming, the spirit is the same. Klaus was bouncing ideas and early prototypes of her product off others to get their reactions and generate additional ideas.

An individual's imagination is the only limiting factor to brainstorming. Asking students to complete a **bug report** is a popular technique that is used in classrooms to teach brainstorming. To compile a bug report, students are instructed to list 50 to 75 conditions

Table 13.4 Rules for a Formal Brainstorming Session

Rule	Explanation
1	No criticism is allowed, including chuckles, raised eyebrows, or facial expressions that express skepticism or doubt. Criticism stymies creativity and inhibits the free flow of ideas.
2	Freewheeling, which is the carefree expression of ideas free from rules or restraints, is encouraged; the more ideas, the better. Even crazy or outlandish ideas may lead to a good idea or a solution to a problem.
3	The session moves quickly, and nothing is permitted to slow down its pace. For example, it is more important to capture the essence of an idea than to take the time to write it down neatly.
4	Leapfrogging is encouraged. This means using one idea as a means of jumping forward quickly to other ideas.

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or "things" that "bug" them in their everyday lives. Asking students to identify a number of conditions or things that bug them reduces the likelihood that they will specify only obvious things that bug them (e.g., campus parking, dorm food, and untidy roommates). Students can also be encouraged to hold focus groups with friends to brainstorm conditions that can be included on their "bug" list.

13.4.2 Focus Groups

A **focus group** is a gathering of 5 to 10 people who are selected because of their relationship to the issue being discussed. Focus groups are used for a variety of purposes, including the generation of new business ideas.

Focus groups typically involve a group of people who are familiar with a topic, are brought together to respond to questions, and shed light on an issue through the give-and-take nature of a group discussion. Focus groups usually work best as a follow-up to brainstorming, when the general idea for a business has been formulated—such as casual electronic games for adults—but further refinement of the idea is needed. Usually, focus groups are conducted by trained moderators. The moderator's primary goals are to keep the group "focused" and to generate lively discussion. Much of the effectiveness of a focus group session depends on the moderator's ability to ask questions and keep the discussion on track. For example, a retail establishment in which coffee is sold, such as Starbucks, might conduct a focus group consisting of 7 to 10 frequent customers and ask the group, "What is it that you *don't* like about our coffee shop?" A customer may say, "You sell 1-pound bags of your specialty ground coffees for people to brew at home. That's okay, but I often run out of the coffee in just a few days. Sometimes it's a week before I get back to the shop to buy another bag. If you sold 3-pound or 5-pound bags, I'd actually use more coffee because I wouldn't run out so often. I guess I could buy two or three 1-pound bags at the same time, but that gets a little pricey. I'd buy a 3- or 5-pound bag, however, if you'd discount your price a little for larger quantities." The moderator may then ask the group, "How many people here would buy 3-pound or 5-pound bags of our coffee if they were available?" If five hands shoot up, the coffee shop may have just uncovered an idea for a new product line.

A relatively new service called Napkin Labs helps companies funnel followers from Facebook and other sites into more intimate, more structured online communities intended to serve as focus groups. For example, Modify, the subject of Case 14.1, is a company that creates custom watches. The watches have interchangable faces, straps, and sliders and come in two sizes. Modify uses Napkin Labs to get people to chime in on what new colors and designs they'd like to see, and where they'd like to see the watches sold. Each lab poses a challenge, such as "where should our watches be sold?" A dialogue is created among the participants. Each participant knows what the other ones are saying and can react to their comments. According to Aaron Schwartz, Modify's founder, one lab showed a surprisingly big interest in seeing his company's watches sold in surf shops. Other online companies, such as UserVoice and Get Satisfaction, help firms connect with their users in a similar manner.[31]

13.4.3 Library and Internet Research

A third approach to generating new business ideas is to conduct library and Internet research. A natural tendency is to think that an idea should be chosen, and the process of

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researching the idea should then begin. This approach is too linear. Often, the best ideas emerge when the general notion of an idea—like creating casual electronic games for adults—is merged with extensive library and Internet research, which might provide insights into the best type of casual games to create.

Libraries are often an underutilized source of information for generating business ideas. The best approach to utilizing a library is to discuss your general area of interest with a reference librarian, who can point out useful resources, such as industry-specific magazines, trade journals, and industry reports. Simply browsing through several issues of a trade journal on a topic can spark new ideas. Very powerful search engines and databases are also available through university and large public libraries, which would cost hundreds or thousands of dollars to access on your own. An example is IBISWorld (www.ibisworld.com), a company that publishes market research on all major industries and subcategories within industries.

Internet research is also important. If you are starting from scratch, simply typing "new business ideas" into Google or Bing will produce links to newspaper and magazine articles about the "hottest" and "latest" new business ideas. Although these types of articles are general in nature, they represent a starting point if you're trying to generate new business ideas from scratch. If you have a specific idea in mind, a useful technique is to set up a Google "email alert" using keywords that pertain to your topic of interest. Google email alerts are email updates of the latest Google results including press releases, news articles, and blog posts based on your topic. This technique, which is available for free, will feed you a daily stream of news articles and blog postings about specific topics. Another approach is to follow business leaders and experts in the industries you're interested in on Twitter. The best way to locate people on Twitter you might be interested in following is by typing into the search bar relevant keywords preceded by the "#" sign. For example, if you're interested in solar power, type "#solarpower" into the search bar. All the results will be people or companies who tweet about solar power topics.

Once an entrepreneur has an idea, it often needs to be shaped and finetuned. One way to do this—in conjunction with the suggestions made previously—is to enlist a mentor to help. An explanation of how to use a mentor in this regard, and where mentors can be found, is described in the "Partnering for Success" feature.

13.4.4 Other Techniques

Firms use a variety of other techniques to generate ideas. Some companies set up **customer advisory boards** that meet regularly to discuss needs, wants, and problems that may lead to new ideas. Other companies conduct varying forms of anthropological research, such as **day-in-the-life research**. Intuit, the maker of Quicken, Quickbooks, and TurboTax, practices day-in-the life research. The company routinely sends teams of testers to the homes and businesses of its users to see how its products are working and to seek insights for new product ideas.

13.5 Encouraging the Development of New Ideas

In many firms, idea generation is a haphazard process. However, entrepreneurial ventures can take certain concrete steps to build an organization that encourages and protects new ideas. Let's see what these steps are.

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PARTNERING FOR SUCCESS

Want Help Fine-Tuning a Business Idea? Find a Mentor

Fine-tuning a business idea isn't easy. While fairly course-grained ideas are rather easy to develop, like creating a smartphone that's designed specifically for elderly people, fleshing out the details is where experience helps. This reality puts first-time entrepreneurs at a disadvantage. While there are many books and websites about new business ideas, what many first-time entrepreneurs find most helpful in the idea generation and perfecting stage is to find a mentor to guide them through the process.

A **mentor** is someone who is more experienced than you and is willing to be your counselor, confidant, and go-to person for advice. There are two ways to find a mentor. First, you can work with your network of acquaintances—professors, business owners, coaches—to determine if there is someone available that you trust, has experience helping first-time entrepreneurs, and is willing to become your mentor. Many first-time entrepreneurs are surprised by the number of talented and experienced people who are eager to share their expertise and enter into a mentoring relationship. The second way is to utilize one of the growing numbers of websites and organizations that help match business founders with people who are willing to become mentors. One website is MicroMentor.org, which is a nonprofit that matches business founders with mentors. You can go to the site and fill out a profile about yourself and your goals, and then search profiles of potential mentors who match your needs. Once a match is made, the mentoring can take place through email, via Web conferencing, over the phone, or in person. There is a tab on MicroMentor's website that provides access to "success stories" of business founders who have had excellent results using its service. A number of organizations provide a similar service. For example, the National Association for Women Business Owners (NAWBO) has over 5,000 members in 60 chapters across the United States. Some chapters sponsor mentorship programs.

Another useful suggestion is to reach out to someone in your college or university's alumni network. Alumni are often looking for a way to "give back" to the institution from which they graduated and are frequently willing to connect with others as a way of doing so. Alumni often serve as judges for college-sponsored pitch or business plan competitions, so that's one way to connect. A particularly useful resource is to do an Advanced People Search on LinkedIn. You can do this by accessing the Advanced People Search function in LinkedIn (www.linkedin.com/search?trk=advsrch). You type in a title and your university. For example, if what you're looking for is a mentor that can help navigate you through the process of raising money for your start-up and you're a student at Oklahoma State University, you might type into the search bar "CFO Oklahoma State University." The results will list everyone with a LinkedIn profile who identifies themself as the CFO (Chief Financial Officer) of an organization and is a graduate of Oklahoma State University. You can then connect with the person through the private email service within LinkedIn. Most people have fond memories of their college days. As a result, even experienced entrepreneurs and executives are often delighted to connect with a student at their alma mater.

The ideal situation is to find a mentor in your own community so you can meet face-to-face, whether it's an alumni of your university of someone else. Still, the online options provide a wide range of mentors to choose from, which may result in a better match. Online mentoring and counseling relationships are becoming increasingly common. For example, a sizeable percent of all the counseling and mentoring done by SCORE counselors is now done online.

Similar to any relationship, a business founder should be careful and only share private information with a mentor once a trusting relationship has been established.

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Questions for Critical Thinking

1. If you were working on fine-tuning a business idea, would you check out one of these online options or an association in your area that provides mentoring and advice for business founders? Why or why not?
2. To what degree do you believe that having a mentor can make the difference between an entrepreneur succeeding or failing? In what areas of the entrepreneurial process do you believe that mentors are called on the most?
3. Make a list of the organizations in your area that provide mentorship and advice for business founders. Which organizations make the most sense to reach out to for someone who is still in the opportunity recognition stage of the start-up process?
4. How do you know what to do with a mentor's advice? If you get advice from several mentors or counselors at organizations like SCORE and local Small Business Development Centers, how can you best sort through the advice and know which advice to take and which advice to set aside?

Source: P. Ryckman, "How to Choose and Work with a Mentor," New York Times, www.nytimes.com/2010/09/02/business/smallbusiness/02sbiz.html?_r=2&emc=eta1 (accessed April 2, 2011, originally posted on September 1, 2010).

13.5.1 Establishing a Focal Point for Ideas

Some firms meet the challenge of encouraging, collecting, and evaluating ideas by designating a specific person to screen and track them—for if it's everybody's job, it may be no one's responsibility.[32] Another approach is to establish an **idea bank** (or vault), which is a physical or digital repository for storing ideas. An example of an idea bank would be a password-protected location on a firm's **intranet** that is available only to qualified employees. It may have a file for ideas that are being actively contemplated and a file for inactive ideas. Other firms do not have idea banks, but instead encourage employees to keep journals of their ideas.

13.5.2 Encouraging Creativity at the Firm Level

There is an important distinction between creativity and innovation. Innovation refers to the successful introduction of new outcomes by a firm. In contrast, creativity is the process of generating a novel or useful idea; however, creativity does not require implementation of an idea. In other words, creativity is the raw material that goes into innovation. A team of employees may come up with a hundred legitimate creative ideas for a new product or service, but only one may eventually be implemented. Of course, it may take a hundred creative ideas to discover the one that ideally satisfies an opportunity.

An employee may exhibit creativity in a number of ways, including solving a problem or taking an opportunity and using it to develop a new product or service idea. Although creativity is typically thought of as an individual attribute, it can be encouraged or discouraged at the firm level. The extent to which an organization encourages and rewards creativity affects the creative output of its employees.[33] Table 13.5 provides a list of actions and behaviors that encourage and discourage creativity at both the organizational level and the individual supervisor level.

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Table 13.5 Actions and Behaviors That Encourage and Discourage Creativity

Organizational Level	*Inhibitors of Creativity*	• Failing to hire creative people • Maintaining an organizational culture that stifles people • Retaining people in the same job for years, preventing them from broad and deep experiences • Promoting a mentality suggesting that the best solutions to all problems are known
	Facilitators of Creativity	• Supporting and highlighting creativity's importance in all parts of the firm • Overtly rewarding those demonstrating creativity in their work • Investing in resources for the purpose of helping employees become more creative • Hiring people with different skills and viewpoints compared to current employees
Individual Supervisory Level	*Inhibitors of Creativity*	• Being pessimistic, judgmental, and critical • Punishing people for failed ideas • Insisting on precision and certainty early in the creative process • Being inattentive, acting distant, and remaining silent when employees want to discuss new ideas
	Facilitators of Creativity	• Listening attentively for the purpose of openly acknowledging and supporting ideas early in their development • Treating employees as equals for the purpose of demonstrating that status isn't important • Speculating, being open, and building on others' ideas • Protecting people who make honest mistakes and commit to learning from them

SUMMARY

13.1 An idea is a thought, an impression, or a notion. An opportunity is an idea that has the qualities of being attractive, durable, and timely and is anchored in a product or service that creates value for its buyers or end-users. Not all ideas are opportunities. Once an opportunity is recognized, a window opens, and the market to fill the opportunity grows. At some point, the market matures and becomes saturated with competitors, and the window of opportunity closes.

13.2 Observing trends, solving a problem, and finding gaps in the marketplace are the three general approaches entrepreneurs use to identify a business opportunity. Economic forces, social forces, technological advances, and political action and regulatory changes are the four environmental trends that are most instrumental in creating opportunities. Through the second approach, entrepreneurs identify problems that they and others encounter in various parts of their lives and then go about developing a good or service that is intended to solve the identified problem. Carefully observing people and the actions they take is an excellent way to find problems that, when solved, would create

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value for a customer. Finding gaps in the marketplace is the third way to spot a business opportunity. Typically, the way this works is that an entrepreneur recognizes that some people are interested in buying more specialized products, such as guitars that are made for left-handed players or scissors for people who are dominant left-handers.

13.3 Over time, research results and observations of entrepreneurs in action indicate that some people are better at recognizing opportunities than others. Prior experience, cognitive factors, social networks, and creativity are the main personal characteristics researchers have identified and that observation indicates tend to make some people better at recognizing business opportunities than others.

13.4 Entrepreneurs use several techniques for the purpose of identifying ideas for new products and services. Brainstorming is one of these. More specifically, brainstorming is a technique used to quickly generate a large number of ideas and solutions to problems. One reason to conduct a brainstorming session is to generate ideas that might represent product, service, or business opportunities. A focus group, a second technique entrepreneurs use, is a gathering of 5 to 10 people who have been selected on the basis of their common characteristics relative to the issue being discussed. One reason to conduct a focus group is to generate ideas that might represent product or business opportunities. Careful and extensive searches of a physical library's holdings and of Internet sites are a third technique. Here, the entrepreneur uses an open mind to sort through large amounts of information and data to see if s/he can identify a problem that could be solved by creating an innovative product or service.

13.5 Entrepreneurs and their firms engage in several actions to encourage the development and retention of business ideas. Creativity is central to a firm's efforts to innovate; as such, firms take actions to nurture creativity. More specifically, entrepreneurs and their firms encourage creativity at the firm level through both organizational and individual supervisory level facilitators of creativity. Examples of organizational level facilitators of creativity include supporting creativity's importance and hiring people with different skills and viewpoints than those of current employees. Examples of individual supervisory level facilitators of creativity include listening attentively for the purpose of acknowledging and supporting ideas early in their development and protecting people who make honest mistakes and commit to learning from them. Ideas flowing from the exercise of creativity are stored in an idea bank, which is a physical or digital respository for storing ideas generated throughout an entrepreneurial venture.

KEY TERMS

brainstorming (p. 515)
bug report (p. 516)
creativity (p. 513)
customer advisory boards (p. 518)
day-in-the-life research (p. 518)
entrepreneurial alertness (p. 512)
focus group (p. 517)
idea (p. 498)
idea bank (p. 520)
intranet (p. 520)
mentor (p. 519)
network entrepreneurs (p. 513)
opportunity (p. 497)
opportunity gap (p. 497)
opportunity recognition (p. 510)
solo entrepreneurs (p. 513)
strong-tie relationships (p. 513)
weak-tie relationships (p. 513)
window of opportunity (p. 497)

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REVIEW QUESTIONS

13.1 What is a product opportunity gap?

13.2 How can an entrepreneur tell if a product opportunity gap exists?

13.3 What is an opportunity?

13.4 What are the qualities of an opportunity, and why is each quality important?

13.5 What four environmental trends are most instrumental in creating business opportunities? Provide an example of each environmental trend and the type of business opportunity it might help create.

13.6 How can "solving a problem" create a business opportunity for an entrepreneur to pursue?

13.7 How can finding a gap in the marketplace create a business opportunity?

13.8 What is the meaning of the term opportunity recognition?

13.9 In what ways does prior industry experience provide an entrepreneur an advantage in recognizing business opportunities?

13.10 What is entrepreneurial alertness and why is it important to entrepreneurs?

13.11 How does an extensive social network provide an entrepreneur an advantage in recognizing business opportunities?

13.12 What is the difference between a weak-tie and a strong-tie relationship? Which type of tie is most likely to help an entrepreneur find an idea and why?

13.13 What is creativity?

13.14 How does creativity contribute to the opportunity recognition process?

13.15 What are the five stages of the creative process for an individual?

13.16 What are the differences between an opportunity and an idea and why are those differences important for entrepreneurs?

13.17 Why is "no criticism" the number-one rule for brainstorming?

13.18 How is a focus group used to generate new business ideas?

13.19 What is the purpose of day-in-the-life research?

13.20 What is the purpose of an idea bank?

13.21 How do businesses encourage creativity at the firm level?

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APPLICATION QUESTIONS

13.1 Justin Coban plans to write an e-mail message to his dad asking for a loan. The purpose of the loan will be to start a company to sell an environmentally friendly line of cleaning supplies that are suitable for light manufacturing facilities. Justin has spent the past two years developing the products in his spare time and wants to convince his dad that the idea represents an attractive business opportunity. What information and insights about his potential company should Justin include in the e-mail message?

13.2 Identify three start-ups, other than those discussed in this chapter or listed in Table 13.2, that were started to solve a problem. Briefly describe the problems the three start-ups are solving and how they are going about doing so.

13.3 Marshall Hanson, the founder of Santa Fe Hitching Rail, a chain of nine steak restaurants in New Mexico, is considering expanding his menu, which is currently restricted to steak, hamburger, potatoes, and fries. He has just read a book about entrepreneurship and learned that entrepreneurs should study social trends to help identify new product opportunities. What are some current social trends that might help Marshall choose items to add to his menu? Given the trends you list, what items do you suggest Marshall add to expand his restaurant's menu?

13.4 Tiffany Jones owns a small chain of fastcasual restaurants in Denver that sell sandwiches, soups, wraps, and desserts. In general, her restaurants are successful, but she feels they are getting "stale" and could benefit from new ideas. What techniques could Tiffany use to generate new ideas for her restaurants?

13.5 As mentioned in this chapter, "prior experience" in an industry helps entrepreneurs recognize business opportunities. This concept of "help" extends to prior experience in any aspect of life—whether it is in sports, music, or a volunteer activity. In what areas to you have a good amount of prior experience? How could this prior experience position you to start a business?

13.6 Make a list of your strong-tie and weak-tie realtionships. Include at least five names on each list. Select two names from your list of weak-tie relationships and speculate on the types of new business ideas you think these individuals would be uniquely qualified to help you contemplate.

13.7 Imagine that you've been hired by Fitbit, the wearable activity tracker, to conduct focus groups on your campus to get a better sense of how Fitbit can be as relevant and useful to college students as possible. How would you go about setting up the focus groups? What are the primary issues on which you would concentrate with the focus groups?

13.8 How could AJ Forsythe and Anthony Martin, the co-founders of iCracked, the subject of the opening feature for this chapter, have utilized library and Internet research to flesh out their business idea?

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YOU BE THE VC 13.1

COMPANY: NatureBox

Business Idea: Launch a monthly subscription service that delivers healthy snacks to subscribers at their doorsteps for a low monthly fee.

Pitch: Snacking is a part of everyday life. As Americans become more health conscious, they are continually looking for healthier snacks. NatureBox provides a subscription service where it delivers a box of healthy snacks to its subscribers on a monthly basis. The boxes come in three sizes: individual, family, and office. The individual box contains five snacks, the family box 10 snacks, and the office box 15 snacks. The boxes contain packages of snack items such as dried fruit strips, harvest nut mix, cranberry almond bits, and roasted kettle kernels. Each package is a NatureBox-branded product that is formulated in-house by NatureBox's nutritional specialists.

With a mission of "Discover a Healthier You," NatureBox's selling proposition is that it provides consumers with a variety of healthy snacks without having to go to the store, walk the aisles, and read the labels on snack selections to make sure they are nutritious. Since snacks are consumed, they need to be regularly replenished, which is facilitated by NatureBox's monthly deliveries. The company also sells full-sized versions of the snacks that it includes in its monthly subscription boxes on its website. A customer can customize his or her monthly subscription box or let NatureBox surprise them. For those that allow NatureBox to surprise them, the service contains an element of anticipation and fun as customers await their monthly box and then discovers what's inside. All of NatureBox's snacks are sourced from local growers and independent food suppliers across the United States. Every NatureBox snack is guaranteed nutritious and is free from high-fructose corn syrup, hydrogenated oils, trans fats, and artificial sweeteners, flavors, and colors.

While NatureBox views the subscription model as a powerful form of distribution, it realizes that not all consumers want to subscribe to a product or service. As a result, the company's goal is to build a brand of nutritious snack foods that can be sold both within and outside the subscription framework. The company's intentions are to continue to sell online. Only 2 percent of all food products are currently sold online. NatureBox believes that as people become increasingly comfortable conducting the majority of their purchases online, that 2 percent number will increase and consumers will be drawn to brands that sell predominately online and are distinctive and unique, such as NatureBox's tasty, nutritious snacks.

NatureBox is spreading the word about its subscription service and products primarily via social media. It currently has more than 786,000 Facebook likes and says that many of its sales come from pass-alongs and word-of-mouth referrals.

1. Based on the material covered in this chapter, what questions would you ask the firm's founders before making your funding decision? What answers would satisfy you?
2. If you had to make your decision on just the information provided in the pitch and on the company's website, would you fund this company? Why or why not?

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YOU BE THE VC 13.2

COMPANY: Parking Panda

Business Idea: Create a service that allows motorists to find parking spots on a regular basis or for special events, and allow parking space owners (both individuals and commercial lots) a way of connecting with drivers to rent underutilized parking spaces.

Pitch: Finding convenient parking in a city or for a major sporting event or concert is a frustration that almost every motorist has experienced. Trouble finding parking is also a major cause of congestion. Experts estimate that 30 percent of urban traffic is caused by motorists trying to find parking. At the same time, commercial lots and garages often have underutilized parking spaces because people can't find them or mistakenly assume they are full. In most cases, there are also homes and businesses within a short walking distance from where people are looking for parking with spaces that are vacant during large portions of the day.

Parking Panda has created a solution for this problem. It is a website and app that connects drivers looking for parking with commercial lots and individuals who have spaces to rent. Here's how it works. In areas where Parking Panda is available (70 cities and counting), drivers that are already on the road can enter their location, and Parking Panda will show them the nearest available spaces. If you're planning ahead, you can browse a collection of parking spots based on price and location, and reserve one. You can search by neighborhood, restaurant, hotel, nightclub, music venue, or stadium. When you arrive at your destination, your spot will be available, even if the ramp or lot is sold out. You gain admittance by showing the reservation on your smartphone to the attendant. If the lot is gated and does not have an attendant, you gain admittance by using the Parking Panda app to scan a code at the entrance, which opens the gate. You exit the lot in the same manner. Parking spots can be reserved on a one-time basis or can be reserved for regular use. Parking Panda collects the fee at the time the reservation is made and then reimburses the owner of the spot.

Parking Panda makes money by taking a commission on each spot that is rented. It negotiates directly with commercial lots and garages. Individuals and businesses that have parking spaces available simply upload a picture of their spot and set a price. Parking Panda lets the owner know when a spot has been rented and handles the payment. Parking Panda also has arrangements with sports leagues such as the National Basketball Association (NBA) and the National Hockey Association (NHL) to facilitate parking for their events.

1. Based on the material covered in this chapter, what questions would you ask the firm's founders before making your funding decision? What answers would satisfy you?
2. If you had to make your decision on just the information provided in the pitch and on the company's website, would you fund this company? Why or why not?

CASE 13.1

Dropbox: Solving a Compelling Problem in a Smooth Manner

Introduction

In early 2007, Drew Houston was on a bus from Boston to New York City. He was excited because he had four hours to work on his laptop. All of a sudden, he had a feeling in the pit of his stomach that something was wrong. He searched through his pockets and discovered that he had forgotten his USB memory stick. He was now stuck on the bus with nothing to work on. Frustrated, he immediately starting building technology to synch files over the Web. Fast

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forward to the present. Houston's eventual solution, Dropbox, has over 200 million users. Dropbox allows users to create a special folder on each of their devices. Once a piece of digital content is placed in a folder (Word file, Excel file, photo, video, etc.), Dropbox automatically syncs it across all the users' devices, permitting the content to be retrieved and updated from any device. The content also appears in a file on Dropbox's website. And if you make a change to a file in one location, that file is updated across all devices. Dropbox completely solves the problem of working on a file on one device, such as an office computer, and then not having it available on another device, like a laptop at home. You can even invite others to view these files, making the sharing of files easy. It's like having a magic pocket that contains all your digital content and is always with you, with the ability to share the digital content with whomever you want.

Although Dropbox's service is easy to use, it wasn't easy to build or even easy to explain at the outset. It's a story of two determined entrepreneurs who set out to solve a problem, build an elegant solution, and then did a lot of things right in executing on their business idea.

Drew Houston

The Dropbox story starts when Houston was young. He started writing code in his early teens. At 14, he signed up to beta test an online game, and began identifying security flaws. The company soon hired him as their networking programmer, in exchange for equity. Houston worked at start-ups through high school and college. By the time he got to MIT, most of his time was spent coding. He knew that to start businesses, he'd need to know more than just coding, so he starting reading business books. He read books on finance, management, negotiations, etc.

After graduating from college, Houston took a job with a tech firm. The day on the bus from Boston to New York City took place about a year into the new job. Four months later, he flew to San Francisco to pitch the idea for Dropbox to Paul Graham of business accelerator Y Combinator. Graham insisted that Houston have a co-founder, even to pitch. Houston was soon introduced to Arash Ferdowsi, who was a junior engineering student at MIT, and the two hit it off. They decided to work on Dropbox together. They were soon admitted and went through Y Combinator in 2007.

Minimal Viable Product and Solving a Problem People Didn't Know They Had

After their Y Combinator experience finished, Houston and Ferdowsi raised $1.2 million in funding. A challenge they faced from the beginning is that they were solving a problem that most people didn't know they had. There were ways for people to transfer files from one device to another, such as USB memory sticks, e-mailing files to yourself, and so forth. The idea of a service that would sync your files across all your devices didn't exist, so no one knew to ask for it. This reality posed a problem. To gain traction, it wouldn't do any good to buy Google AdWords, for example, because no one was searching for a file syncing service.

To test demand and get feedback on early versions of Dropbox, Houston and Ferdowsi opted for a novel solution. They made two short product videos. The first video, which was made just before Y Combinator, appeared on Dropbox's Homepage. It was a simple, 2-minute-and-17-second stick figure video showing what the service did—nothing complicated, just a guy who loses stuff and goes on a trip to Africa. The second video was a year later. It was a bland, simple three-minute demonstration of Dropbox as it was meant to work, targeted at a community of technology early adopters. Houston narrated the video. It was both informative and playful. If you look closely, you'll notice that the files that Houston is moving around (on the video) are full of humorous references that were appreciated by the audience to whom he was talking.

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At the time of the videos, Dropbox was available only to a small group of beta-users. Houston and Ferdowsi were reluctant to release the product to a wider audience because it wasn't completely ready. As noted by Eric Riese in a TechCrunch article titled "How DropBox Started As a Minimal Viable Product," the videos were essentially the minimal viable product—they provided sufficient detail to test whether there was a market for the service. The videos did the trick, with the second one driving hundreds of thousands of people to Dropbox's website. Its waiting list for beta users went from 5,000 people to 75,000 people overnight. Dropbox was off and running.

If you'd like to watch the videos, they are available on YouTube. For the first video, go to YouTube and type in the search box "Original Dropbox Video." For the second video, type in the search box "Dropbox Digg Video." (It was originally posted on the website Digg.)

Building a Company

In Dropbox's early days, Houston and Ferdowsi were the only employees. They didn't hire anyone until they got their first round of funding. Two years later, long after the second video was released, Dropbox had 200,000 customers, but only nine employees. In 2011, Dropbox grossed more than three times per employee than Google. All of the early hires were engineers. Despite Dropbox's seeming simplicity, it required significant technical expertise to build.

Houston and Ferdowsi have always believed in keeping Dropbox lean, which remains a central element in the firm's culture today. The company has raised substantial venture capital funding. Dropbox utilizes a freemium business model, where users are offered a free account with a set storage size and paid subscriptions for accounts with more capacity. Along the way, Houston and Ferdowsi have done several clever things to spur Dropbox's growth. The freemium model itself drives user adoption. The company also has a referral system to get new user sign-ups. A current user could get additional memory for free by making a referral. Interestingly, almost 96 percent of Dropbox's users pay nothing. They utilize the free service. The 4 percent that do pay represent a large enough crucial mass of subscribers to fund Dropbox's operations and its growth. Dropbox is a private company, so it doesn't reveal its financial results.

Compelling Nature of Service

More than anything else, Dropbox's success can be attributed to the compelling nature of its service. Early in the company's history, there was a sign in its corporate office that said "It simply works!" Here are some specific facts and figures about Dropbox's service that illustrate the compelling nature of what it has to offer.

- Install the Dropbox application, and a Dropbox folder appears on your desktop. Anything you drag into the folder is uploaded automatically to the Dropbox service and is then instantly replicated across all your computers, smartphones, and other devices. How cool is that?
- Dropbox folders are extremely convenient for group projects.
- The service is easy and simple to learn. Most people upload and start using the service without ever referring to the instructions. The Dropbox team knew that with millions of people using its service, it had to be simple.
- It is supported on all platforms. Apple iCloud, for example, is a comparable service, but it only works for Apple devices. Dropbox has vowed to remain neutral and support all platforms.

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- In April 2012, Dropbox announced a new feature allowing users to automatically upload (to their Dropbox account) photos and videos from cameras, tablets, SD cards, and smartphones.
- In September 2012, Facebook and Dropbox integrated to allow group users to share files to Facebook Groups using Dropbox's cloud-based storage system.

The Advent of the Smartphone

The advent of the smartphone, including the Apple iPhone and Android-equipped devices, has created an interesting point of differentiation for Dropbox. Prior to the smartphone, Dropbox was a nice to have, but not necessarily a have-to-have product. People could still transfer information using USB memory sticks. Memory sticks can't be attached to smartphones. Apple allows users to upload the data on their smartphones to iCloud, but iCloud is limited to Apple devices, as mentioned above. If people want to have all the digital content they own, including what's on their smartphone in one place, the clear choice is Dropbox.

Challenges Ahead

Despite its impressive success, Dropbox has vexing challenges ahead. Some observers feel the long-term potential of Dropbox will be determined by how they meet these challenges.

There are two primary challenges that Dropbox is facing. First, it deals with enormous complexity. Its 200 million users save one billion files every 24 hours. In addition, anytime a device manufacturer tweaks the software or hardware associated with their device, the Dropbox team must remain on top of the change to make sure that its service will still work for that device. Second, Dropbox is facing an increasing number of competitors. Apple iCloud is an example. Dropbox has an edge over iCloud because it's available across platforms, but more challenging competition may be coming. If Google, Apple, or Samsung, for example, decided to go head-to-head with Dropbox, those companies would have the technological chops to give Dropbox a go. Many believe Dropbox is up to the challenge. In January 2014, *Fast Company* magazine listed Dropbox as the most innovative company in America in the category of Productivity.

Discussion Questions

1. What environmental trends are working in Dropbox's favor as the firm seeks to operate profitably? What environmental trends may work against Dropbox and why?
2. What personal characteristics does Drew Houston possess that suggest he may have what it takes to be a successful entrepreneur?
3. What *problem* did Dropbox's founders solve with the service they developed?

Sources: Dropbox Homepage, www.dropbox.com, accessed March 24, 2014; Forbes, "Dropbox: The Inside Story of Tech's Hottest Startup," November 7, 2011; E. Ries, "How Dropbox Started As a Minimal Viable Product," available at http://techcrunch.com/2011/10/19/dropbox-minimal-viable-product; A. Walsh, "Dropbox: A Social Web Business Case Study," Social Web Q&A Homepage, available at httpsocialwebquanda.com, posted August 26, 2012, accessed March 21, 2014.

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CASE 13.2

Rover.com: Don't Chuckle: This Is One Impressive Business Idea

Introduction

Jill is a 26-year-old sales rep for a technology company. She lives in a two-bedroom townhouse with her Golden Retriever Rex. Jill travels about twice a month, and when she's gone, she has three options regarding care for Rex. Option #1—She can ask a neighbor to watch him, but that's hit-and-miss, and she hasn't found anyone she can depend on; Option # 2—She can take him to her parents' house, but they live about an hour away; and Option #3—She can take Rex to one of the two kennels that are close to where Jill lives. There is nothing wrong with them, but they are typical kennels. The dogs are cooped up most of the day, and a month ago, Rex came home from the kennel with a cough he picked up from another dog.

Jill loves Rex and has no plans to give him up, but every time she travels, it's a problem to decide what to do with Rex.

A Bad Experience at a Kennel Leads to a Business Idea

Many people are just like Jill. They either have trouble finding suitable arrangements for their dog when they travel, or they feel bad when they're packing for an exciting trip with their dog's big, sad eyes staring at them. The idea for Rover.com—a service that connects dog owners with dog sitters—occurred to Greg Gottesman after his yellow Labrador Ruby Tuesday had a bad experience at a traditional kennel. To see if the idea had legs, Gottesman pitched it at a Startup Weekend event in Seattle in 2011. Startup Weekends are events that are held across the country. Anyone can pitch a business idea and get feedback from peers. Gottesman's idea received top prize, and six months later, he launched Rover.com.

While Gottesman may have had a good pitch, a little research helps validate the business idea. The dog boarding/sitting market is about $6 billion a year. More encouraging is that the market could be much larger. Many people don't travel because there is no one they can trust to watch their dog(s). In addition, a survey of 1,000 dog owners by PetCare.com indicated that 80 percent worry about the care their dogs are getting while they're away, and 66 percent are unhappy with their current boarding situation. A total of 70 percent said they would travel more if they had a trusted dog sitter. To get a sense of just how deeply some people care about their pets, a survey of dog owners (commissioned by Rover.com) found that 76 percent of dog owners self-identify themselves as "pet parents," as opposed to "dog owners." A growing number of people see their dogs as "family members" rather than pets. The American Veterinary Medical Association found that people who consider their dogs to be family members spend twice as much money on them annually ($438 vs. $190) as those who view pets as property.

How Rover.com Works

Rover.com's service is run through its website. If you're a dog owner, you simply follow the prompts on the website, which asks you to identify your location and select the dates you need your dog to be watched. You can indicate whether you'd like your dog to be watched at your home or the sitter's household. You're then provided profiles of Rover.com-approved dog sitters in the area. The profile includes prices (per night), photos, reviews, certifications, and a full description of the sitter. The reviews are particularly helpful. For example, a Rover.com customer wrote the following about Jennifer, a Rover.com sitter in Central Florida: "I boarded my 1-year old Beagle with Jennifer for eight nights while on a cruise. She took great care of him and e-mailed us every night with an update. I highly recommend her and will definitely be using her in the future." Some sitters send text and photo updates along

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with e-mails. Rover sitters charge between $25 and $75 per night. In San Francisco, Rover.com's biggest market, there are over 500 sitters registered on the site.

The profiles also reveal the nature of the sitter. Some are professionals who watch dogs on a full-time basis. Others are large families with their own dogs. Some have rural property with park-like settings. Still, others are elderly people who enjoy watching dogs in their homes.

If you'd like to become a Rover.com sitter, the website walks you through the application process. You must create a profile and must be approved by Rover.com. The company says that it approves only 10 percent of the sitters who apply. Rover also encourages a "meet-and-greet" session before a dog owner tries a sitter. This suggestion recommends that the dog owners (with their dog in tow) meet the dog sitter at a mutually agreeable time and place to talk before they try each other out. The meet-and-greet can be arranged through Rover.com's website. Rover helps sitters get started by providing them access to $20 coupons to provide to new clients. A sitter can get up to 250 of the coupons, and Rover pays the bill.

Rover handles client billing. It takes a 15 percent commission for its part. Many Rover.com sitters leave successful careers to dog-sit full time. While critics chuckle when they hear statements like this, Rover.com can be a serious business. There are now over 25,000 dog sitters with profiles on Rover.com's website. Top Rover.com sitters earn several thousand dollars a month. A Rover sitter can also work as much or as little as they want. A sitter's profile includes a calendar indicating when the sitter is available. The average stay for a dog at a sitter's home is just over four days.

Rover tries to take care of both the dog owner and dog sitter by offering additional layers of protection. For example, every stay booked through Rover includes premium insurance for emergency vet bills, property damage, liability, and more. Rover offers additional services for dog owners, an area of its business that is destined to grow. Rover subscribers can currently purchase an annual $49.99 protection package that includes a 24/7 vet consultation and special Rover tags for extra safety and security.

To reassure dog owners and make things fun, Rover.com has an app that allows sitters to send photos of the dogs they are watching during their stay.

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Making Things Fun

Rover.com also makes things fun for both its dog owners and dog sitters. Its website features RoverCam, which is a camera inside Rover.com's Seattle headquarters aimed at the part of the building where Rover.com's employees let their dogs hang out. The day this case was written, there were six dogs in-house, including Carmel, Georgie Girl, Gus, Charlie, Oscar, and another Gus. Oscar, for example, is a three-year, one-month-old Miniature Schnauzer. He was lounging on a comfy chair the day the case was written. Rover's sitters are also equipped with some cool technology. The company's app allows sitters to send photos of the dogs they are watching to their owners while they're away.

In late 2013, Rover.com introduced Rover Reel, which offers Rover customers free videos of their dog's experience during their stay with a Rover.com sitter. Sitters simply submit sufficient photos of a dog they're watching, and they will receive a personalized video (Rover Reel) of the dog's stay to share with the owner.

Growth Plans & Venture Capital

Rover.com's potential has garnered plenty of attention. In 2013, the company increased revenue by 800 percent and currently has about 200,000 dog owners listed on its site. Incredibly, as of January 2014, the 43-person company had raised $25 million in funding from topshelf venture capital firms and pet retailer PetCo. The numbers in the pet industry are staggering. Americans spent $53 billion on their pets in 2012. Currently, there are roughly 78 million dogs in the United States (this number is an all-time high).

In light of these statistics and what it has learned in its three years of existence, Rover.com has a threeprong growth strategy, as follows:

1. Spread geographically, including in international markets.
2. Provide new services, including dog grooming and dog walking.
3. Add other animals, such as cats, horses, and reptiles.

Rover.com's CEO Aaron Easterly, a passionate dog lover, believes the company is only a fraction of the size it can become.

Discussion Questions

1. In the United States, what environmental trends are supporting the development of Rover.com's business?
2. How might Rover.com use focus groups to gain a better understanding of its current and potential customers and their needs?
3. In this chapter, we noted that a true business opportunity is attractive, durable, timely, and anchored in a product or service that creates value for a buyer. To what extent does Rover.com's service satisfy each of these criteria?

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CHAPTER 14

Feasibility Analysis

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OPENING PROFILE

LUMINAID: The Value of Validating a Business Idea

At 4:53 P.M. on January 12, 2010, Haiti experienced a devastating earthquake. The epicenter of the 7.0 magnitude quake was near Leogane, approximately 16 miles west of Port-au-Prince, Haiti's capital and largest city. The Haitian government later reported that 316,000 people were killed, 300,000 were injured, and approximately 1 million were left homeless.

Two weeks later in New York City, Anna Stork and Andrea Sreshta, master's in architecture students at Columbia University, were tasked with a project to design solutions for disaster relief aid as part of their design studio course. In the nearby photo, Andrea Sreshta is on the left and Anna Stork is on the right. Design studio courses within Columbia's architecture school are open ended and without prescriptive assignments, and students are given the freedom to define and execute their projects to a large degree. Both Stork and Sreshta were deeply affected by the Haiti earthquake, and decided to focus their project on redesigning disaster relief aid to better serve people in emergency situations. They had read and heard about the dangerous conditions in the tent cities erected in Haiti to provide shelter for homeless people. It occurred to them that light—something we take for granted—is often unavailable in emergency situations. They also learned that more broadly, 1.6 billion people across the globe lack access to reliable electricity. Many of these people use kerosene lanterns to light their homes. This is dangerous, in that kerosene lamps are a fire hazard and produce toxic fumes.

The convergence of these two factors led Stork and Sreshta to the idea for their project—something they nicknamed the "solar pillow." The idea was to create a simple, affordable source of light that could be easily and affordably shipped to disaster locations. As part of their research, Stork and Sreshta looked at the small-scale solar products currently on the market. There were many, which prompted them to ask the question "Is there a need for another product in the mix?" The answer ultimately was yes, largely because many of the existing products, while useful, could not be easily and affordably shipped to disaster locations. Stork and Sreshta's solution was an inflatable plastic bag, about the size of a small pillow, that had a rectangular pouch in the middle. The pouch contained a solar panel, three LEDs, and a rechargeable battery. When inflated, the bag became a diffuser for the LED light. Because the solar pillow was inflatable, it packs and ships flat. That provides it an advantage, particularly in a disaster situation. For every eight flashlights packed in a box, a total of 50 solar pillows could be placed into the same container. Once set in the sun for a few hours, the solar pillow could produce a substantial amount of reliable light.

A second factor that was part of Stork and Sreshta's thinking is a principle they called "here and there." The same product—the solar pillow—could be used by someone who is camping or pursuing any form of outdoor recreation as easily as someone in a disaster situation or a developing country using the solar pillow as an alternative to a kerosene lantern. That facet of the device provided the solar pillow a more robust market than a product designed exclusively for a disaster situation or to be used in developing countries.

The design studio class eventually ended, but Stork and Sreshta couldn't let go of the solar pillow idea. Through the summer and fall of 2010, they entered their idea, now called LuminAID, into several business plan competitions. They also shipped 50 early prototypes of the device to places like Haiti, Ghana, and Nicaragua for feedback and advice. They continued to work on the device while finishing school. During that time, the initial prototype evolved to reduce the cost, make it more durable, and brighten the light. In November 2011, Stork and Sreshta launched an Indiegogo crowdfunding campaign titled "LuminAID: An Inflatable Solar Light." The campaign included a short 2-minute, 51-second video that explained the device and the entrepreneurs' passion to bring it to market. If you'd like to see the video and hear directly from Stork and Sreshta, simply go to Indiegogo.com and type in the search bar "LuminAID." The goal of the Indiegogo campaign was threefold: test interest and demand for the device, raise money for the initial product run (assuming sufficient interest existed), and get feedback and advice. One thing that is helpful about running an Indiegogo campaign (the same is true for Kickstarter) is that anyone can write a comment about the campaign, during and after the campaign is concluded. Stork and Sreshta's campaign generated over 500 comments, some of which were helpful to them in tweaking the LuminAid device. The campaign was a hit, raising $51,829, more than five times the original goal.

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Stork and Sreshta were not only heartened by the overall response, but were pleased to see pledges come in from several developing countries. The pledges from the developing countries, in particular, affirmed in their minds the potential for their device.

Stork and Sreshta managed a successful production run of the LuminAid device and fulfilled their Indiegogo commitments. They used the shipping of the devices as another opportunity to obtain feedback. The e-mail they posted on Indiegogo when the devices were shipped was addressed to "Dear Friends." In part, the e-mail said "When you receive the light, we would greatly value your feedback. This is our first manufacturing run and your comments will help us to improve the product and develop additional products. Please e-mail us at info@luminAIDlab.com with questions or suggestions." After providing instructions on how to use the LuminAID device, the e-mail ended with: "We included instructions with each LuminAID. Feel free to email us if you have any questions and don't forget to send us pictures and stories of the LuminAID in use."

The Indiegogo campaign concluded in late 2012, and the devices were shipped in early 2013 to over 25 countries! LuminAID is now moving forward, but at a measured pace. Stork is working on LuminAID full time, and at the time this feature was written, March 2014, Sreshta was an MBA student at the University of Chicago Booth School of Business. Upon graduation, she plans to work on LuminAID full time. The LuminAID device is now available via the company's website, Amazon.com, LLBean, and several similar outlets. Stork and Sreshta have and are continuing to establish partnerships with relief agencies to utilize the LuminAID solution in disaster situations and in developing countries.

In this chapter, we'll discuss the importance of feasibility analysis. Conducting a well-crafted feasibility analysis, prior to developing a business model, is a critical step in discerning the merits of a business idea. The LuminAID devices provide a surprising amount of light given their relatively simple design and attractive price-point.

14.1 Feasibility Analysis

Feasibility analysis is the process of determining if a business idea is viable (see Figure 14.1). If a business idea falls short on one or more of the four components of feasibility analysis, it should be dropped or rethought, as shown in the figure. Many entrepreneurs make the mistake of identifying a business idea and then jumping directly to developing a business model to describe and gain support for the idea. This sequence often omits or provides little time for the important step of testing the feasibility of a business idea.

A mental transition must be made when completing a feasibility analysis from thinking of a business idea as just an idea to thinking of it as a business. A feasibility analysis is an assessment of a potential business rather than strictly a product or service idea. The sequential nature of the steps shown in Figure 14.1 cleanly separates the investigative portion of thinking through the merits of a business idea from the planning and selling portion of the process. Feasibility analysis is investigative in nature and is designed to critique the merits of a proposed business. A business plan (see Chapter 16) is more focused on planning and selling. The reason it's important to complete the entire process, according to John W. Mullins, the author of the highly regarded book *The New Business Road Test*, is to avoid falling into the "everything about my opportunity is wonderful" mode. In Mullins's view, failure to properly investigate the merits of a business idea before developing a business model and a business plan is written runs the risk of

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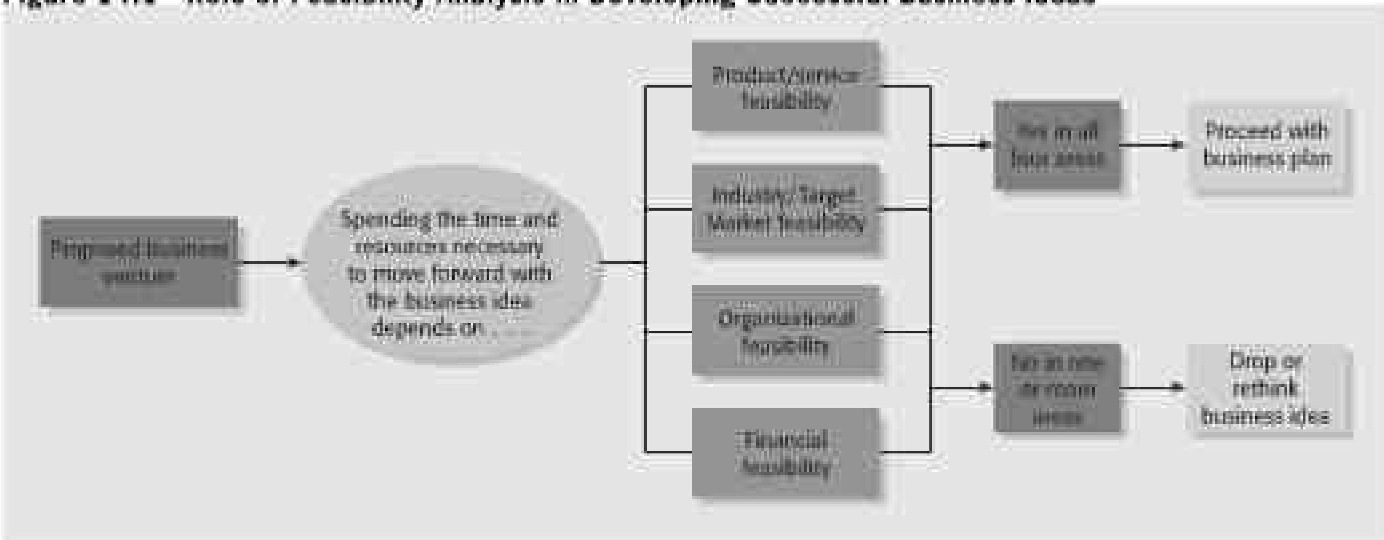
Figure 14.1 Role of Feasibility Analysis in Developing Successful Business Ideas



blinding an entrepreneur to inherent risks associated with the potential business and results in too positive of a plan.[1]

This chapter provides a methodology for conducting a feasibility analysis by describing its four key areas: product/service feasibility, industry/target market feasibility, organizational feasibility, and financial feasibility. We introduce supplemental material in two appendixes to the chapter. Appendix 14A contains a tool called First Screen, which is a template for completing a feasibility analysis. Appendix 14B contains an Internet Resource Table that provides information on Internet resources that are helpful in completing First Screen.

An outline for the approach to feasibility analysis we describe in this chapter is provided in Table 14.1. Completing a feasibility analysis requires both primary and secondary research. **Primary research** is research that is collected by the person or persons

Table 14.1 Feasibility Analysis

Part 1: Product/Service Feasibility
A. Product/service desirability
B. Product/service demand
Part 2: Industry/Target Market Feasibility
A. Industry attractiveness
B. Target market attractiveness
Part 3: Organizational Feasibility
A. Management prowess
B. Resource sufficiency
Part 4: Financial Feasibility
A. Total start-up cash needed
B. Financial performance of similar businesses
C. Overall financial attractiveness of the proposed venture
Overall Assessment

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completing the analysis. It normally includes talking to prospective customers, getting feedback from industry experts, conducting focus groups, and administering surveys. **Secondary research** probes data that is already collected. The data generally includes industry studies, Census Bureau data, analyst forecasts, and other pertinent information gleaned through library and Internet research. The Internet Resource Table in Appendix 14B is useful for conducting secondary research.

It should be emphasized that while a feasibility analysis tests the merits of a specific idea, it allows ample opportunity for the idea to be revised, altered, and changed as a result of the feedback that is obtained and the analysis that is conducted. The key objective behind feasibility analysis is to put an idea to the test—by eliciting feedback from potential customers, talking to industry experts, studying industry trends, thinking through the financials, and scrutinizing it in other ways. These types of activities not only help determine whether an idea is feasible but also help shape and mold the idea.

Now let's turn our attention to the four areas of feasibility analysis. The first area we'll discuss is product/service feasibility.

14.2 Product/Service Feasibility Analysis

Product/service feasibility analysis is an assessment of the overall appeal of the product or service being proposed. Although there are many important things to consider when launching a new venture, nothing else matters if the product or service itself doesn't sell. There are two components to product/service feasibility analysis: product/service desirability and product/service demand.

14.2.1 Product/Service Desirability

The first component of product/service feasibility is to affirm that the proposed product or service is desirable and serves a need in the marketplace. You should ask yourself, and others, the following questions to determine the basic appeal of the product or service:

- Does it make sense? Is it reasonable? Is it something real customers will buy?
- Does it take advantage of an environmental trend, solve a problem, or fill a gap in the marketplace?
- Is this a good time to introduce the product or service to the market?
- Are there any fatal flaws in the product or service's basic design or concept?

The proper mind-set at the feasibility analysis stage is to get a general sense of the answers to these and similar questions, rather than to try to reach final conclusions. The best way to achieve this is to "get out of the building" and talk to potential customers. This sentiment is the primary mantra of the lean startup movement, referred to in more detail in Chapter 16. A tool that is particularly useful in soliciting feedback and advice from prospective customers is to administer a concept test.

Concept Test

A **concept test** involves showing a preliminary description of a product or service idea, called a **concept statement,** to industry experts and prospective customers to solicit their feedback. It is a one-page document that normally includes the following:

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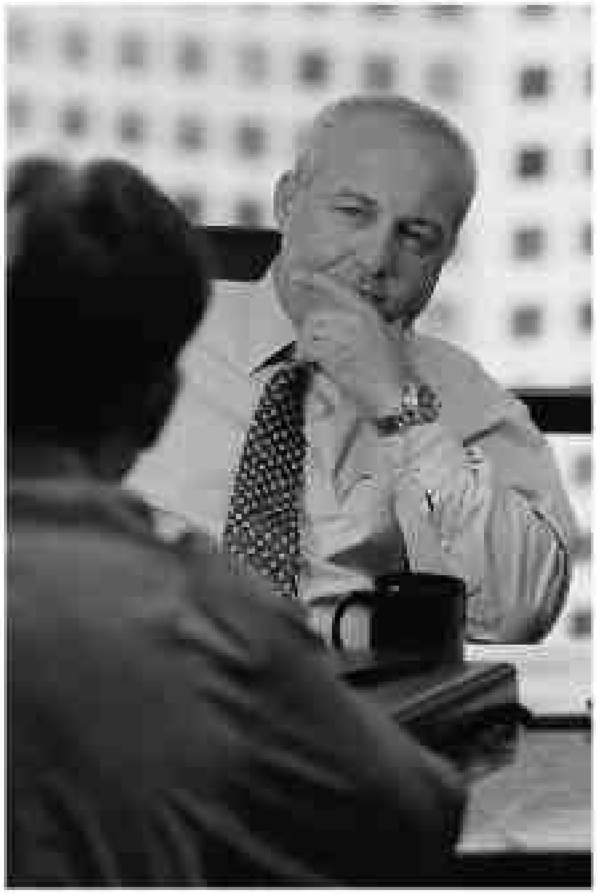
One of the most effective techniques for discerning the feasibility of a product or service idea is to get out and talk to prospective users. Here, a young entrepreneur is explaining a product idea to a potential customer.



Bill Varie/Corbis/Glow Images

- A description of the product or service. This section details the features of the product or service; many include a sketch of it as well.
- The intended target market. This section lists the consumers or businesses who are expected to buy the product or service.
- The benefits of the product or service. This section describes the benefits of the product or service and includes an account of how the product or service adds value and/or solves a problem.
- A description of how the product or service will be positioned relative to competitors. A company's position describes how its product or service is situated relative to its rivals.
- A brief description of the company's management team.

After the concept statement is developed, it should be shown to at least 20 people who are familiar with the industry that the firm plans to enter and who can provide informed feedback. The temptation to show it to family members and friends should be avoided because these people are predisposed to give positive feedback. Instead, it should be distributed to people who will provide candid and informed feedback and advice.

The concept statement for a fictitious company named New Venture Fitness Drinks is provided in Figure 14.2. New Venture Fitness Drinks sells a line of nutritious fitness drinks and targets sports enthusiasts. Its strategy is to place small restaurants, similar to

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Figure 14.2 New Venture Fitness Drinks' Concept Statement

New Business Concept
New Venture Fitness Drinks Inc.

Product

New Venture Fitness Drinks will sell delicious, nutrition-filled, all-natural fitness drinks to thirsty sports enthusiasts. The drinks will be sold through small storefronts (600 sq. ft.) that will be the same size as popular smoothie restaurants. The drinks were formulated by Dr. William Peters, a world-renowned nutritionist, and Dr. Michelle Smith, a sports medicine specialist, on behalf of New Venture Fitness Drinks and its customers.

Target Market

In the first three years of operation, New Venture Fitness Drinks plans to open three or four restaurants. They will all be located near large sports complexes that contain soccer fields and softball diamonds. The target market is sports enthusiasts.

Why New Venture Fitness Drinks?

The industry for sports drinks continues to grow. New Venture Fitness Drinks will introduce exciting new sports drinks that will be priced between $1.50 and $2.50 per 16-ounce serving. Energy bars and other over-the-counter sports snacks will also be sold. Each restaurant will contain comfortable tables and chairs (both inside and outside) where sports enthusiasts can congregate after a game. The atmosphere will be fun, cheerful, and uplifting.

Special Feature—No Other Restaurant Does This

As a special feature, New Venture Fitness Drinks will videotape select sporting events that take place in the sports complexes nearest its restaurants and will replay highlights of the games on video monitors in their restaurants. The "highlight" film will be a 30-minute film that will play continuously from the previous day's sporting events. This special feature will allow sports enthusiasts, from kids playing soccer to adults in softball leagues, to drop in and see themselves and their teammates on television.

Management Team

New Venture Fitness Drink is led by its cofounders, Jack Petty and Peggy Wills. Jack has 16 years of experience with a national restaurant chain, and Peggy is a certified public accountant with seven years of experience at a Big 4 accounting firm.

smoothie restaurants, near large sports complexes. It is important to keep a concept statement relatively short (no more than one page) to increase the likelihood that it will be read. The concept statement is followed by a short buying intentions survey. The information gleaned from the survey should be tabulated and carefully read. If time permits, the statement can be used in an iterative manner to strengthen the product or service idea. For example, you might show the statement to a group of prospective customers, receive their feedback, tweak the idea, show it to a second group of customers, tweak the idea some more, and so on.

The problem with not talking to potential customers prior to starting a business is that it's hard to know if a product is sufficiently desirable based simply on gut instinct or secondary research. A common reason new businesses fail is that there isn't a large enough market for the venture's product. This scenario played out for Matt Cooper, who was a partner in a business called Soggy Bottom Canoe and Kayak Rental. It was his first start-up and turned out to be, as Cooper put it, an "unmitigated disaster." Cooper and his partner owned 10 acres near a national forest in Mississippi, where they decided to launch a canoe rental business. They invested heavily in finishing out the facilities on

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the property and bought 32 canoes, 16 kayaks, 4 trailers, and 2 vans. They opened on a July 4th weekend and everything was immaculate. The following is what happened, in Cooper's words:

> "In our quest to have the best facilities and equipment, we neglected to speak to a single prospective customer. No Boy Scout troops, no church youth groups, no fraternities from Southern Mississippi University. As a result, I can count on only one hand the number of times, in the seven years that we owned the business, that we reached even half of our booking capacity."[2]

Cooper goes on to admit that he's learned his lesson. Reflecting on his Soggy Bottom Canoe and Kayak Rental experience he said:

> "Today, I still fight against the urge to make big investments before we've "beta tested." Every time that urge pops up, I picture gleaming new canoes hitched up to sad empty passenger vans."[3]

Rather than developing a formal concept statement, some entrepreneurs conduct their initial product/service feasibility analysis by simply talking through their ideas with prospective customers or conducting focus groups to solicit feedback. The ideal combination is to do both—distribute a concept statement to 20 or more people who can provide informed feedback and engage in verbal give-and-take with as many industry experts and prospective customers as possible. There are also a growing number of online tools that help entrepreneurs quickly and inexpensively make contact with prospective customers and complete other steps in the feasibility analysis process. These tools range from services like Quirky, which provides direct feedback on product ideas, to 3D printing services like Shapeways, which converts CAD drawings of product ideas into physical prototypes that you can show to potential customers. We provide a sample of the online tools that are available in Table 14.2.

Table 14.2 Online Tools Available for Completing Feasibility Analysis

Tool	Brief Description	URL
3D Printing Services		
i.materialise	Allows you to convert your ideas into physical objects via a 3D printing service. Also provides a platform for sharing and selling your designs.	http://i.materalise.com
Shapeways	Provides a platform for converting ideas into physical objects to use as product prototypes or to sell through the Shapeways community.	www.shapeways.com
A/B Split Testing		
PickFu	Provides instant market feedback, A/B testing, and polls directed toward early users of your product.	www.pickfu.com
Ubounce	Allows you to create simple landing pages and conduct A/B split testing.	www.ubounce.com
Feedback on Business Ideas		
Foundersuite	Allows you to submit an executive summary of a business idea and get feedback from potential customers, advisers, and others.	http://foundersuite.com

(continued)

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Table 14.2 Continued

Tool	Brief Description	URL
Quirky	Allows you to submit product ideas to a community that vets and provides feedback on the ideas.	www.quirky.com
Unassumer	Allows you to test your ideas and assumptions about what people want.	www.unassumer.com
Landing Pages		
LaunchRock	Allows you to create a "coming soon" landing page in seconds and collect e-mail addresses of potential early users of your product.	www.launchrock.com
Market Research		
AskYourTargetMarket	Allows you to setup surveys that reach a specific target market.	www.aytm.com
CrowdPicker	Allows you to ask a "crowd" of potential customers which logo, tagline, company name, packaging design, etc. is the best choice for your start-up.	www.crowdpicker.com
Google Trends	Allows you to enter a search term (such as running or swimming) and see if it's trending upwards or downwards in Google search queries.	www.google.com/trends
Facebook Ads	Allows you to put together a Facebook ad campaign to assess how a specific target market responds to a new product idea. Can be something as simple as "fill out this form to be one of our first beta testers."	www.facebook.com/ads
Google AdWords	Allows you to put together an AdWords campaign, which usually directs prospective customers to landing pages that assess the demand for a new product or service idea.	www.google.com/adwords
Online Whiteboard		
RealTimeBoard	Allows you to create a whiteboard on your computer (with the capability to draw and erase) and collaborate with team members in real time.	http://realtimeboard.com
Prototyping Service		
Proto Labs	Get prototypes built from CAD drawings.	www.protolabs.com
Stratasys	Offers design validation and rapid prototyping from CAD drawings.	www.stratasys.com
Q&A Sites		
Quora	Platform allows you to ask any business-related question and get answers from the Quora community.	www.quora.com
Stack Overflow	Q&A site for programmers.	www.stackoverflow.com

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Tool	Brief Description	URL
Surveys		
Google Consumer Surveys	An easy, quick, and inexpensive way to create online surveys.	www.google.com/consumersurveys
Survey.io	A customer development platform that helps start-ups quickly learn what customers like and don't like about their product offerings.	www.survey.io
Survey Monkey	A popular and inexpensive way to create and distribute online surveys.	www.surveymonkey.com
Website Usability Testing		
Usertesting	The company's network of testers will review your website and provide audio commentary while they are using it.	www.usertesting.com
Verify	The company's testers provide feedback on the design and functionality on early to completed versions of your website.	www.verifyapp.com

14.2.2 Product/Service Demand

The second component of product/service feasibility analysis is to determine if there is demand for the product or service. Three commonly utilized methods for doing this include (1) talking face-to-face with potential customers, (2) utilizing online tools, such as Google Adwords and landing pages, to assess demand, and (3) library, Internet, and gumshoe research.

Talking Face-to-Face with Potential Customers

The only way to know if your product or service is what people want is by talking to them. Curiously, this often doesn't happen. One study of 120 business founders revealed that more than half fully developed their products without getting feedback from potential buyers.[4] In hindsight, most viewed it as a mistake. The authors of the study quoted one of the participants as saying "You'll learn more from talking to five customers than you will from hours of market research (at a computer)." The idea is to gauge customer reaction to the general concept of what you want to sell. Entrepreneurs are often surprised to find out that a product idea that they think solves a compelling problem gets a lukewarm reception when they talk to actual customers.

In some instances, you have to pause and think carefully about who the potential customer is. For example, in health care the "customer" is typically not the patient who will use the drugs or benefit from a medical procedure. Instead the actual customer, or the entity that will be paying the bill, is often an insurance company, hospital, or Medicare or Medicaid. You should also talk to as many of the relevant players in an industry as possible. Sometimes this involves a complex list of people, but it is necessary to fully vet the initial feasibility of an idea. For example, say you were thinking about launching an innovative new type of home health care service. The service would allow elderly people to stay in their homes longer before going into assisted living or a nursing home, and it would help people remember to take their medicine on time and provide other health care monitoring services. Table 14.3 contains a list of the categories of

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Table 14.3 Categories of People to Talk to as Part of Product/ServiceTool Feasibility Analysis for a New Type of Home Health Care Service

Category of people to talk to
1. Potential users of the service
2. Family members of potential users of the service
3. Physicians
4. Nurses
5. Health insurance companies
6. Medicare and Medicaid personnel
7. Pharmaceutical companies
8. Owners/managers of assisted living facilities and nursing homes
9. Hospital and physician office administrators
10. Founders of other companies in the home health care industry

people that you might want to talk to as part of your product/service feasibility analysis. While the list is long, imagine the rich insight that you could get on your business idea from people in these categories.

One approach to finding qualified people to talk to about a product or service idea or to react to a concept statement is to contact trade associations and/or attend industry trade shows. If your product idea is in the digital media space, for example, you may be able to call the Digital Media Association (which is a national trade association devoted primarily to the online audio and video industries) and get a list of members who live in your area. Attending trade shows in the industry you're interested in will place you in direct contact with numerous people who might be of assistance. A website that provides a directory of trade associations is included in the Internet Resource Table in Appendix 14B. Online surveys are also useful to reach a large number of people quickly. Services such as SurveyMonkey and AYTM are making it increasingly easy to survey specific target markets and receive detailed analytics for a very affordable price.

Utilizing Online Tools, Such as Google AdWords and Landing Pages, to Assess Demand

Another common approach to assessing product demand is to use online tools, such as Google AdWords and landing pages. The way this works is as follows. Suppose you've developed a new type of sunglasses for snowboarders and want to assess likely demand. One way of doing this is to buy keywords on the Google search page like "snowboarding" and "sunglasses." You can purchase the keywords through Google's AdWords program. Once you buy the keywords, when someone searches for the term "snowboarding" or "sunglasses" a link to an ad you've prepared will show up either at the top or to the right of the organic search results. The text below the link will say something such as "Innovative new sunglasses for snowboarders." If someone clicks on the link, they'll be taken to what online marketers call a landing page. A **landing page** is a single Web page that typically provides direct sales copy, like "click here to buy a Hawaiian vacation." Your landing page, which can be inexpensively produced through a company like LaunchRock (see Table 14.2), will show an artist's depiction of your innovative new sunglasses, provide a brief explanation, and will then say something like "Coming Soon—Please Enter Your E-mail Address for Updates." How often your ad

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appears will depend on what you purchase through Google's automated AdWord's keyword auction. Google will provide you analytics regarding how many people click on the ad and how many follow through and provide their e-mail address. You can also capture the e-mail addresses that are provided.

The beauty of using Google AdWords is that the people who click on the ad were either searching for the term "snowboarding" or "sunglasses" or they wouldn't have seen the ad. So you're eliciting responses from a self-selected group of potential buyers. The overarching purpose is to get a sense of interest in your product. If, over a three-day period, 10,000 people click on the ad and 4,000 provide their e-mail address to you, that might signal a fairly strong interest in the product. On the other hand, if only 500 people click on the ad and 50 give you their e-mail address, that's a much less affirming response. It's strictly a judgment call regarding how many clicks represent an encouraging response to your product idea. Normally, utilizing an AdWords and landing page campaign wouldn't be the only thing you'd do to assess demand. You'd still want to talk to prospective customers face-to-face, as discussed earlier. Running an AdWords and landing page campaign is, however, a practical and often surprisingly affordable way to get another data point in regard to assessing demand for a new product or service idea.

Library, Internet, and Gumshoe Research

The third way to assess demand for a product or service idea is by conducting library, Internet, and gumshoe research. While talking to prospective customers is critical, collecting secondary data on an industry is also helpful. For example, Spring Toys makes super-safe, environmentally friendly, educational toys for children. Sounds like a good idea. But "sounds like a good idea," as mentioned in previous sections, isn't enough. We need feedback from prospective customers and industry-related data to make sure. Industry-related data can help us answer the following types of questions: What's the trajectory of the toy industry? What do industry experts say are the most important factors that parents consider when they buy their children toys? Is there an "educational toy" segment within the larger toy industry? If so, is this segment growing or shrinking? Is there a trade association for the makers of educational toys that already has statistics about the market demand for educational toys?

The overarching point is that for your particular product or service you need archival as well as primary forms of research to assess likely demand. Your university or college library is a good place to start, and the Internet is a marvelous resource. The Internet Resource Table in Appendix 14B provides specific recommendations of online resources to utilize. For example, IBISWorld, which is available for free through most university libraries, provides current industry reports on hundreds of industries. Its report on the toy industry, which is frequently updated, is titled "Toy, Doll and Game Manufacturing in the US (NAICS 33993)." This report would be a good place to start in terms of understanding relevant industry trends. More general Internet research is also often helpful. Simply typing a query into the Google or Bing search bar such as "market demand for educational toys" will often produce helpful articles and industry reports.

Simple gumshoe research is also important for gaining a sense of the likely demand for a product or service idea. A gumshoe is a detective or an investigator that scrounges around for information or clues wherever they can be found. Don't be bashful. Ask people what they think about your product or service idea. If your idea is to sell educational toys, spend a week volunteering at a day care center and watch how children interact with toys. Take the owner of a toy store to lunch and discuss your ideas. Spend some time browsing through toy stores and observe the types of toys that get the most

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attention. If you actually launch a business, there is simply too much at stake to rely on gut instincts and cursory information to assure you that your product or service will sell. Collect as much information as you can within reasonable time constraints.

The importance of library, Internet, and gumshoe research doesn't wane once a firm is launched. It's important to continually assess the strength of product or service ideas and learn from users. A colorful example of the value of ongoing gumshoe research is provided in the "Savvy Entrepreneurial Firm" feature. In this feature, a successful company made a 180-degree turn regarding how to position a particular product simply by watching how customers interacted with the product in retail stores.

14.3 Industry/Target Market Feasibility Analysis

Industry/target market feasibility is an assessment of the overall appeal of the industry and the target market for the product or service being proposed. There is a distinct difference between a firm's industry and its target market; having a clear understanding of this difference is important. An **industry** is a group of firms producing a similar product or service, such as computers, children's toys, airplanes, or social networks. A firm's **target market** is the limited portion of the industry that it goes after or to which it wants to appeal. Most firms, and certainly entrepreneurial start-ups, typically do not try to service an entire industry. Instead, they select or carve out a specific target market and try to service that group of customers particularly well. Sprig Toys, for example, is not trying to target the entire children's toy industry. Its target market is parents who are willing to pay a premium for super-safe, environmentally friendly, educational toys.

There are two components to industry/target market feasibility analysis: industry attractiveness and target market attractiveness.

14.3.1 Industry Attractiveness

Industries vary in terms of their overall attractiveness.[5] In general, the most attractive industries have the characteristics depicted in Table 14.4. The top three factors are particularly important. Industries that are young rather than old, are early rather than late in their life cycle, and are fragmented rather than concentrated are more receptive to new entrants than industries with the opposite characteristics. You also want to pick an

Table 14.4 Characteristics of Attractive Industries

- Are young rather than old
- Are early rather than late in their life cycle
- Are fragmented rather than concentrated
- Are growing rather than shrinking
- Are selling products or services that customers "must have" rather than "want to have"
- Are not crowded
- Have high rather than low operating margins
- Are not highly dependent on the historically low price of a key raw material, like gasoline or flour, to remain profitable

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SAVVY ENTREPRENEURIAL FIRM

How Learning from Customers Caused a Successful Firm to Make a 180-Degree Turn on the Positioning of a Product

Bill Gross is both a serial entrepreneur and the founder of Idealab, an incubator-type organization that has launched over 75 companies. He's also an Internet pioneer and the creator of the pay-per-click model of Internet advertising. In speaking to groups about entrepreneurship and in working with start-ups at Idealab, there is a story that Gross likes to tell about the importance of feasibility analysis and getting close to customers. It's an experience that has shaped his views about how important it is to learn from the potential users of your product.

In the early 1990s Gross started a software company named Knowledge Adventure. It started by making educational CD-ROM products for children, such as Space Adventure and Dinosaur Adventure. The firm also launched a line of products under the JumpStart brand. These products help kids with topics they encounter in school, such as math and science.

One Christmas, in the early 1990s, Gross really wanted his company to excel, so he decided to have employees spend weekends in places where Knowledge Adventure products were sold, to demo the products to parents and hopefully boost sales. So the company's 65 employees took turns traveling to electronics stores, where they would set up booths at the end of aisles to demo their firm's products. Each Monday, following a weekend when employees were in stores, the employees met to talk about their experiences. One interesting theme emerged from these meetings. When looking at educational software products, parents were often confused about whether a particular product was age-appropriate for their child. They would often look at the back of the box (software was sold on CDs in boxes in those days), look at their child, look back at the box, and appear puzzled about whether the software was a good match for their child. Many companies, Knowledge Adventure included, would put wide age ranges on their products to broaden their appeal. Apparently, this practice inadvertently caused parents to wonder whether a product with a wide age range was really a good match for their particular child.

Thinking through what the employees had observed, Gross and his team came up with a novel idea. What if they produced educational software products that were targeted for a specific grade—like one for preschoolers, one for kindergarteners, one for first grade students, and so forth, to try to avoid confusion for parents trying to determine if a product was age-appropriate for their child. Gross remembers that there was a big fight in his company over this idea. The sales force said, "We can't convince stores to sell software for one age group. They'll never sell enough product." After listening to all the arguments, Gross concluded it was worth a try. So Knowledge Adventure created JumpStart Pre-School and JumpStart Kindergarten to test the concept. The result: The products sold 20 to 50 times the company's other products. Parents loved it—now they knew exactly what product was right for their child. There was even an aspirational quality to the products. Parents would see a product like JumpStart Kindergarten and buy it for their preschool child hoping to give them a head start in kindergarten. Knowledge Adventure has sold over 20 million copies of its grade-specific JumpStart products, and they are still for sale today.

What Gross likes to emphasize when telling this story is that he and his team would have never discovered the confusion that parents had in trying to determine if particular software products were age-appropriate for their children without directly observing them in stores. As a result of this experience, Gross is now a passionate advocate of start-ups directly interacting with potential users of their products.

Questions for Critical Thinking

1. In putting wide age ranges on their products (e.g., suitable for ages 4 through 7), do you think that software companies prior to the advent of JumpStart's grade-specific products ever thought that the wide age range

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caused parents angst in trying to determine if a particular product was suitable for their child? If your answer is "no," how could companies have missed such a fundamental factor? What is the broader implication of this lesson?

2. Could Gross and his team have gleaned the same type of insights they gained via directly observing parents shopping for educational software for their kids through surveys and focus groups? Explain your answer.
3. Design a program for August Smart Lock, the subject of the "You Be the VC 14.1" feature, to directly observe its customers use its service. How should August Smart Lock go about it? What type of insights might emerge from this initiative?
4. How can a start-up that hasn't already launched apply the lessons learned from Gross's experience with JumpStart and grade-specific software products?

Source: B. Gross, "A Devotion to New Ideas," Stanford Technology Ventures Entrepreneurial Thought Leaders Podcast (accessed April 4, 2014, originally posted on February 23, 2011).

industry that is structurally attractive—meaning start-ups can enter the industry (in various target markets) and compete effectively. Some industries are characterized by such high barriers to entry or the presence of one or two dominant players that potential new entrants are essentially shut out.

Other factors are also important. For example, the degree to which environmental and business trends are moving in favor rather than against the industry are important for the industry's long-term health and its capacity to spawn new target or niche mar-

Information pertaining to industry growth rates, trends, and future prospects is available via online databases like the one accessed here. IBISWorld and BizMiner are additional databases that provide particularly helpful information.

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kets. Are changing economic and societal trends helping or hurting industry incumbents? Are profit margins increasing or falling? Is innovation accelerating or waning? Are input costs going up or down? Are new markets for the industry's staple products opening up or are current markets being shut down by competing industries? You can't cover every facet of an industry, but you should gain a sense of whether the industry you're entering is a good one or a poor one for start-ups.

Information that addresses each of these issues is available via industry reports published by IBISWorld, Mintel, Bizminer, and similar fee-based databases that are typically free if accessed through a university or large public library's website. These resources are listed in the Internet Resource Table in Appendix 14B. The First Screen, which is the feasibility analysis template included in Appendix 14A, includes a section that draws attention to the most important issues to focus on regarding industry attractiveness during the feasibility analysis stage of investigating a business idea.

14.3.2 Target Market Attractiveness

We noted previously that a target market is a place within a larger market segment that represents a narrower group of customers with similar needs. Most start-ups simply don't have the resources needed to participate in a broad market, at least initially. Instead, by focusing on a smaller target market, a firm can usually avoid head-to-head competition with industry leaders and can focus on serving a specialized market very well. It's also not realistic, in most cases, for a start-up to introduce a completely original product idea into a completely new market. In most instances, it's just too expensive to be a pioneer in each area. Most successful start-ups either introduce a new product into an existing market (like Sprig Toys introducing new toys into the existing toy market) or introduce a new market to an existing product (like Wello is introducing Web-based, real-time fitness instruction, which is a new market for an existing product offered by personal trainers, yoga instructors, etc.).

The challenge in identifying an attractive target market is to find a market that's large enough for the proposed business but yet is small enough to avoid attracting larger competitors at least until the entrepreneurial venture can get off to a successful start. Tommy John, a maker of men's undershirts, is an example of a company that has targeted a market that meets these criteria. Tommy John began in 2008 by making custom-fitted men's undershirts, and has now expanded to men's briefs and men's socks. The undershirts are sold under the brand name Second Skin, based on the idea that they fit so well they feel like a "second skin" when worn. Tommy John started by selling through a single retailer and eventually persuaded Neiman Marcus to give its undershirts a try. Today, Tommy John undershirts are sold in Neiman Marcus stores nationwide and are making their way into other retailers as well. Although Tommy John operates in the worldwide market for men's undershirts, it has carved out a specialized target or niche market for itself and is gaining momentum. One key to its success is that it has remained laser-focused on a clearly defined target market. The number one question the company gets is "when will it start producing women's undergarments?" So far it's resisted, preferring to remain focused on its Second Skin line of men's undershirts.[6]

While it's generally easy to find good information to assess the attractiveness of an entire industry, discerning the attractiveness of a small target market within an industry is tougher, particularly if the start-up is pioneering the target market. Often, under these circumstances, information from more than one industry and/or market must be collected and synthesized to make an informed judgment. For example, say you were developing new, innovative sunglasses for snowboarders, consistent with the illustration

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provided earlier. The question for a product like this is what market to assess? Obviously, a combination of markets must be studied, including the market for sunglasses and the market for snowboarding. It would be important to not only know how well sunglasses are selling but whether the market for snowboarding accessories (and the number of people who participate in snowboarding) is on the rise or decline. If the market for sunglasses is on an upward trajectory but the market for snowboarding accessories is on a sharp decline, the target market you would be pursuing would be much less attractive than if both markets were on the rise.

A failure to fully understand both the broad HR/recruitment industry and the specific markets it was targeting contributed to the problems encountered by Standout Jobs, a company that developed an innovative recruitment portal in 2008. The Standout Jobs story, which is rich in lessons about the importance of feasibility analysis, is included in the nearby "What Went Wrong?" feature.

14.4 Organizational Feasibility Analysis

Organizational feasibility analysis is conducted to determine whether a proposed business has sufficient management expertise, organizational competence, and resources to successfully launch.[7] There are two primary issues to consider in this area: management prowess and resource sufficiency.

14.4.1 Management Prowess

A proposed business should evaluate the prowess, or ability, of its initial management team, whether it is a sole entrepreneur or a larger group.[8] This task requires the individuals starting the firm to be honest and candid in their self-assessments. Two of the most important factors in this area are the passion that the solo entrepreneur or the management team has for the business idea and the extent to which the management team or solo entrepreneur understands the markets in which the firm will participate.[9] There are no practical substitutes for strengths in these areas.[10]

A collection of additional factors help define management prowess. Managers with extensive professional and social networks have an advantage in that they are able to reach out to colleagues and friends to help them plug experience or knowledge gaps. In addition, a potential new venture should have an idea of the type of new-venture team that it can assemble. A **new-venture team** is the group of founders, key employees, and advisers that either manage or help manage a new business in its start-up years. If the founder or founders of a new venture have identified several individuals they believe will join the firm after it is launched and these individuals are highly capable, that knowledge lends credibility to the organizational feasibility of the potential venture. The same rationale applies for highly capable people a new venture believes would be willing to join its board of directors or board of advisers.

One thing that many potential business founders find while assessing management prowess is that they may benefit from finding one or more partners to help them launch their business. Tips for finding an appropriate business partner are provided in the "Partnering for Success" feature.

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WHAT WENT WRONG?

How Feasible Was Standout Jobs from the Beginning?

The idea for Standout Jobs emerged in 2007, when its founders, Ben Yoskovitz, Fred Ngo, and Austin Hill, saw an opportunity to revitalize the job recruitment process. At the time, most companies recruited by placing static position descriptions on job boards and hoping for the best. The idea behind Standout Jobs was to create more energy in the recruitment process. To do that, Standout Jobs built a customizable recruitment platform, named RECEPTION, that enabled companies to showcase their culture and team to job candidates. The platform was built on social media tools, such as video, blogs, and a variety of widgets, to make the recruting process dynamic and engaging, and help the company's clients "stand out" from the competition.

Standout Jobs launched at the DEMO conference in early 2008. It raised $1.58 million in venture funding and picked up some early traction. It also seemed to have substantial upside potential. In early 2008, one of its initial investors, John Elton, partner with iNovia Capital, made the following remarks about Standout Jobs: "We believe in the team and Standout Jobs' market potential because they are changing the way companies recruit great employees." Elton went on to observe that at the time, the recruitment sector represented about one-fourth of all online advertising, and that many companies were dissatisfied with the results they were getting. Standout Jobs, in Elton's opinion, helped companies approach online recruiting in a fresh and promising manner.

In 2010, Standout Jobs was sold to Talent Technology, another recruitment company. It wasn't a financial success. After the sale, one of Standout Jobs' founders, Ben Yoskovitz, wrote a thoughtful blog post on why Standout Jobs essentially failed, and the lessons he took away from his Standout Jobs experience. Yoskovitz highlighted five reasons, several of which are directly related to the need to complete a thorough feasibility analysis before a company launches.

First, the company's timing was bad. The company launched in 2008, just before the U.S. economy went sour. Most companies weren't hiring. In fact, Yoskovitz said that he got feedback on sales calls like this: "That's a great product, really love it, but we won't be hiring for another 18 months or so. You have anything to help us fire people?" Obviously, Standout Jobs couldn't help that the economy turned sour, but in retrospect, Yoskovitz feels that the company didn't react fast enough. When things weren't working, he didn't sound alarm bells, and the company continued doing what it was doing.

Second, Yoskovitz believes that prior to launch, he didn't have a strong enough understanding of the HR/recruitment market. He indicated that he looked at the market and thought he could fix it, only to find out that when he was in neck-deep there were a lot of issues that he didn't understand. He did do a lot of networking in the industry and brand building among industry evangelists. But that can create a false sense of success, Yoskovitz now believes. Industry evangelists aren't necessarily buyers. It's important to do as much homework as possible, he now urges, about an industry upfront, before you launch a company.

Third, Yoskovitz feels that his team didn't get its product in the hands of customers fast enough and iterate based on their feedback. It's easier, Yoskovitz learned, to build a product to specifications rather than deal with the constant tweaking that occurs when soliciting customer feedback. In the future, Yoskovitz is committed to building a minimum viable product (MVP) and getting it into the hands of customers as early as possible. He's also committed to soliciting real, hard feedback from them.

Fourth, Yoskovitz learned that you can't shove a solution down your customers' throats. In the blog post, Yoskovitz said then when Standout Jobs did get its product into the hands of customers, the customers weren't using it as actively as the Standout Jobs team had expected. It boils down to changing behavior. The Standout Jobs team underestimated just how hard it is to change people's behavior, even if you think you're providing them a much better solution to problems they face.

Finally, Yoskovitz feels that Standout Jobs raised too much money, too early. Looking back,

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he feels the company didn't have the validation needed to justify raising the money they did. Raising money also comes with strings attached. Because Standout Jobs raised money, it quickly built a big product, based on assumptions that weren't tested in the marketplace. Raising money also takes time—time that could be spent building and validating a product. Yoskovitz found that raising money isn't a validation that something works and has a market. It's a validation that someone will write a check.

Questions for Critical Thinking

1. Of the five reasons that Standout Jobs didn't reach its full potential, which reason do you think damaged the company's chances of success the most? Explain your answer.
2. Describe the difference between Standout Jobs as an idea and an actual business. Is it possible for something to be an exciting idea but a poor business?
3. Make a list of the categories of people that the founders of Standout Jobs should have talked to prior to launching the firm. Based on the experience that the company had, what do you think some of the feedback would have been? Do you think the founders would have received any feedback that might have caused them to dramatically change their business idea or consider shelving the idea all together?
4. What can a start-up learn from Standout Jobs' experience about the importance of feasibility analysis?

Sources: B. Yoskovitz, "A Postmortem Analysis of Standout Jobs," available at http://www.instigator blog.com/postmortem-analysis-of-standout-jobs/2010/10/05/, posted on October 5, 2010, accessed on April 4, 2014; Standout Jobs, "Standout Jobs Raises $2 Million Financing from iNovia Capital," www.prnewswire.com, accessed April 4, 2014.

14.4.2 Resource Sufficiency

The second area of organizational feasibility analysis is to determine whether the proposed venture has or is capable of obtaining sufficient resources to move forward. The focus in organizational feasibility analysis is on nonfinancial resources. The objective is to identify the most important nonfinancial resources and assess their availability. An example is a start-up that will require employees with specialized skills. If a firm launches in a community that does not have a labor pool that includes people with the skill sets the firm needs, a serious resources sufficiency problem exists.

Another key resource sufficiency issue is the ability to obtain intellectual property protection on key aspects of the business. This issue doesn't apply to all start-ups; but, it is critical for companies that have invented a new product or are introducing a new business process that adds value to the way a product is manufactured or a service is delivered. One quick test a start-up can administer is to see if a patent has already been filed for its product or business process idea. Google Patents (www.google.com/patents) is a user-friendly way to search for patents. Although it isn't a substitute for utilizing a patent attorney, this approach can give a start-up a quick assessment of whether someone has beaten them to the punch regarding a particular product or business process idea.

To test resource sufficiency, a firm should list the 6 to 12 most critical nonfinancial resources that it will need to move its business idea forward and determine if those resources are available. Table 14.5 provides a list of the types of nonfinancial resources that are critical to many start-ups' success.

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PARTNERING FOR SUCCESS

Finding the Right Business Partner

One thing that becomes clear to many potential business founders while conducting organizational feasibility analysis is that they need one or more partners to help launch their business. You might be a computer programmer who has a great idea for a cooking website, for example, but have no experience in marketing or sales. In this instance, you may need to find a partner with marketing and sales experience to successfully launch and run the firm. There are five key criteria to look for in a business partner. You want to get this right because picking the wrong partner or partners can lead to a lot of heartaches and business challenges.

1. **Know the skills and experiences you need.** Make an honest assessment of the skills and experience you bring to the business and the gaps that remain. Pick someone who fills the gaps. For example, if you're an experienced computer programmer you probably don't want to partner with another experienced computer programmer. Pick someone who brings other competencies that you need to the venture, such as marketing or finance.
2. **Make sure your personalities and work habits are compatible.** While you don't need someone who is just like yourself, you do need to be comfortable with the person you'll be in business with. For example, if you'd rather work 16 hours a day if that is what it takes to finish a project on time, and your partner would rather quit after 8 hours a day and try to renegotiate the due date for the project, that difference in work styles will invariably cause conflict. Similarly, if you like to wear a coat and tie when meeting with clients and your partner thinks wearing blue jeans is fine, obvious disagreements could arise.
3. **Make sure you and your partner have common goals and aspirations.** Be sure that you and your partner are shooting for the same target. For example, if your goal is to build a billion-dollar company but your partner would be perfectly satisfied growing the company to $10 million in sales and then selling out, obvious problems could ensue.
4. **Look in the right places.** If you don't have ... know where to look for a potential partner. Generic networking events, like Chamber of Commerce mixers, are usually ineffective for finding a business partner. Instead, if you're looking for an engineer, contact engineering trade associations for leads or attend engineering trade fairs. Social networking sites for professionals, such as LinkedIn, can be an effective way to make contacts. Most cities have startup networking events. There are also websites and events specifically designed to help bring people together to start companies. Examples include Startup Weekend (http://startupweekend.org), Founder2Be (www.founder2be.com), and CofoundersLab (www.cofounderslab.com).
5. **Hire a lawyer.** When you have identified a potential partner and you're confident that the first four criteria we've discussed have been satisfied, you should hire a lawyer to sit down with the two (or more) of you to help hammer out the details. You should decide what each partner will contribute to the business, how the equity in the business will be split, what form of business ownership to select, what each partner's role in the company will be, and so forth. It's important to hire someone who's not loyal to any specific partner (even if it's you). Hire someone who is impartial and everyone feels good about.

Questions for Critical Thinking

1. Think about your personality and work habits. What type of person (in terms of personality and work habits) do you think you'd work well with and what type of person do you think you'd be in constant conflict with?
2. Do you think it's a good idea or a bad idea to form a business partnership with a close friend? How could you go about discerning if a good friend would make a good business partner?
3. Provide some suggestions, other than those mentioned in the feature, for places (online or offline) for finding a business partner.
4. Spend some time looking at LinkedIn. How could you use LinkedIn to help find a business partner?

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Table 14.5 Types of Nonfinancial Resources That Are Critical to Many Start-Ups' Success

- Affordable office space
- Lab space, manufacturing space, or space to launch a service business
- Contract manufacturers or service providers
- Key management employees (now and in the future)
- Key support personnel (now and in the future)
- Key equipment needed to operate the business (computers, machinery, delivery vehicles)
- Ability to obtain intellectual property protection on key aspects of the business
- Support of local governments and state government if applicable for business launch
- Ability to form favorable business partnerships

14.5 Financial Feasibility Analysis

Financial feasibility analysis is the final component of a comprehensive feasibility analysis. For feasibility analysis, a preliminary financial assessment is usually sufficient; indeed, additional rigor at this point is typically not required because the specifics of the business will inevitably evolve, making it impractical to spend a lot of time early on preparing detailed financial forecasts.

The most important issues to consider at this stage are total start-up cash needed, financial performance of similar businesses, and the overall financial attractiveness of the proposed venture.

If a proposed new venture moves beyond the feasibility analysis stage, it will need to complete pro forma (or projected) financial statements that demonstrate the firm's financial viability for the first one to three years of its existence. In Chapter 15, we'll provide you with specific instructions for preparing these statements.

14.5.1 Total Start-Up Cash Needed

This first issue refers to the total cash needed to prepare the business to make its first sale. An actual budget should be prepared that lists all the anticipated capital purchases and operating expenses needed to get the business up and running. After determining a total figure, an explanation of where the money will come from should be provided. Avoid cursory explanations such as "I plan to bring investors on board" or "I'll borrow the money." Although you may ultimately involve investors or lenders in your business, a more thoughtful account is required of how you'll provide for your initial cash needs.

If the money will come from friends and family or is raised through other means, such as credit cards or a home equity line of credit, a reasonable plan should be stipulated to repay the money. Showing how a new venture's start-up costs will be covered and repaid is an important issue. Many new ventures look promising as ongoing concerns but have no way of raising the money to get started or are never able to recover from the initial costs involved. When projecting start-up expenses, it is better to overestimate rather than underestimate the costs involved. Murphy's Law is prevalent in the start-up world—things will go wrong. It is a rare start-up that doesn't experience some unexpected expenses during the start-up phase.

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There are worksheets posted online that help entrepreneurs determine the start-up costs to launch their respective businesses. Start-up cost worksheets are available via SCORE (www.score.org) and the Small Business Administration (www.sba.gov).

14.5.2 Financial Performance of Similar Businesses

The second component of financial feasibility analysis is estimating a proposed start-up's potential financial performance by comparing it to similar, already established businesses. Obviously, this effort will result in approximate rather than exact numbers. There are several ways of doing this, all of which involve a little gumshoe labor.

First, substantial archival data, which offers detailed financial reports on thousands of individual firms, is available online. The easiest data to obtain is on publicly traded firms through Hoovers or a similar source. These firms are typically too large, however, for meaningful comparisons to proposed new ventures. The challenge is to find the financial performance of small, more comparable firms. Samples of websites that are helpful in this regard are provided in the Internet Resource Table in Appendix 14B. IBISWorld, BizMiner, and Mintel provide data on the average sales and profitability for the firms in the industries they track. Reference USA provides revenue estimates for many private firms, but fewer libraries subscribe to its service. (This resource is more commonly available at large city libraries.) On the expense side, a very useful website is BizStats.com, where an entrepreneur can type in the projected revenue of his or her firm, by industry classification (not all industries are covered), and receive a mock income statement in return that shows the average profitability and expense percentages of U.S. businesses in the same category. IBISWorld also normally provides a chart of the average expenses (as a percentage of sales) for major items such as wages, rent, office and administrative expenses, and utilities for firms in the industries they follow. Another source to help estimate a firm's sales and net profit is BizMiner (www.bizminer.com). BizMiner provides a printout of the average sales and profitability for firms in the industries it follows and provides more detail than similar reports. It is a fee-based site but is free if accessed through a university library that subscribes to the service.[11]

There are additional ways to obtain financial data on smaller firms. If a start-up entrepreneur identifies a business that is similar to the one he or she wants to start, and the business isn't likely to be a direct competitor, it's perfectly acceptable to ask the owner or manager of the business to share sales and income data. Even if the owner or manager is only willing to talk in general terms (e.g., our annual sales are in the $3 million range, and we're netting around 9 percent of sales), that information is certainly better than nothing. Simple Internet, ProQuest, and LexisNexis Academic searches are also helpful. If you're interested in the sports apparel industry, simply typing "sports apparel industry sales" and "sports apparel industry profitability" will invariably result in links to stories about sports apparel companies that will mention their sales and profitability.

Simple observation and legwork is a final way to obtain sales data for similar businesses. This approach is suitable in some cases and in others it isn't. For example, if you were proposing to open a new smoothie shop, you could gauge the type of sales to expect by estimating the number of people who patronize similar smoothie shops in your area, along with the average purchase per visit. A very basic way to do this is to frequent these stores and count the number of customers who come in and out of the stores during various times of the day.

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Table 14.6 Financial Feasibility

- Steady and rapid growth in sales during the first five to seven years in a clearly defined market niche
- High percentage of recurring revenue—meaning that once a firm wins a client, the client will provide recurring sources of revenue
- Ability to forecast income and expenses with a reasonable degree of certainty
- Internally generated funds to finance and sustain growth
- Availability of an exit opportunity (such as an acquisition or an initial public offering) for investors to convert equity into cash

14.5.3 Overall Financial Attractiveness of the Proposed Venture

A number of other factors are associated with evaluating the financial attractiveness of a proposed venture. These evaluations are based primarily on a new venture's projected sales and rate of return (or profitability), as just discussed. At the feasibility analysis stage, the projected return is a judgment call. A more precise estimation can be computed by preparing pro forma (or projected) financial statements, including one- to three-year pro forma statements of cash flow, income statements, and balance sheets (along with accompanying financial ratios). This work can be done if time and circumstances allow, but is typically done at the business plan stage rather than the feasibility analysis stage of a new venture's development.

To gain perspective, a start-up's projected rate of return should be weighed against the following factors to assess whether the venture is financially feasible:

- The amount of capital invested
- The risks assumed in launching the business
- The existing alternatives for the money being invested
- The existing alternatives for the entrepreneur's time and efforts

As promising as they seem on the surface, some opportunities simply may not be worth it financially. For example, it makes no economic sense for a group of entrepreneurs to invest $10 million in a capital-intense, risky start-up that offers a relatively low return (say around 3 percent) on the capital the entrepreneurs are investing. The adequacy of returns also depends on the alternatives the individuals involved have. For example, an individual who is thinking about leaving a $150,000-per-year job to start a new firm requires a higher rate of return than the person thinking about leaving a $50,000-per-year job.[12]

Other factors used to weigh the overall financial attractiveness of a new business are listed in Table 14.6.

14.6 A Feasibility Analysis Template

First Screen, shown in Appendix 14A, is a template entrepreneurial firms use to complete a feasibility analysis. It is called First Screen because a feasibility analysis is an entrepreneur's (or a group of entrepreneurs') initial pass at determining the feasibility of a business idea. If a business idea cuts muster at this stage, the next step is to complete a business plan.

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The mechanics for filling out the First Screen worksheet are straightforward. It maps the four areas of feasibility analysis described in the chapter, accentuating the most important points in each area. The final section of the worksheet, "Overall Potential," includes a section that allows for suggested revisions to a business idea to improve its potential or feasibility. For example, a business might start out planning to manufacture its own product, but through the process of completing First Screen, learn that the capital needed to set up a manufacturing facility is prohibitive in terms of both the money that would need to be raised and the extended time to break even for the business. As a result, two of five items in Part 5, "Initial Capital Investment" and "Time to Break Even," might be rated "low potential." This doesn't need to be the end of the story, however. In the column labeled "Suggestions for Improving the Potential," the founders of the business might write, "Consider contract manufacturing or outsourcing as an alternative to manufacturing the product ourselves." The value of the First Screen worksheet is that it draws attention to issues such as this one and forces the founders to think about alternatives. If this particular suggestion is realistic and is determined to be a better way to proceed, a revised version of First Screen might rate the two factors referred to previously, "Initial Capital Requirements" and "Time to Break Even," as "high potential" rather than "low potential" because of the change in the business concept that was made. Business ideas at the feasibility analysis stage should always be seen as fluid and subject to change. Little is lost if several versions of First Screen are completed for the same business idea; however, there is much more to be lost if a start-up gets halfway through writing a business plan and concludes that the business isn't feasible, or actually launches a business without having at least most of the kinks worked out.

Although completing First Screen does take some research and analysis, it is not meant to be a lengthy process. It is also not meant to be a shot in the dark. The best ideas are ones that emerge from analysis that is based on facts and good information, rather than speculation and guesses, as emphasized throughout the chapter. Appendix 14B contains the Internet Resource Table that may be particularly helpful in completing a First Screen analysis. It is well worth your time to learn how to use these resources—they are rich in terms of their content and analysis.

It's important to be completely candid when completing First Screen for your business idea. No business scores "high potential" on every item. There is also no definitive way of discerning, after the worksheet is completed, if an idea is feasible. First Screen, like the feasibility analysis itself, is meant to convey an overall impression or sense of the feasibility of a business idea. Copies of the First Screen worksheet, in both MS Word and PDF format, are available at www.pearsonhighered.com/barringer.

SUMMARY

14.1 Feasibility analysis is the process of determining whether a business idea is viable. It is a preliminary evaluation of a business idea, conducted for the purpose of determining whether the idea is worth pursuing. The proper time to conduct a feasibility analysis is early in thinking through the prospects for a new business idea. It follows opportunity recognition but comes before the development of a business model and a business plan.

14.2 A product/service feasibility analysis is an assessment of the overall appeal of the product or service being proposed. The two components of product/service feasibility analysis are product desirability and product demand. A concept statement, which is a preliminary description of a product idea, is developed during this particular aspect of the

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REVIEW QUESTIONS

14.1 How would you describe the four areas that a properly executed feasibility analysis explores?

14.2 What is a product/service feasibility analysis?

14.3 What is the difference between primary research and secondary research?

14.4 What is a concept statement?

14.5 What are the two ways that entrepreneurs assess the likely product demand for the proposed product or service they are analyzing?

14.6 What is gumshoe research in the context of product/service feasibility analysis?

14.7 What is an industry/target market feasibility analysis?

14.8 What are the attributes or characteristics of an attractive industry for a new venture?

14.9 What is a target market?

14.10 Why do most start-ups focus on relatively small target markets to begin with rather than larger markets with more substantial demand?

14.11 What are some of the ways to determine the attractiveness of a small target market within a larger industry?

14.12 What is an organizational feasibility analysis?

14.13 What are the two primary issues to consider when conducting an organizational feasibility analysis?

14.14 What is a new venture team?

14.15 What is a financial feasibility analysis?

14.16 What are the three separate components of financial feasibility analysis?

14.17 What are some of the techniques a start-up can use to estimate its potential financial performance by comparing it to similar, already established businesses?

14.18 What are some factors that make a potential start-up attractive from an overall financial perspective?

14.19 What is the purpose of a First Screen analysis?

APPLICATION QUESTIONS

14.1 Jackson Reed, a friend of yours, just told you an interesting story. He was at his parents' house over the weekend. While there, his father saw your entrepreneurship book laying to the side of your backpack. He looked through the book and spent a bit of time studying Chapter 14. After doing so, he said to Jackson, "When you were growing up, I launched and sold three successful businesses and never once completed a feasibility analysis. What do you think the authors of your text would say about that?" What would you suggest that Jackson say in response to his father's question?

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14.2 Jennifer Pisano just applied for a bank loan to finance an Italian restaurant she wants to launch. When visiting with the banker about the loan application, she was asked if she had conducted any primary research to assess the feasibility of her proposed business. Jennifer replied that she had spent many, many evenings and weekends in the library and on the Internet collecting information about restaurants in general and Italian restaurants in particular. She further noted that the information she had collected through these efforts increased her confidence that she could open and operate a successful restaurant. One reason for her confidence, Jennifer noted to the banker, was that her library and Internet searches were carefully conducted in ways that allowed her to verify that Italian restaurants did well in demographic areas that are similar to the one in which she wants to open her business. If you were the banker, what would you say to Jennifer in response to her comments?

14.3 If you were one of the recipients of New Venture Fitness Drink's concept statement, as presented earlier in the chapter, what type of feedback would you have given the company about the viability of its product idea?

14.4 Linda Toombs, who has considerable experience in the home security industry, is planning to launch a new line of home security alarms that she believes would be superior to other products in the market. Linda knows how to develop a concept statement and administer a buying intentions survey but is less clear about the type of library and Internet research that might help her assess the demand for her product. If Linda asked you about this, what advice would you give to her about how to conduct successful library and Internet searches?

14.5 Assess the industry attractiveness for the industry in which August Smart Lock, the firm featured in the You Be the VC 14.1 feature, competes.

14.6 If you were interested in opening a musical instruments store near the college or university you are attending in order to sell guitars, drums, and other types of musical instruments, what online resources would you draw on to conduct secondary research regarding the industry/target market feasibility of your business idea?

14.7 Keith Ambrose, who is a physical therapist, is thinking about starting a firm to provide in-home therapy services for people suffering from sports-related injuries. Keith lives in Columbus, Ohio. He doesn't know if Columbus is large enough to support his proposed business or if people would pay a premium to receive treatment in their homes for their sports-related injuries. What suggestions do you have for Keith about primary and secondary research he might conduct to learn more about the potential target market for his proposed business?

14.8 If you were considering the possibility of launching a website that you've developed in order to sell sports apparel for petite women, what are some specific actions you could take to collect feedback regarding the usability of your website?

14.9 What are some of the red flags that would suggest that the overall financial attractiveness of a proposed new venture is poor? Which of the red flags you identified would suggest that realistically, a proposed venture isn't feasible?

14.10 A friend of yours just completed a First Screen analysis for an e-commerce site that she hopes to launch to sell horse riding supplies such as saddles, tacks, lead ropes, and feed buckets. She's disappointed because she rated 10 of the 25 items included in First Screen as having either low or moderate potential. After thinking about this, your friend says to you, "Well that's that. Good thing I completed a feasibility analysis. I definitely do not want to start the business I was thinking about." Is your friend correct in reaching this conclusion? How would you advise her to interpret the results of her First Screen analysis?

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YOU BE THE VC 14.1

COMPANY: August Smart Lock

Business Idea: Develop a safer, simpler, and more social way to lock and unlock the front door of a home or an apartment.

Pitch: Conventional door locks have several downsides. First, they require a key that can be lost or misplaced. Second, if the owner of a house wants to provide access during the middle of the day to someone such as a dog walker or housekeeper, it creates a problem. The person accessing the house has to be given a key or a key has to be hidden somewhere, like under the flower pot near the door (which is the first place a burglar would look). Finally, if a friend stops by to drop something off and the house is locked, s/he may have made a wasted trip.

The August Smart Lock solves all these problems. It is an attractive hardware device that retrofits over an existing single-cylinder deadbolt lock, which is the type of lock found on the majority of front doors for homes and apartments. The August Smart Lock fits on the interior portion of the door. It does not affect the ability to use the same key that has always been used to lock and unlock the door.

Once the August Smart Lock is installed, it allows the door to be locked and unlocked via a smartphone app. The app allows you to send a virtual key to anyone you choose to have access to your home or apartment. Your guest then uses their smartphone to gain access to the residence without the need to exchange physical keys. You can specify the duration that the August virtual key is active, and the key can be disabled at any time. For example, if someone walks your dog from 1:00 P.M. to 1:30 P.M. every day, access to the home can be granted to that specific person for that time each day.

The August Smart Lock is easy to install. It is completely self-sufficient, meaning that it does not need access to electricity or Wi-Fi, like more complicated keyless door lock systems. It literally takes 10 minutes to install. The August Smart Lock app is compatible with the iPhone and Android-based products, and will soon be adding BlackBerry and Windows Phone 8. If you lose your phone you can log onto august.com and remove access authorization for that device. The system is completely safe and will not allow entry for people who do not have a virtual or physical key. The virtual key function uses the same secure communications technology used by financial institutions. August has additional safety features. For example, for guests who are provided a virtual key, August keeps track of how many times they enter your home and keeps track of the duration of each visit.

1. Based on the material covered in this chapter, what questions would you ask the firm's founders before making your funding decision? What answers would satisfy you?
2. If you had to make your decision on just the information provided in the pitch and on the company's website, would you fund this company? Why or why not?

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YOU BE THE VC 14.2

COMPANY: Blue Apron

Business Idea: Launch a service that provides ready-to-cook meals with premeasured ingredients and cooking instructions. Deliver the ingredients directly to customers' homes in refrigerated boxes.

Pitch: Many people enjoy cooking but do not have the time and expertise to cook elaborate meals. People also tire of restaurants, takeout meals, and quick meals at home. Even people who have time to do the actual cooking often don't have the time it takes to find a recipe, shop for the ingredients, and then cook the meal. This is a frustrating reality for people who enjoy cooking and spending time in the kitchen.

Blue Apron was founded to address this problem. It is a weekly subscription service that delivers to its customers a refrigerated box each week that contains the ingredients and cooking instructions for three fresh meals. For Blue Apron, each week involves four steps. First, its recipe team brainstorms meal ideas, drawing inspiration from restaurants, cookbooks, and anywhere food is served. Second, the company sources ingredients, mostly from local family-owned businesses. Third, they test cook the meal and, if it takes more than 35 minutes to prepare, requires advanced skills, or needs utensils that wouldn't be found in a normal kitchen, it gets cut from the roster. Finally, if the meal makes it, it is put in the queue for Blue Apron customers.

From the customer's standpoint, Blue Apron offers six meal choices each week. The customer picks three. The meals arrive in a refrigerated box once a week. The meals cost $9.99 per person, per meal. So, for two people the box would cost $60 per week. The box includes premeasured ingredients for each meal. Also inside the box is a card featuring step-by-step instructions with photographs of how to prepare and cook the meal. Each recipe serves two people.

Along with providing people a way to quickly prepare fresh meals, Blue Apron's aim is to introduce people to new things. The company rarely repeats a recipe. The company's name is a tip of the hat to cooking tradition in that in the culinary world, beginner cooks wear blue aprons while more experienced chefs wear aprons with black and white stripes. In recent years high profile chefs have set aside the tradition and have donned the blue apron, in recognition that cooking involves a lifetime of learning.

Blue Apron has distribution centers in New York and Northern California. It currently ships approximately 17,000 meals a month. The firm's products are available in 80 percent of the United States.

1. Based on the material covered in this chapter, what questions would you ask the firm's founders before making your funding decision? What answers would satisfy you?
2. If you had to make your decision on just the information provided in the pitch and on the company's website, would you fund this company? Why or why not?

CASE 14.1

How "Listening to Customers" Has Shaped Modify Watches

Introduction

Modify Watches was started by Aaron Schwartz and Gary Coover, shortly after the two received their MBAs from UC-Berkeley's Hass School of Business in 2010. While in college, Schwartz started a sustainability business called Refill Revolution. He also took a class from Steve Blank and Eric Ries—champions of the lean start-up movement. The class was called "Customer Development in High-Tech Enterprises." The staple concepts underlying the

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class were "building a minimal viable product" and "get out of the building." Building a minimal viable product means that a start-up's initial product should include just enough core features to allow early adopters to provide feedback. The start-up can then iterate based on the feedback. "Get out of the building" refers to the notion that it's impossible to know what customers really want without talking to them.

Blank and Ries's class impacted Schwartz. He realized that Refill Revolution, which he eventually sold, wasn't built utilizing Blank and Ries's principles. Instead, he and his co-founders built a service based on what they thought was right, rather than on what customers told them they wanted. Luckily, they found a buyer that was able to take advantage of the Refill Revolution platform. The company itself wouldn't have been successful as a stand-alone business.

Giving Steve Blank and Eric Ries's Philosophy a Try

Modify Watches started from a different premise. The general idea was to sell affordable watches that have interchangeable faces and bands. That approach would give customers the ability to switch their watch face and band to match their clothing or mood. Rather than pushing forward, the firm chose to give Blank and Ries's philosophy a try. They knew the idea rested on a core hypothesis: people would buy interchangeable watch parts. To test the hypothesis, they went to eBay and bought cheap interchangeable watches. They then built an inexpensive website, using Weebly.com, that featured jokes, images of the watch parts, nicknames for every single watch-color combination, and "Buy Now" buttons. The inexpensive watches were their minimal viable product. They just wanted to see how people would buy. The test validated the idea that they could sell interchangeable watch faces and brands.

Company Launch

Modify Watches launched soon afterwards. It didn't take the company long to develop a certain character, which was customer focused. They called their customers "The ModiFamily." When people complimented them on their products, they referred to their motto, which is "We're not craftsmen, we're just good listeners." Not everything went swimmingly, though. Coover left Modify in August 2010 to join a strategy team with Samsung in South Korea. Schwartz, like Coover, planned to resume a full-time job but decided to commit to Modify on a full-time basis instead. He did not take a salary the first year to help the company get up and running, and the company was initially run out of his apartment. A big break occurred shortly after launch when Schwartz was on a cross-country

A sample of Modify Watches

Modify Industries, Inc.

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flight. He met a business executive on the plane and ended up selling him 2,500 watches. That sale earned Schwartz the blessing of his family and advisers to stick with the business. Schwartz also started surrounding himself with a talented team. He hired Ashil Parag, who he describes as an A+ designer. As his tech director he hired a UC-Berkeley student named Sean Linehan, whom Schwartz described as "as talented as anyone I have ever met."

The company's focus on customers wasn't forced. In fact, in an article Schwartz wrote for *Startup America* he said that "interacting with customers gives us (the Modify Watch team) happiness on a daily basis." Similarly, in an article Schwartz wrote for *Forbes*, he provided the following advice for business founders: "Think of your customers as family and friends. It sounds silly, but when you believe that folks you care about rely on your product or service, you will work harder to make sure they are treated well." Schwartz's actions indicated that his sentiments are real. From the beginning, for example, whoever does the packing for a Modify Watches order includes their business card. The card includes the team member's e-mail address and their cell phone number, just in case a customer wants to give them a shout. The more Modify's team members interact with customers, Schwartz figures, the better the company will be able to design watches that their customers want.

Modify Watches

From the get-go, Modify Watches tapped into the customization movement. Its line of watches includes multiple faces and straps, all of which are interchangeable, so you can design any style you'd like. To fully appreciate the number of watch faces and bands the company offers, pause for a moment and visit its website. The watches come in two sizes, big and bigger. They're water resistant and made of stainless steel and plastic. Changing straps is very simple. If you have a large enough collection of straps and faces, you can have a different daily look on your wrist for some time. The least expensive combination of face and strap costs $40 plus shipping. The company also has a license with the Major League Baseball Player's Association, so you can get a watch face with your favorite baseball team's logo on it.

Modify has continued to involve customers every step of the way, often in very substantive manners. An illustrative example is an initiative launched in November 2011. Modify rolled out crowd-sourcing platform Napkin Labs' (www.napkinlabs.com) brainstorming app to its Facebook page. The app allows companies to create virtual, interactive focus groups with its customers. Modify ran a competition that asked customers to submit suggestions for co-branding products. An idea to co-brand a watch with the Wounded Warrior Project won. Modify had to push back the deadline for the competition because of the large number of submissions it received.

Kickstarter

Modify Watches' current initiative is its Mod-to-Order campaign. It is an initiative that will allow the company to produce individual customized watches for people. So if you'd like a watch with your best friend's image on it, Modify Watch will be able to do that for you. To raise money for the machinery and staff needed to make individually customized watches, Modify ran a Kickstarter campaign in early 2014. If you'd really like to get a sense of what Modify Watches is all about, go to www. kickstarter.com, type Modify in the search bar, and watch the videos that the company made to promote the campaign. They are expertly done and fully convey Modify Watches' culture and values. Modify reached its goal and received contributions from 790 backers. Of course, while the outward purpose of the campaign was to raise $50,000 to buy equipment and hire people, the campaign had another purpose. Harkening back to Blank and Ries's philosophy of launching a minimal viable product, the Kickstarter campaign and its accompanying videos were the minimal viable product for Mod-

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to-Order. The $54,873 in pledges from 790 backers was the validation needed to move the idea forward.

The Difference Listening to Customers Makes

One thing Schwartz likes to emphasize is that listening to customers makes a difference. Along with the practices mentioned above, Modify surveys its fans at least quarterly, and its entire team has calls with customers every week. In a guest post written on the Tech Cocktail blog, Schwartz noted the following substantive changes the company has made strictly as a result of listening to customers.

- Business model change. A good share of Modify's business comes from customizing watches for brands. The idea to do this came from a Google employee who contacted Modify and asked if they could make a Google Chrome watch. Modify said yes, and a new product line was born. It now designs branded watches for Google, Facebook, the Pac 12 conference, and a number of other businesses and organizations.
- The right product improvements. Modify reaches out to customers in a variety of ways to ask what they want (and don't want) in their watches. At one point, Modify assumed that people would want the watches to be water resistant, have a stopwatch, and have a backlight. A total of 95 percent wanted the watches to be water resistant while less than 10 percent wanted a stopwatch and even fewer wanted a backlight.
- Adding brand-name licensing. Modify's fans asked early and often for licensed properties like Major League Baseball. The company took the feedback, and it has been rewarded with significant product sales.
- Design decisions. Before Modify launches a new limited-edition watch, it always asks its fans to vote on what should be made.

Discussion Questions

1. What type of research did those leading Modify Watches conduct when completing a product/service feasibility analysis and what additional research might the founders have pursued when assessing the feasibility of their firm's product?
2. What target market is Modify Watches seeking to serve and how attractive is that market?
3. What evidence can you provide from the case to support the view that Schwartz is very interested in understanding customers' reactions to Modify's products?
4. If you were asked to complete an organizational analysis of Modify, what conclusions would you reach regarding the firm's management prowess and resource sufficiency at the time the firm launched and immediately thereafter?

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CASE 14.2

Embrace Infant Warmer: Sometimes a Business Start Is a Matter of Life and Death

Introduction

When Rahul Panicker, Jane Chen, and Linus Liang enrolled in Design for Extreme Affordability, a course taught in the Design School at Stanford University, little did they know that the class would change their lives. And little did they know that a short three years later, premature babies born in rural India, who often don't survive because of hypothermia, would have a new chance at life because of a product they designed.

The Design for Extreme Affordability class draws students from across the Stanford campus. The goal of the class is to develop solutions for formidable, real-world problems. The project Panicker, Chen, and Liang were assigned was to develop a low-cost infant incubator for use in developing countries. This was a topic that the three knew nothing about. They were electrical engineering, MBA, and computer science students, respectively. To get started, they did some simple Google searches. They learned that millions of premature babies are born annually in developing countries. About a million of them die, often within 24 hours. The biggest cause of death is hypothermia. Premature babies don't have enough fat to regulate their body temperature. As a result, they can literally freeze to death in a room that is at room temperature. Nearly half of the world's low-birth-weight babies are born in India. Hospitals have incubators that provide consistent, life-saving heat to premature babies. But incubators cost up to $20,000 a piece.

The obvious solution was to drive down the cost of incubators. The team could systematically reduce the cost of traditional incubators by eliminating nonessential parts and using cheaper materials. Rather than moving forward, Liang got funding for a trip to Nepal to study incubators in developing countries. While visiting a hospital he noticed something that was odd. Many of the incubators were empty. He then learned the sad truth. About 80 percent of the premature babies born in the developing world are born in rural villages. They never are brought to a hospital and placed in an incubator. Even when they are, they're often taken home before the baby is ready to leave due to family needs back at the village.

Back at Stanford, the team grappled with what to do with the insight. The easier road ahead would be to redesign the traditional incubator, to make them more affordable. But that wasn't the answer. The harder challenge was to find a solution for saving premature babies where they were born—in rural villages.

Early Prototypes

The team tackled the harder challenge: How to create a baby-warming device that doctors and parents in rural villages could use to save premature babies? The team set to work and started creating rough prototypes of an original design. The earliest prototypes were made using old sleeping bags, baby dolls, and blankets. The design was a portable infant warmer that looks like a tiny sleeping bag. The warmer opens in the front, allowing mothers to nurse their babies and maintain intimate contact. The bag contained a pouch of wax-like phase-change material that keeps the baby warm for up to six hours at regular body temperatures. It required just 30 minutes of electricity to heat the pouch, an ideal situation for areas where the availability of electricity is spotty. To provide additional warmth, mothers would be instructed to hold their babies as much as possible against their skin. This activity prompted the team to call the product "Embrace."

The class ended and the team had a decision to make. All had promising prospects. In the end, the team members couldn't walk away. The lives of premature babies were at

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Embrace Infant Warmer

Embrace

stake. They would move forward and continue to work on what was now known as the Embrace Infant Warmer.

Embrace Infant Warmer

The team, now joined by a fourth Stanford student, Naganand Murty, took the prototye to India to solicit customer feedback. They used rapid prototyping techniques to iterate on feedback and zero in on the attributes that are of highest relevance and value in a rural setting. Some of what they found out was surprising, and would have never been learned had they remained in California. For example, they found that women in India believe that Western medicine is very powerful, so they routinely cut back on the recommended dosages of Western medicines, just to be safe. That knowledge impacted early prototypes of the Embrace Infant Warmer. The early prototypes instructed mothers to set the temperature at 37 degrees Celsius. What they found was that the devices were being set at about 30 degrees. To solve the problem, they preprogrammed the ideal temperature into the device and just put an OK and Not OK switch on it. Commenting on the decision to go to India rather than remain at Stanford to build out the Embrace Infant Warmer, Chen told Helen Walters, who wrote an article on Embrace, "There are so many nuances that are critical to design and effective implementation, so many nuances that you don't understand unless you're there and living and breathing the culture every day."

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Talking to potential customers raised other issues. For example, they learned that villagers wanted different pricing options—like an option to rent the device. Commenting on changes that were made as a result of feedback from rural villagers, Chen said in an *HBR* blog post, "Entrepreneurs often fall in love with their original product idea or business model and fail to listen to customers. We (meaning the Embrace team), on the other hand, have no qualms about modifying our product features and pricing again and again until we find a solution that delivers the highest value to our customers at the lowest cost for them."

Gaining Momentum

The initial prototypes of the Embrace Infant Warmer were a success, which emboldened the team to keep working. Additional field research took place, involving village mothers in every aspect of design, from the straps on the warmer to the instructions printed on its front. Spending time in homes in rural India produced additional insights. "Oftentimes the mother-in-law is the decision maker," Chen said in the same interview as the one cited above. As a result, they determined a way to involve mother-in-laws in the process of using the Embrace Infant Warmer. In December of 2010, Embrace was featured in a segment of the ABC News show *20/20*. The show contained images of a five-pound baby girl in India named Nisha, the first child to use the Embrace Infant Warmer in a clinical trial—and maybe the first life saved by the device.

The Embrace Infant Warmer was formally launched in April 2011, after completing clinical trials. It went through more than 60 iterations before a final design was settled on. All manufacturing is done in Bangalore, India. Some of the parts are outsourced, but the final assembly and quality testing is done by the company. To ensure distribution, Embrace is partnering with multinational medical devices companies like GE Healthcare and with local NGOs. An organizational structure has also emerged. Embrace has both a nonprofit arm, which donates its baby warmer to those in need and runs educational programs, and a for-profit side, which sells the baby warmers to government entities and private clinics. It's a two-pronged approach that the founders hope will allow the company to prosper, grow, and save an increasing number of premature babies.

Embrace Today

As of the end of 2013, roughly two and a half years after launch, the Embrace Infant Warmer had been used on about 10,000 babies. Panicker and Chen lead Embrace, while their Stanford classmates and co-founders have moved on. The company is private and doesn't disclose financial information, other than to say that its margins are sufficient to keep growing and try additional products. The Embrace Infant Warmer is not only used in rural villages. Its also used in hospitals and clinics, to move premature babies from location to location and to use when a premature baby is born and all of the traditional incubators are already in use.

In addition to continuing to improve the Embrace Infant Warmer, the company has aspirations to tackle some of the other factors that cause infant mortality. Other potentially fatal conditions include meningitis, pneumonia, infections such as sepsis, and diarrhea.

To fully appreciate the heart of Embrace and the company's goals, visit its website at http://embraceglobal.org or Facebook page at Embrace. A particularly heart-warming portion of its website is titled "Spread the Warmth with Embrace." A $25 donation provides the life-saving warmth of an Embrace warmer to one low-birth-weight or premature baby.

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Discussion Questions

1. What target market does Embrace seek to serve and how attractive is that market?
2. What examples of primary research that Embrace's founders completed appear in the case?
3. What actions did Embrace's founders take to solicit feedback from prospective customers and what did they learn from these efforts?
4. If you were asked to conduct a financial feasibility analysis for Embrace, what issues would you consider to complete this analysis and why are those important?

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Appendix 14A First Screen

Part 1: Strength of Business Idea

For each item, circle the most appropriate answer and make note of the (−1), (0), or (+1) score.

	Low Potential (−1)	Moderate Potential (0)	High Potential (+1)
1. Extent to which the idea: • Takes advantage of an environmental trend • Solves a problem • Addresses an unfilled gap in the marketplace	Weak	Moderate	Strong
2. Timeliness of entry to market	Not timely	Moderately timely	Very timely
3. Extent to which the idea "adds value" for its buyer or end user	Low	Medium	High
4. Extent to which the customer is satisfied by competing products that are already available	Very satisfied	Moderately satisfied	Not very satisfied or ambivalent
5. Degree to which the idea requires customers to change their basic practices or behaviors	Substantial changes required	Moderate changes required	Small to no changes required

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Part 2: Industry-Related Issues

	Low Potential (–1)	Moderate Potential (0)	High Potential (+1)
1. Number of competitors	Many	Few	None
2. Stage of industry life cycle	Maturity phase or decline phase	Growth phase	Emergence phase
3. Growth rate of industry	Little or no growth	Moderate growth	Strong growth
4. Importance of industry's products and/or services to customers	"Ambivalent"	"Would like to have"	"Must have"
5. Industry operating margins	Low	Moderate	High

Part 3: Target Market and Customer-Related Issues

	Low Potential (–1)	Moderate Potential (0)	High Potential (+1)
1. Identification of target market for the proposed new venture	Difficult to identify	May be able to identify	Identified
2. Ability to create "barriers to entry" for potential competitors	Unable to create	May or may not be able to create	Can create
3. Purchasing power of customers	Low	Moderate	High
4. Ease of making customers aware of the new product or service	Low	Moderate	High
5. Growth potential of target market	Low	Moderate	High

Part 4: Founder- (or Founders-) Related Issues

	Low Potential (–1)	Moderate Potential (0)	High Potential (+1)
1. Founder's or founders' experience in the industry	No experience	Moderate experience	Experienced
2. Founder's or founders' skills as they relate to the proposed new venture's product or service	No skills	Moderate skills	Skilled
3 Extent of the founder's or founders' professional and social networks in the relevant industry	None	Moderate	Extensive

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	Low Potential (–1)	Moderate Potential (0)	High Potential (+1)
4. Extent to which the proposed new venture meets the founder's or founders' personal goals and aspirations	Weak	Moderate	Strong
5. Likelihood that a team can be put together to launch and grow the new venture	Unlikely	Moderately Likely	Very likely

Part 5: Financial Issues

	Low Potential (–1)	Moderate Potential (0)	High Potential (+1)
1. Initial capital investment	High	Moderate	Low
2. Number of revenue drivers (ways in which the company makes money)	One	Two to three	More than three
3. Time to break even	More than two years	One to two years	Less than one year
4. Financial performance of similar businesses	Weak	Modest	Strong
5. Ability to fund initial product (or service) development and/or initial start-up expenses from personal funds or via bootstrapping	Low	Moderate	High

Overall Potential

Each part has five items. Scores will range from –5 to +5 for each part. The score is a guide—there is no established rule of thumb for the numerical score that equates to high potential, moderate potential, or low potential for each part. The ranking is a judgment call.

Score (–5 to +5)	Overall Potential of the Business Idea Based on Each Part	Suggestions for Improving the Potential
Part 1: Strength of Business Idea	High potential Moderate potential Low potential	
Part 2: Industry-Related Issues	High potential Moderate potential Low potential	
Part 3: Target Market and Customer Related Issues	High potential Moderate potential Low potential	

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Score (–5 to +5)	Overall Potential of the Business Idea Based on Each Part	Suggestions for Improving the Potential
Part 4: Founder- (or Founders-) Related Issues	High potential Moderate potential Low potential	
Part 5: Financial Issues	High potential Moderate potential Low potential	
Overall Assessment	High potential Moderate potential Low potential	

SUMMARY

Briefly summarize your justification for your overall assessment:

Appendix 14B Internet Resource Table

Resources to Help Complete the First Screen Worksheet in Appendix 14A

Source	Description	Applicable Parts of First Screen	Cost/ Availability
American Factfinder (www.factfinder2.census.gov)	An easy-to-use portal for obtaining census data. One quick way to retrieve data is to get a "Fact Sheet" on a geographic area (by city, county, or zip code), which provides population, median household income, demographic breakdown (age, gender, race), and other information.	Part 3	Free
A–Z Index of Trade Associations (www.usa.gov/directory/tradeassc/index.shtml)	Directory provides access to the phone numbers and website addresses of trade associations in all industries. Trade associations can be contacted to obtain information on all areas of feasibility analysis.	Parts 1, 2, 3, 4, and 5	Free

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Source	Description	Applicable Parts of First Screen	Cost/ Availability
BizMiner (www.bizminer.com)	Industry statistics, sample pro forma financial statements by industry (and size of business), business start activity and failure rates by industry, and similar information. Provides data on small private firms.	Parts 2, 3, and 5	Fee based (more affordable than most); typically free if accessed through a university library
BizStats (www.bizstats.com)	Has a variety of detailed financial data on various retail categories. On the site, a user can type in the projected income of a firm, by industry, and receive a mock income statement in return.	Parts 2 and 5	Free
City-Data.com (www.city-data.com)	Contains detailed information on cities, including median resident age, median household income, ethnic mix of residents, and aerial photos.	Part 3	Free
County Business Patterns (www.census.gov/econ/cbp)	Good resources for looking at business activity, including the number of competitors, at a city, county, or state level. For example, you can find the number of dry cleaners (or any other business) in a specific zip code or city.	Parts 2 and 3	Free
Factiva (www.factiva.com)	Robust search engine that aggregates content from more than 36,000 sources such as newspapers, magazines, journals, photos, and radio and television transcripts.	Parts 1, 2, 3, 4, and 5	Fee based; typically free if accessed through a university library website
FedStats (www.fedstats.gov)	Provides easy access to information generated by over 100 federal agencies.	Parts 1, 2, 3, 4, and 5	Free
Hoovers Online (www.hoovers.com)	Brief histories and financial information on companies, industries, people, and products. Premium service provides access to detailed financial information and 10-K reports for publicly traded firms.	Parts 2, 3, and 5	Free; premium version available on a fee basis or typically for free if accessed through a university library
IBISWorld (www.ibisworld.com)	Detailed reports available on hundreds of industries, including industry statistics, trends, buyer behavior, and expected returns.	Parts 1, 2, 3, and 5	Fee based; typically free if accessed through a university library

(continued)

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Source	Description	Applicable Parts of First Screen	Cost/ Availability
LexisNexis Academic (www.lexisnexis.com)	Provides access to sales data for public and private firms, which can be searched in a number of useful ways. Helps start-ups estimate the financial performance of similar businesses. Go to "Business" and then "Company Financial."	Part 5	Fee based; typically free if accessed through a university library
Magportal.com (www.magportal.com)	Search engine and directory for finding online magazine articles. Helps start-ups by providing access to magazine articles about their product/service and industry of interest. This information may be helpful in all areas of feasibility analysis.	Parts 1, 2, 3, 4, and 5	Free
Mergent Online (www.mergentonline.com.)	Provides near instant access to financial data, including income statements, balance sheets, and cash flows, on more than 10,000 U.S. public corporations.	Parts 2 and 5	Fee based; typically free if accessed through a university library
Mintel (www.mintel.com)	Detailed reports available on hundreds of industries, including industry statistics, trends, buyer behavior, and expected returns.	Parts 1, 2, 3, and 5	Fee based; typically free if accessed through a university library
ProQuest (http://proquest.com)	Very robust search engine for searching publications such as the *Wall Street Journal* and the *New York Times*. Useful for all areas of feasibility analysis.	Parts 1, 2, 3, 4, and 5	Fee based; typically free if accessed through a university library
Quickfacts (http://quickfacts.census.gov)	A very quick way to access census bureau data, including population, median household income, census breakdowns by age and other demographic characteristics, and so on.	Parts 2 and 3	Free
ReferenceUSA (www.referenceusa.com)	Provides contact information, estimated annual sales, credit rating score, year established, news, and other information on both public and private companies. Contains more information on private firms than many similar sites. Helps start-ups estimate the financial performance of similar businesses.	Part 5	Fee based; typically free if accessed through a university library

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Source	Description	Applicable Parts of First Screen	Cost/ Availability
Salary.com	Useful resources for determining salary ranges for positions (such as computer programming) in a specific city or zip code.	Part 5	Free
SimilarWeb (www.similarweb.com)	Allows users to assess the website traffic for any URL. Information can be helpful in assessing the attractiveness of a similar business idea.	Part 1	Free
Standard & Poor's NetAdvantage (www.netadvantage .standardpoor.com)	Detailed reports available on hundreds of industries, including industry statistics, trends, buyer behavior, and expected returns.	Parts 1, 2, 3, and 5	Free; premium version available on a fee basis or typically free if accessed through a university library
Thomas Register of American Manufacturers	Search engine for sourcing components, equipment, raw materials, and customer manufacturing services. Helpful in determining how much it will cost to manufacture a product.	Part 5	Free
U.S. Small Business Administration (www.sba.com)	Describes loan availability, eligibility, sources of grants, etc. Helpful in determining the financial feasibility of a business idea.	Part 5	Free
Yahoo! Industry Center (http://biz.yahoo.com/ic)	Provides a directory of industries, along with a list of the companies in each industry, the latest industry-related news, and performance data on the top companies in an industry.	Parts 2, 3, and 5	Free

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CHAPTER 15

Assessing a New Venture's *Financial Strength* and Viability

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OPENING PROFILE

GYMFLOW: Managing Finances Prudently

Have you ever gone to a gym only to have your heart sink because the machines you planned to work out on were already in use? If so, you would be interested in joining a gym that features GymFlow. GymFlow is a mobile app that helps people determine before they show up just how crowded a gym is. It works by tapping into a gym's IT center to provide realtime traffic data.

GymFlow is the creation of Jimmy Liu and Jiangyang Zhang, two USC students. In the nearby photo, Jiangyang Zhang is on the left and Jimmy Liu is on the right. Liu was a double major in entrepreneurship and finance, while Zhang was a PhD student in engineering. The two met in fall 2012, in USC's Viterbi School of Engineering's "Building the High Tech Startup" course. The course combines business and engineering students to conceive and develop new product ideas. Liu and Zhang identified a two-sided problem that gyms face. Gym members are often frustrated when they show up at the gym and it's more crowded than they anticipated. At the same time, gym owners are frustrated by low retention rates. About 40 percent of the people who belong to gyms turn over every year. This is a huge problem for gyms. If a gym has 1,000 members, it must gain 400 new members a year just to stay even.

To solve the two-sided problem that gyms and its members face, Liu and Zhang developed a mobile app called GymFlow. Although there are now over one million apps in the Apple App Store alone, Liu and Zhang found a gap. There was no app that accurately showed how busy a gym was at any given point in time. GymFlow was set up to do two things. First, show the user in real time how crowded a particular gym is. And second, forecast future traffic flows to help the user plan workouts and avoid waiting time for equipment at the gym. The benefit to the gym would be more satisfied users, a smoothing out of when people come to the gym, and higher member retention. The app would be free to the member. Gyms would be charged for the back-end technology needed to make the system work. The app would have no ads. Liu and Zhang wanted the user experience to be as high quality as possible.

After the class concluded, Liu and Zhang decided to pursue GymFlow further. From the beginning, they were mindful of the costs and financials involved. To make sure they were on the right track, the two talked to both gyms and gym members prior to spending any money. They found that gym members saw the value of the app instantly. Gym owners were a tougher sell. Still, the feedback was sufficiently positive to move forward. Early 2013 was spent building the app. Zhang, a former Google employee, had programming skills that he used to write the code for the app himself. The pair's first funding was $20,000 in cash from the Virerbi Startup Garage, a startup accelerator affiliated with USC. GymFlow was one of 10 USC start-ups, out of 100 applicants, accepted into the accelerator. Beyond the money, the accelerator program provided Liu and Zhang access to mentors and an entrepreneurial network to plug into. An additional $5,000 came from an innovation grant and another $5,000 came from winning a pitch competition.

To avoid loan payments or pressure to grow quickly from investors, Liu and Zhang decided to rely on the money mentioned above and bootstrap the remaining costs needed to get GymFlow up and running. While their initial plan was to work on GymFlow full time, they decided to pursue the venture part time and maintain jobs on the side. Prior to marketing GymFlow beyond USC, Liu and Zhang conducted a pilot study at USC's Lyon Recreational Center. The first month that GymFlow was available it was downloaded by 2,000 USC students and was used over 20,000 times. The pilot test was successful and provided Liu and Zhang the confidence to press forward and market GymFlow to a wider audience.

As of August 2014, GymFlow was in seven gyms on three college campuses, all in Southern California. The company has encouraging prospects for expansion, not only in the United States but abroad. Liu and Zhang remain focused on GymFlow's finances. One thing that's helped them, particularly from a cash flow standpoint, is that the app required very little capital to build and the company started earning revenue as soon as the first GymFlow system was deployed. As a result, GymFlow has not experienced the type of cash-flow gaps that B2B

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(business-to-business) companies often experience when they incur substantial up-front expenses for a product run or job, and then have to wait 30 to 60 days to get paid. While Liu and Zhang did not write a formal business plan, they did complete financial projections, which they felt were useful. They have found that projecting future income is one of their most difficult challenges. They've also found that this is one of the most important things an entrepreneur can do. Other things have worked to Liu and Zhang's advantage when it comes to managing finances. For example, selling via the Apple App Store and Google Play (primary source for Android Apps) is an advantage for an appbased company. Apple and Google Play essentially act as GymFlow's distributor for the app. This relieves a company like GymFlow of the financial burden of building its own distribution platform.

In terms of overall financial management, Liu and Zhang are comfortable with where GymFlow is today. Many lessons have been learned, however, about the importance of cash flow and the need for sharp financial management for a growing company.

In this chapter, we'll look at how new ventures manage their finances and assess their financial strength and viability. For the purposes of completeness, we'll look at how both existing firms and entrepreneurial ventures accomplish these tasks. First, we'll consider general financial management and discuss the financial objectives of a firm and the steps involved in the financial management process. **Financial management** deals with two activities: raising money and managing a company's finances in a way that achieves the highest rate of return.[1] This chapter focuses on how a company manages its finances in an effort to increase its financial strength and earn the highest rate of return. Next, we'll examine how existing firms track their financial progress through preparing, analyzing, and maintaining past financial statements. Finally, we'll discuss how both existing firms and start-up ventures forecast future income and expenses and how the forecasts are used to prepare pro forma (i.e., projected) financial statements. Pro forma financial statements, which include the pro forma income statement, the pro forma balance sheet, and the pro forma statement of cash flows, are extremely helpful to firms in financial planning.

15.1 Introduction to Financial Management

An entrepreneur's ability to pursue an opportunity and turn the opportunity into a viable entrepreneurial firm hinges largely on the availability of money. Regardless of the quality of a product or service, a company can't be viable in the long run unless it is successful financially. Money either comes from external sources (such as investors or lenders) or is internally generated through earnings. It is important for a firm to have a solid grasp of how it is doing financially. One of the most common mistakes young entrepreneurial firms make is not emphasizing financial management and putting in place appropriate forms of financial controls.[2]

Entrepreneurs and those managing established companies must be aware of how much money they have in the bank and if that amount is sufficient to satisfy their firm's financial obligations. Just because a firm is successful doesn't mean that it doesn't face financial challenges.[3] For example, many of the small firms that sell their products to larger companies such as Apple, General Electric (GE), and The Home Depot aren't paid for 30 to 60 days from the time they make a sale. Think about the difficulty this scenario creates. The small firm must buy parts, pay its employees, pay its routine bills, build and ship its products, and then wait for one to two months for payment. Unless a firm manages its money carefully, it is easy to run out of cash, even if its products or services are selling like hotcakes.[4] Similarly, as a company grows, its cash demands often increase to

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service a growing clientele. It is important for a firm to accurately anticipate whether it will be able to fund its growth through earnings or if it will need to look for investment capital or borrowing to raise needed cash.

The financial management of a firm deals with questions such as the following on an ongoing basis:

- How are we doing? Are we making or losing money?
- How much cash do we have on hand?
- Do we have enough cash to meet our short-term obligations?
- How efficiently are we utilizing our assets?
- How do our growth and net profits compare to those of our industry peers?
- Where will the funds we need for capital improvements come from?
- Are there ways we can partner with other firms to share risk and reduce the amount of cash we need?
- Overall, are we in good shape financially?

A properly managed firm stays on top of the issues suggested by these questions through the tools and techniques that we'll discuss in this chapter.

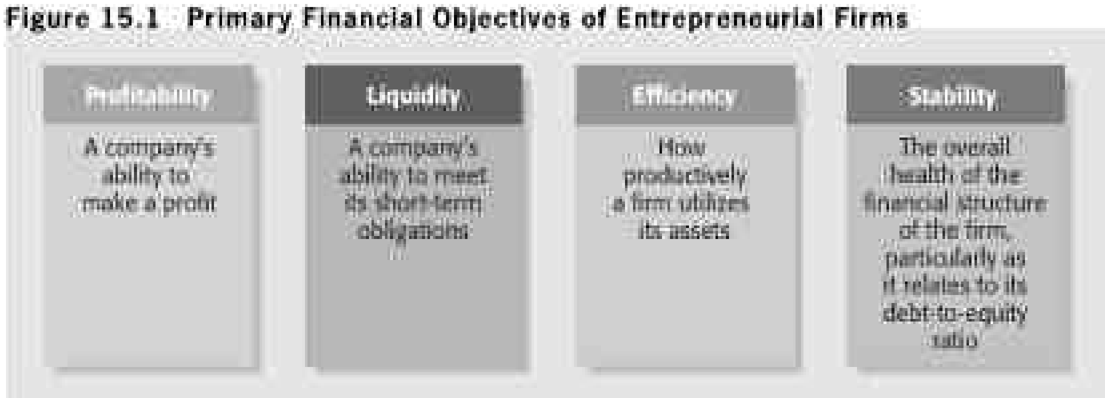
15.2 Financial Objectives of a Firm

Most entrepreneurial firms—whether they have been in business for several years or they are start-ups—have four main financial objectives: profitability, liquidity, efficiency, and stability. Understanding these objectives sets a firm on the right financial course and helps it track the answers to the previously posed questions. Figure 15.1 describes each of these objectives.

Profitability is the ability to earn a profit. Many start-ups are not profitable during their first one to three years, while they are training employees and building their brands, but a firm must become profitable to remain viable and provide a return to its owners.

Liquidity is a company's ability to meet its short-term financial obligations. Even if a firm is profitable, it is often a challenge to keep enough money in the bank to meet its routine obligations in a timely manner. To do so, a firm must keep a close watch on accounts receivable and inventories. A company's **accounts receivable** is money owed to it by its customers. Its **inventory** is its merchandise, raw materials, and products waiting to be sold. If a firm allows the levels of either of these assets to get too high, it may not be able to keep sufficient cash on hand to meet its short-term obligations.[5]

Figure 15.1 Primary Financial Objectives of Entrepreneurial Firms



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Efficiency is how productively a firm utilizes its assets relative to its revenue and its profits. Southwest Airlines, for example, uses its assets very productively. Its turnaround time, or the time that its airplanes sit on the ground while they are being unloaded and reloaded, is the lowest in the airline industry. As Southwest officials are quick to point out, "Our planes don't make any money sitting on the ground—we have to get them back into the air."[6]

Stability is the strength and vigor of the firm's overall financial posture. For a firm to be stable, it must not only earn a profit and remain liquid but also keep its debt in check. If a firm continues to borrow from its lenders and its **debt-to-equity ratio,** which is calculated by dividing its long-term debt by its shareholders' equity, gets too high, it may have trouble meeting its obligations and securing the level of financing needed to fuel its growth.

An increasingly common way that small companies improve their prospects across several of these areas is to join buying groups or co-ops, where businesses band together to attain volume discounts on products and services. Gaining access to products and services this way facilitates smaller firms' efforts to compete on more of a "level playing field" with larger, more established companies. The way buying groups work, and how they're able to help businesses cut costs without adversely affecting their competitiveness, is described in this chapter's "Partnering for Success" feature.

15.3 The Process of Financial Management

To assess whether its financial objectives are being met, firms rely heavily on analyses of financial statements, forecasts, and budgets. A **financial statement** is a written report that quantitatively describes a firm's financial health. The income statement, the balance sheet, and the statement of cash flows are the financial statements entrepreneurs use most commonly. **Forecasts** are an estimate of a firm's future income and expenses, based on its past performance, its current circumstances, and its future plans.[7] New ventures typically base their forecasts on an estimate of sales and then on industry averages or the experiences of similar start-ups regarding the cost of goods sold (based on a percentage of sales) and on other expenses. **Budgets** are itemized forecasts of a company's income, expenses, and capital needs and are also an important tool for financial planning and control.[8]

The process of a firm's financial management is shown in Figure 15.2. It begins by tracking the company's past financial performance through the preparation and analysis of financial statements. These statements organize and report the firm's financial transactions. They tell a firm how much money it is making or losing (income statement), the structure of its assets and liabilities (balance sheet), and where its cash is coming from and going (statement of cash flows). The statements also help a firm discern how it stacks up against its competitors and industry norms. Most firms look at two to three years of past financial statements when preparing forecasts.

The next step is to prepare forecasts for two to three years in the future. In turn, forecasts are used to prepare a firm's pro forma financial statements, which, along with its more fine-tuned budgets, constitute its financial plan.

The final step in the process is the ongoing analysis of a firm's financial results. **Financial ratios,** which depict relationships between items on a firm's financial statements, are used to discern whether a firm is meeting its financial objectives and how it stacks up against its industry peers. These ratios are also used to assess trends. Obviously, a completely new venture would start at step 2 in Figure 15.2. It is important

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PARTNERING FOR SUCCESS

Organizing Buying Groups to Cut Costs and Maintain Competitiveness

One challenge that businesses confront is cutting costs in ways that do not erode their ability to remain competitive. Many cost-cutting techniques, such as scaling back on hiring, lowering marketing expenses, or reducing inventory, may save money but may also decrease a business's chances of remaining competitive. Joining or organizing a buying group is one technique that can help to conserve a product-based business's financial assets without adverse side effects.

A buying group, or buying co-op, is a partnership that bands small businesses and start-up firms together to attain volume discounts on products and services. An example is Intercounty Appliance, a buying co-op for 105 independent appliance stores in the Northeast. The co-op aggregates the purchasing power of its members to get volume discounts on appliances and other items such as flat-screen TVs. A similar buying group is ADO, a group that services eye care professionals. ADO Buying Group has relationships with a large number of vendors to obtain discount prices on glasses, contacts, and other supplies for its members.

An example of a much larger buying co-op is the Independent Pharmacy Cooperative (IPC) which was founded in Madison, Wisconsin, in 1984. It has since grown into the nation's largest purchasing organization for independent pharmacies with over 4,500 pharmacy members. IPC is one of the major reasons that independent pharmacies are able to compete against Walgreens, Walmart, and CVS. There are similar buying co-ops in other industries.

The beauty of buying groups is that they generally allow businesses to obtain the exact same product for a lower price, with no undesirable impact (other than the membership fee) on the other parts of their operations. The money that's freed up can go directly to a business's bottom line or be used to invest in customer service or other methods to increase competitiveness. There is no national directory of industry buying groups. The best way to find out whether there are buying groups servicing an industry is to conduct Internet research and ask industry participants.

Questions for Critical Thinking

1. Which of the four financial objectives of a firm, profitability, liquidity, efficiency, or stability, does participating in a buying cooperative contribute to the most?
2. Do some Internet and/or library research to try to discern whether there is a small business buying group or groups that New Venture Fitness Drinks, the fictitious company introduced in Chapter 14 and used as an example throughout this chapter, could benefit from. New Venture Fitness Drinks's products contain all the ingredients used to make smoothies and similar fitness drinks and shakes.
3. Identify three ways, other than buying cooperatives, that small businesses partner with other small businesses to cut costs without sacrificing their competitiveness.
4. In an effort to improve the financial position of their firms, do you think the majority of entrepreneurs spend an equal amount of time focusing on (1) cost cutting and (2) increasing revenues? If not, which of the two do you think they spend more time on and why?

that a new venture be familiar with the entire process, however. Typically, new ventures prepare financial statements quarterly so that as soon as the first quarter is completed, the new venture will have historic financial statements to help prepare forecasts and pro forma statements for future periods.

It is important for a firm to evaluate how it is faring relative to its industry. Sometimes raw financial ratios that are not viewed in context are deceiving. For example, a firm's past three years' income statements may show that it is increasing its sales at

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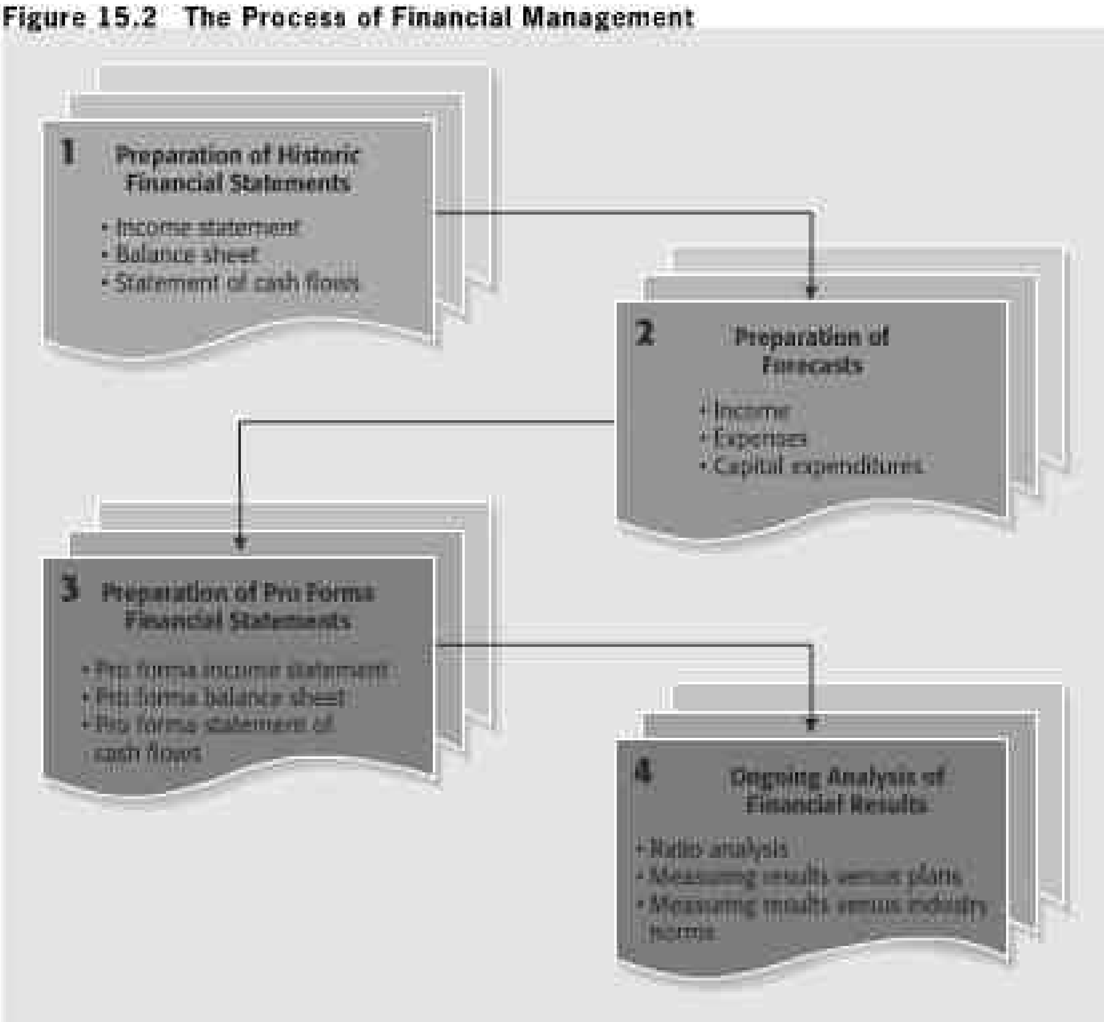
Figure 15.2 The Process of Financial Management



the industry in which the firm competes is growing at a rate of 30 percent per year, showing that the firm is steadily losing market share.

Many experienced entrepreneurs stress the importance of keeping on top of the financial management of a firm. In the competitive environments in which most firms exist, it's simply not good enough to shoot from the hip when making financial decisions. Reinforcing this point, Bill Gates, the founder of Microsoft, said,

> The business side of any company starts and ends with hard-core analysis of its numbers. Whatever else you do, if you don't understand what's happening in your business factually and you're making business decisions based on anecdotal data or gut instinct, you'll eventually pay a big price.[9]

15.4 | Financial Statements

Historical financial statements reflect past performance and are usually prepared on a quarterly and annual basis. Publicly traded firms are required by the Securities and Exchange Commission (SEC) to prepare financial statements and make them available to the public. The statements are submitted to the SEC through a number of required filings. The most comprehensive filing is the **10-K**, which is a report similar to the annual report except that it contains more detailed information about the company's business.[10]

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Pro forma financial statements are projections for future periods based on forecasts and are typically completed for two to three years in the future. Pro forma financial statements are strictly planning tools and are not required by the SEC. In fact, most companies consider their pro forma statements to be confidential and reveal them to outsiders, such as lenders and investors, only on a "need-to-know" basis.

To illustrate how these financial instruments are prepared, let's look at New Venture Fitness Drinks, the fictitious sports drink company to which you were introduced in Chapter 14. New Venture Fitness Drinks has been in business for five years. Targeting sports enthusiasts, the company sells a line of nutritional fitness drinks. It opened a single location in 2012, added a second location in 2014, and plans to add a third in 2015. The company's strategy is to place small restaurants, similar to smoothie restaurants, near large outdoor sports complexes. The company is profitable and is growing at a rate of 25 percent per year.

15.4.1 Historical Financial Statements

Historical financial statements include the income statement, the balance sheet, and the statement of cash flows. The statements are usually prepared in this order because information flows logically from one to the next. In start-ups, financial statements are typically scrutinized closely to monitor the financial progress of the firm. On the rare occasion when a company has not used financial statements in planning, it should prepare and maintain them anyway. If a firm goes to a banker or investor to raise funds, the banker or investor will invariably ask for copies of past financial statements to analyze

Keeping good records is the first step toward prudent financial management. This entrepreneur, who is the owner of a barbeque restaurant, takes a minute at the end of a busy day to add several receipts to his records.

DreamPictures/Blend Images/Corbis

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the firm's financial history. If a firm does not have these statements, it may be precluded from serious consideration for an investment or a loan. Let's look at each of these statements.

Income Statement

The **income statement** reflects the results of the operations of a firm over a specified period of time.[11] It records all the revenues and expenses for the given period and shows whether the firm is making a profit or is experiencing a loss (which is why the income statement if often referred to as the "profit-and-loss statement"). Income statements are typically prepared on a monthly, quarterly, and annual basis. Most income statements are prepared in a multiyear format, making it easy to spot trends.

The consolidated income statement for the past three years for New Venture Fitness Drinks is shown in Table 15.1. The value of the multi period format is clear. It's easy to see that the company's sales are increasing at the rate of about 25 percent per year, it is profitable, and its net income is increasing. The numbers are used to evaluate the effect of past strategies and to help project future sales and earnings.

The three numbers that receive the most attention when evaluating an income statement are the following:

- **Net sales: Net sales** consist of total sales minus allowances for returned goods and discounts.
- **Cost of sales (or cost of goods sold): Cost of sales** includes all the direct costs associated with producing or delivering a product or service, including the material costs and direct labor. In the case of New Venture Fitness Drinks, this would

Table 15.1 Consolidated Income Statements for New Venture Fitness Drinks, Inc.

	December 31, 2014	December 31, 2013	December 31, 2012
Net sales	$586,600	$463,100	$368,900
Cost of sales	268,900	225,500	201,500
Gross profit	317,700	237,600	167,400
Operating expenses			
Selling, general, and administrative expenses	117,800	104,700	90,200
Depreciation	13,500	5,900	5,100
Operating income	186,400	127,000	72,100
Other income			
Interest income	1,900	800	1,100
Interest expense	(15,000)	(6,900)	(6,400)
Other income (expense), net	10,900	(1,300)	1,200
Income before income taxes	184,200	119,600	68,000
Income tax expense	53,200	36,600	18,000
Net income	131,000	83,000	50,000
Earnings per share	1.31	0.83	0.50

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include the ingredients that go into the fitness drinks and the labor needed to produce them.

- **Operating expenses: Operating expenses** include marketing, administrative costs, and other expenses not directly related to producing a product or service.

One of the most valuable things that entrepreneurs and managers do with income statements is to compare the ratios of cost of sales and operating expenses to net sales for different periods. For example, the cost of sales for New Venture Fitness Drinks, which includes the ingredients for its fitness drinks and the labor needed to make them, has been 55, 49, and 46 percent of sales for 2012, 2013, and 2014, respectively. This is a healthy trend. It shows that the company is steadily decreasing its material and labor costs per dollar of sales. This is the type of trend that can be noticed fairly easily by looking at a firm's multiyear income statements.

Profit margin is a ratio that is of particular importance when evaluating a firm's income statements. A firm's **profit margin,** or return on sales, is computed by dividing net income by net sales. For the years 2012, 2013, and 2014, the profit margin for New Venture Fitness Drinks has been 13.6, 17.9, and 22.3 percent, respectively. This is also a healthy trend. A firm's profit margin tells it what percentage of every dollar in sales contributes to the bottom line. An increasing profit margin means that a firm is either boosting its sales without increasing its expenses or that it is doing a better job of controlling its costs. In contrast, a declining profit margin means that a firm is losing control of its costs or that it is slashing prices to maintain or increase sales.

One ratio that will not be computed for New Venture Fitness Drinks is **price-to-earnings ratio, or P/E ratio.** New Venture Fitness Drinks is incorporated, so it has stock, but its stock is not traded on a public exchange such as the NASDAQ or the New York Stock Exchange. P/E is a simple ratio that measures the price of a company's stock against its earnings.[12] Generally, the higher a company's price-to-earnings ratio goes, the greater the market thinks it will grow. In 2014, New Venture Fitness Drinks earned $1.31 per share. If it was listed on the NASDAQ and its stock was trading at $20 per share, its P/E would be 15.3. This is what is meant when you hear that a company is selling for "15 times earnings."

The importance of looking at several years of income statements rather than just one is illustrated in this chapter's "Savvy Entrepreneurial Firm" feature.

Balance Sheet

Unlike the income statement, which covers a specified *period* of time, a **balance sheet** is a snapshot of a company's assets, liabilities, and owners' equity at a specific *point* in time.[13] The left-hand side of a balance sheet (or the top, depending on how it is displayed) shows a firm's assets, while the right-hand side (or bottom) shows its liabilities and owners' equity. The assets are listed in order of their "liquidity," or the length of time it takes to convert them to cash. The liabilities are listed in the order in which they must be paid. A balance sheet must always "balance," meaning that a firm's assets must always equal its liabilities plus owners' equity.[14]

The major categories of assets listed on a balance sheet are the following:

- **Current assets: Current assets** include cash plus items that are readily convertible to cash, such as accounts receivable, marketable securities, and inventories.
- **Fixed assets: Fixed assets** are assets used over a longer time frame, such as real estate, buildings, equipment, and furniture.
- **Other assets: Other assets** are miscellaneous assets, including accumulated goodwill.

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SAVVY ENTREPRENEURIAL FIRM

Know the Facts Behind the Numbers

Let's say that New Venture Fitness Drinks was interested in hiring a new chief executive officer (CEO) and was interviewing the CEOs of three small restaurant chains. To get a sense of how savvy each candidate was at managing a firm's finances, the board of directors of New Venture Fitness Drinks asked each person to submit the 2014 income statement for his or her current firm. An analysis of an abbreviated version of each firm's income statement is shown here.

	Candidate 1: CEO of New Venture Soup and Salad	Candidate 2: CEO of New Venture Beef	Candidate 3: CEO of New Venture Sea Food
Net sales	$326,400	$281,200	$486,700
Cost of sales	150,500	143,900	174,700
Gross profit	175,900	137,300	312,000
All expenses, including taxes and depreciation	114,200	112,400	150,000
Net income	61,700	24,900	162,000

By glancing at these statements, it would appear that the shrewdest financial manager of the three is the CEO of New Venture Sea Food. The company's net income is more than double that of the other two firms. In addition, New Venture Sea Food's cost of sales was 35.9 percent of net sales in 2014, compared to 46.1 percent for New Venture Soup and Salad and 51 percent for New Venture Beef. Similarly, New Venture Sea Food's expenses were 30.9 percent of sales, compared to 35.0 percent for New Venture Soup and Salad and 40 percent for New Venture Beef.

Fortunately, one of the board members of New Venture Fitness Drinks asked a series of questions during the personal interviews of the candidates and uncovered some revealing information. As it turns out, New Venture Sea Food was in the hottest segment of the restaurant industry in 2014. Seafood restaurants of comparable size produced about 1.5 times as much net income as New Venture Sea Food did. So if candidate 3 had done his job properly, his company's net income should have been in the neighborhood of $240,000 instead of $162,000. New Venture Soup and Salad was in a slow-growth area and at midyear feared that it might not meet its financial targets. So the CEO pulled several of his best people off projects and reassigned them to marketing to develop new menu items. In other words, the company borrowed from its future to make its numbers work today.

As for New Venture Beef, the CEO found herself in a market that was losing appeal. Several reports that gained national publicity were published early in the year warning consumers of the risks of eating red meat. To compensate, the CEO quickly implemented a productivity improvement program and partnered with a local beef promotion board to counter the bad press with more objective research results about beef's nutritional value. The company also participated in several volunteer efforts in its local community to raise the visibility of its restaurants in a positive manner. If the CEO of New Venture Beef hadn't moved quickly to take these actions, its 2014 performance would have been much worse.

Ultimately, New Venture Fitness Drinks decided that candidate 2, the CEO of New Venture Beef, was the best candidate for its job.

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This example illustrates the need to look at multiple years of an income statement rather than a single year to fairly assess how well a firm is performing financially. It also illustrates the need to look beyond the numbers and understand the circumstances that surround a firm's financial results.

Questions for Critical Thinking

1. Show the income statements for the three candidates to two or three friends who are majoring in business. Ask them to select the best CEO from among these three people on the basis of these income statements. In addition, ask your friends to explain their choices to you. Did your friends choose the same candidate? If not, what do you think caused the differences in their choices?
2. Based on material presented in this chapter, earlier chapters in this book, and your general business knowledge, where would you go to find information about the growth of the different segments of the restaurant industry? Where would you go to find information about the profitability of the restaurant industry in general?
3. What would have been the appropriate financial information to request from the three candidates for the job?
4. What are the three most important insights you gained from studying this feature? Which of these insights surprised you, and why?

The major categories of liabilities listed on a balance sheet are the following:

- **Current liabilities: Current liabilities** include obligations that are payable within a year, including accounts payable, accrued expenses, and the current portion of long-term debt.
- **Long-term liabilities: Long-term liabilities** include notes or loans that are repayable beyond one year, including liabilities associated with purchasing real estate, buildings, and equipment.
- **Owners' equity: Owners' equity** is the equity invested in the business by its owners plus the accumulated earnings retained by the business after paying dividends.

Balance sheets are somewhat deceiving. First, a company's assets are recorded at cost rather than fair market value. A firm may have invested $500,000 in real estate several years ago that is worth $1 million today, but the value that is reflected on the firm's current balance sheet is the $500,000 purchase price rather than the $1 million fair market value. Second, intellectual property, such as patents, trademarks, and copyrights, receive value on the balance sheet in some cases and in some cases they don't, depending on the circumstances involved. In many cases, a firm's intellectual property will receive no value on its balance sheet even though it may be very valuable from a practical standpoint.[15] Third, intangible assets, such as the amount of training a firm has provided to its employees and the value of its brand, are not recognized on its balance sheet. Finally, the goodwill that a firm has accumulated is not reported on its balance sheet, although this may be the firm's single most valuable asset.

The consolidated balance sheet for New Venture Fitness Drinks is shown in Table 15.2. Again, multiple years are shown so that trends can be easily spotted. When evaluating a balance sheet, the two primary questions are whether a firm has sufficient short-term assets to cover its short-term debts and whether it is financially sound overall. There are two calculations that provide the answer to the first question. In 2014, the **working capital** of New Venture Fitness Drinks, defined as its current assets minus its current liabilities, was $82,500. This number represents the amount of liquid assets the firm has available. Its **current ratio,** which equals the firm's current assets divided by its current liabilities, provides another picture of the relationship between its current assets

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Table 15.2 Consolidated Balance Sheets for New Venture Fitness Drinks, Inc.

Assets	December 31, 2014	December 31, 2013	December 31, 2012
Current assets			
Cash and cash equivalents	$63,800	$54,600	$56,500
Accounts receivable, less allowance for doubtful accounts	39,600	48,900	50,200
Inventories	19,200	20,400	21,400
Total current assets	122,600	123,900	128,100
Property, plant, and equipment			
Land	260,000	160,000	160,000
Buildings and equipment	412,000	261,500	149,000
Total property, plant, and equipment	672,000	421,500	309,000
Less: accumulated depreciation	65,000	51,500	45,600
Net property, plant, and equipment	607,000	370,000	263,400
Total assets	729,600	493,900	391,500
Liabilities and shareholders' equity			
Current liabilities			
Accounts payable	30,200	46,900	50,400
Accrued expenses	9,900	8,000	4,100
Total current liabilities	40,100	54,900	54,500
Long-term liabilities			
Long-term debt	249,500	130,000	111,000
Long-term liabilities	249,500	130,000	111,000
Total liabilities	289,600	184,900	165,500
Shareholders' equity			
Common stock (100,000 shares)	10,000	10,000	10,000
Retained earnings	430,000	299,000	216,000
Total shareholders' equity	440,000	309,000	226,000
Total liabilities and shareholders' equity	729,600	493,900	391,500

and current liabilities and can tell us more about the firm's ability to pay its short-term debts.

New Venture Fitness Drinks's current ratio is 3.06, meaning that it has $3.06 in current assets for every $1.00 in current liabilities. This is a healthy number and provides confidence that the company will be able to meet its current liabilities. The company's trend in this area is also positive. For the years 2012, 2013, and 2014, its current ratio has been 2.35, 2.26, and 3.06, respectively.

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Computing a company's overall debt ratio will give us the answer to the second question, as it is a means of assessing a firm's overall financial soundness. A company's debt ratio is computed by dividing its total debt by its total assets. The present debt ratio for New Venture Fitness Drinks is 39.7 percent, meaning that 39.7 percent of its total assets are financed by debt and the remaining 60.3 percent by owners' equity. This is a healthy number for a young firm. The trend for New Venture Fitness Drinks in this area is also encouraging. For the years 2012, 2013, and 2014, its debt ratio has been 42.3, 37.4, and 39.7 percent, respectively. These figures indicate that over time, the company is relying less on debt to finance its operations. In general, less debt creates more freedom for the entrepreneurial firm in terms of taking different actions.

The numbers across all the firm's financial statements are consistent with one another. Note that the $131,000 net income reported by New Venture Fitness Drinks on its 2014 income statement shows up as the difference between its 2014 and 2013 retained earnings on its 2014 balance sheet. This number would have been different if New Venture Fitness Drinks had paid dividends to its stockholders, but it paid no dividends in 2014. The company retained all of its $131,000 in earnings.

Statement of Cash Flows

The **statement of cash flows** summarizes the changes in a firm's cash position for a specified period of time and details why the change occurred. The statement of cash flows is similar to a month-end bank statement. It reveals how much cash is on hand at the end of the month as well as how the cash was acquired and spent during the month.

The statement of cash flows is divided into three separate activities: operating activities, investing activities, and financing activities. These activities, which are explained in the following list, are the activities from which a firm obtains and uses cash:

- **Operating activities: Operating activities** include net income (or loss), depreciation, and changes in current assets and current liabilities other than cash and short-term debt. A firm's net income, taken from its income statement, is the first line on the corresponding period's cash flow statement.
- **Investing activities: Investing activities** include the purchase, sale, or investment in fixed assets, such as real estate, equipment, and buildings.
- **Financing activities: Financing activities** include cash raised during the period by borrowing money or selling stock and/or cash used during the period by paying dividends, buying back outstanding stock, or buying back outstanding bonds.

Interpreting and analyzing cash flow statements takes practice. On the statement, the *uses* of cash are recorded as negative figures (which are shown by placing them in parentheses) and the *sources* of cash are recorded as positive figures. An item such as depreciation is shown as a positive figure on the statement of cash flows because it was deducted from net income on the income statement but was not a cash expenditure. Similarly, a decrease in accounts payable shows up as a negative figure on the cash flow statement because the firm used part of its cash to reduce its accounts payable balance from one period to the next.

The statement of cash flows for New Venture Fitness Drinks is shown in Table 15.3. As a management tool, it is intended to provide perspective on the following questions: Is the firm generating excess cash that could be used to pay down debt or returned to stockholders in the form of dividends? Is the firm generating enough cash to fund its investment activities from earnings, or is it relying on lenders or investors? Is the firm generating sufficient cash to pay down its short-term liabilities, or are its short-term lia-

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Table 15.3 Consolidated Statement of Cash Flows for New Venture Fitness Drinks, Inc.

	December 31, 2014	December 31, 2013
Cash flows from operating activities		
Net income	$131,000	$83,000
Additions (sources of cash)		
Depreciation	13,500	5,900
Decreases in accounts receivable	9,300	1,300
Increase in accrued expenses	1,900	3,900
Decrease in inventory	1,200	1,000
Subtractions (uses of cash)		
Decrease in accounts payable	(16,700)	(3,500)
Total adjustments	9,200	8,600
Net cash provided by operating activities	140,200	91,600
Cash flows from investing activities		
Purchase of building and equipment	(250,500)	(112,500)
Net cash flows provided by investing activities	(250,500)	(112,500)
Cash flows from financing activities		
Proceeds from increase in long-term debt	119,500	19,000
Net cash flows provided by financing activities		19,000
Increase in cash	9,200	(1,900)
Cash and cash equivalents at the beginning of each year	54,600	56,500
Cash and cash equivalents at the end of each year	63,800	54,600

Again, a multi period statement is created so that trends can easily be spotted. A large increase in a firm's cash balance is not necessarily a good sign. It could mean that the firm is borrowing heavily, is not paying down its short-term liabilities, or is accumulating cash that could be put to work for a more productive purpose. On the other hand, it is almost always prudent for a young firm to have a healthy cash balance.

Table 15.3 shows the consolidated statement of cash flows for New Venture Fitness Drinks for two years instead of three because it takes three years of balance sheets to produce two years of cash flow statements. The statements show that New Venture Fitness Drinks is funding its investment activities from a combination of debt and earnings while at the same time it is slowly decreasing its accounts receivable and inventory levels (which is good—these items are major drains on a company's cash flow). It is also steadily increasing its cash on hand. These are encouraging signs for a new venture.

Ratio Analysis

The most practical way to interpret or make sense of a firm's historical financial statements is through ratio analysis. Table 15.4 is a summary of the ratios used to evaluate New Venture Fitness Drinks during the time period covered by the previously provided financial statements. The ratios are divided into profitability ratios, liquidity ratios, and overall financial stability ratios. These ratios provide a means of interpreting the historical financial statements for New Venture Fitness Drinks and provide a starting point for

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Table 15.4 Ratio Analysis for New Venture Fitness Drinks, Inc.

Ratio	Formula	2014	2013	2012
Profitability ratios: associate the amount of income earned with the resources used to generate it				
Return on assets	ROA = net income/average total assets[a]	21.4%	18.7%	14.7%
Return on equity	ROE = net income/average shareholders' equity[b]	35.0%	31.0%	24.9%
Profit margin	Profit margin = net income/net sales	22.3%	17.9%	13.6%
Liquidity ratios: measure the extent to which a company can quickly liquidate assets to cover short-term liabilities				
Current	Current assets/current liabilities	3.06%	2.26%	2.35%
Quick	Quick assets/current liabilities	2.58%	1.89%	1.96%
Overall financial stability ratio: measures the overall financial stability of a firm				
Debt	Total debt/total assets	39.7%	37.4%	42.3%
Debt to equity	Total liabilities/owners' equity	65.8%	59.8%	73.2%

[a] Average total assets = beginning total assets + ending total assets ÷ 2.

[b] Average shareholders' equity = beginning shareholders' equity + ending shareholders' equity ÷ 2.

Comparing a Firm's Financial Results to Industry Norms

Comparing its financial results to industry norms helps a firm determine how it stacks up against its competitors and if there are any financial "red flags" requiring attention. This type of comparison works best for firms that are of similar size, so the results should be interpreted with caution by new firms. Many sources provide industry-related information. For example, both Hoover's premium service and BizMiner provide industry norms to which a new firm can compare itself and are typically free of charge if accessed via a university library. BizMiner (www.bizminer.com) is particularly good for providing comparison data for private firms. Several suggestions for obtaining comparison data for private firms are provided in Chapter 14.

15.5 Forecasts

As depicted in Figure 15.2, the analysis of a firm's historical financial statement is followed by the preparation of forecasts. **Forecasts** are predictions of a firm's future sales, expenses, income, and capital expenditures. A firm's forecasts provide the basis for its pro forma financial statements. A well-developed set of pro forma financial statements helps a firm create accurate budgets, build financial plans, and manage its finances in a proactive rather than a reactive manner.

As mentioned earlier, completely new firms typically base their forecasts on a good-faith estimate of sales and on industry averages (based on a percentage of sales) or the experiences of similar start-ups for cost of goods sold and other expenses. As a result, a completely new firm's forecast should be preceded in its business plan by an explanation of the sources of the numbers for the forecast and the assumptions used to generate them. This explanation is called an **assumptions sheet,** as mentioned in Chapter 16. Investors

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typically study assumptions sheets like hawks to make sure the numbers contained in the forecasts and the resulting financial projections are realistic. For example, the assumptions sheet for a new venture may say that its forecasts are based on selling 500 units of its new product the first year, 1,000 units the second year, and 1,500 units the third year, and that its cost of goods sold will remain stable (meaning that it will stay fixed at a certain percentage of net sales) over the three-year period. It's up to the reader of the plan to determine if these numbers are realistic.[16] If the reader feels they are not, then the credibility of the entire plan is called into question.

15.5.1 Sales Forecast

A **sales forecast** is a projection of a firm's sales for a specified period (such as a year), though most firms forecast their sales for two to five years into the future.[17] It is the first forecast developed and is the basis for most of the other forecasts.[18] A sales forecast for an existing firm is based on (1) its record of past sales, (2) its current production capacity and product demand, and (3) any factor or factors that will affect its future production capacity and product demand. To demonstrate how a sales forecast works, Figure 15.3 is a graph of the past sales and the forecasted future sales for New Venture Fitness Drinks. The company's sales increased at a rate of about 26 percent per year from 2012 to 2014 as the company became established and more people became aware of its brand. In forecasting its sales for 2015 and 2016, the company took into consideration the following factors:

- The fitness craze in America continues to gain momentum and should continue to attract new people to try its fitness drinks.
- The interest in intramural sports, especially soccer, baseball, and softball, should continue to provide a high level of traffic for its restaurants, which are located near large intramural sports complexes.
- The company expanded from a single location in 2011 to two locations in 2014 (the second restaurant was added in November 2014), and this should increase its capacity to serve fitness drinks by approximately 50 percent. The second restaurant

Figure 15.3 Historical and Forecasted Annual Sales for New Venture Fitness Drinks

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is smaller than the first and is located in an area where the company is not as well known. The company will be actively promoting the new restaurant but knows it will take time to win market share.

- The general economy in the city where the company is located is flat—it is neither growing nor shrinking. However, layoffs are rumored for a larger employer near the location of the new restaurant.

The combination of these factors results in a forecast of a 40 percent increase in sales from 2014 to 2015 and a 25 percent increase in sales from 2015 to 2016. It is extremely important for a company such as New Venture Drinks to forecast future sales as accurately as possible. If it overestimates the demand for its products, it might get stuck with excess inventory and spend too much on overhead. If it underestimates the demand for its product, it might have to turn away business, and some of its potential customers might get into the habit of buying other firms' fitness drinks.

Note that sophisticated tools are available to help firms project their future sales. One approach is to use **regression analysis,** which is a statistical technique used to find relationships between variables for the purpose of predicting future values.[19] For example, if New Venture Fitness Drinks felt that its future sales were a function of its advertising expenditures, the number of people who participate in intramural sports at the sports complexes near its restaurants, and the price of its drinks, it could predict future sales using regression analysis as long as it had historical data for each of these variables. If the company used simpler logic and felt that its future sales would increase a certain percentage over its current sales, regression analysis could be used to generate a more precise estimate of future sales than was predicted from the information contained in Figure 15.3. For a new firm that has limited years of "annual data," monthly data could be used to project sales.

15.5.2 Forecast of Costs of Sales and Other Items

After completing its sales forecast, a firm must forecast its cost of sales (or cost of goods sold) and the other items on its income statement. The most common way to do this is to use the **percent-of-sales method,** which is a method for expressing each expense item as a percentage of sales.[20] For example, in the case of New Venture Fitness Drinks, its cost of sales has averaged 47.5 percent over the past two years. In 2014, its sales were $586,600 and its cost of sales was $268,900. The company's sales are forecast to be $821,200 in 2015. Therefore, based on the percent-of-sales method, its cost of sales in 2015 will be $390,000, or 47.5 percent of projected sales. The same procedure could be used to forecast the cost of each expense item on the company's income statement.

Once a firm completes its forecast using the percent-of-sales method, it usually goes through its income statement on an item-by-item basis to see if there are opportunities to make more precise forecasts. For example, a firm can closely estimate its depreciation expenses, so it wouldn't be appropriate to use the percent-of-sales method to make a forecast for this item. In addition, some expense items are not tied to sales. For those items, the firm makes reasonable estimates.

Obviously, a firm must apply common sense in using the percent-of-sales method. If a company is implementing cost-cutting measures, for example, it might be able to justify projecting a smaller percentage increase in expenses as opposed to sales. Similarly, if a firm hires an upper-level manager, such as a chief financial officer, toward the end of the year and plans to pay the person $100,000 the next year, that $100,000 may not have an immediate impact on sales. In this case, the firm's forecast for administrative expenses may have to be adjusted upward beyond what the percent-of-sales method would suggest.

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If a firm determines that it can use the percent-of-sales method and it follows the procedure described previously, then the net result is that each expense item on its income statement (with the exception of those items that may be individually forecast, such as depreciation) will grow at the same rate as sales. This approach is called the **constant ratio method of forecasting.** This approach will be used in preparing the pro forma financial statements for New Venture Fitness Drinks in the next section.

A summary of the forecasts used to prepare the pro forma financial statements for New Venture Fitness Drinks is provided in Table 15.5.

In addition to computing sales forecasts, when a company like New Venture Fitness Drinks considers opening a new restaurant or producing a new product, it often calculates a break-even analysis to determine if the proposed initiative is feasible. The **break-even point** for a new restaurant or product is the point where total revenue received equals total costs associated with the output of the restaurant or the sale of the product.[21] In the case of opening a new restaurant, New Venture Fitness Drinks could use break-even analysis as one way of determining whether the proposed initiative is feasible. The formula for

Table 15.5 Forecasts Used to Prepare Pro Forma Financial Statements for New Venture Fitness Drinks, Inc.

Pro Forma Income Statements	
Net sales	
Historic	Average sales increase of 25% per year
2015	Increase to 40% as the result of increased brand awareness and the opening of a second service location
2016	Increase to 25% as the result of increased brand awareness (a third service location will be opened late in the year)
Cost of goods sold (COGS)	
Historic	Average of 47.5% of sales the past two years
2015	47.5% of sales
2016	47.5% of sales
Selling, general, and administrative expenses	
Historic	Average 22% of sales the past two years
2015	Increase to 25% of sales as the result of the opening of a second service location (the increase will not be any larger as the result of increased operating efficiencies)
2016	25% of sales
Interest expense	
Historic	6% to 7% of long-term debt
2015	7% of long-term debt
2016	7% of long-term debt
Other income	
Historic	Licensing income of $10,900 per year
2015	Licensing income will increase to $20,000 as the result of the renegotiation of the licensing contract
2016	Licensing income will be $20,000

(continued)

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Table 15.5 Continued

Pro Forma Balance Sheets	
Accounts receivable	
Historic	Accounts receivable have trended down to 6.8% of sales in 2014 from 13.6% of sales in 2013
2015	7% of sales
2016	7% of sales
Inventories	
Historic	Inventories have trended down to 3.3% of sales in 2014 from 4.4% of sales in 2013
2015	4% of sales (reflecting slight increase over 2014 as the result of the opening of a second service location)
2016	4% of sales
Land, buildings, and equipment	
2015	$100,000 in equipment purchases and capital improvements made to existing buildings
2016	$275,000 in capital improvements, including a $100,000 real estate purchase and $175,000 in buildings and equipment
Accounts payable	
Historic	Accounts payable have trended down to 5.1% of sales in 2014 from 13.6% of sales in 2013 because of the implementation of more effective collection methods (a slightly higher level of accounts payable will be projected for the future)
2015	7% of sales
2016	7% of sales
Long-term debt	
2015	$75,000 reduction in long-term debt from earnings
2016	$150,000 will be borrowed to finance $275,000 to acquire land, equipment, and buildings (the balance of the acquisition costs will be funded from earnings)

break-even analysis is as follows: Total fixed costs/(price – average variable costs). In most instances, average variable cost is the same number as average cost of goods sold. As a result, if the total fixed cost associated with opening a new restaurant is $101,000 per year, the average price for a fitness drink is $2.75, and the variable cost (or cost of goods sold) for each drink is $1.10, then the break-even point for the new restaurant is as follows:

$101,000 (total fixed costs)/($2.75 − $1.10) or $1.65 = 61,212 units

This number means that the new restaurant will have to sell 61,212 "units," or fitness drinks, per year to "break even" at the current price of the drinks. That number breaks down to the sale of 170 fitness drinks per day, on average, based on a 360-day year. To determine whether opening the new restaurant is feasible, the managers of New Venture Fitness Drinks would compare this number against the historic sales figures for their other restaurants, making adjustments as appropriate (e.g., the new restaurant may have a better or worse location than the existing restaurants). If selling 170 fitness drinks per

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day seems unrealistic, then the managers of New Fitness Drinks might opt to not open the new restaurant, or find ways to lower fixed or variable costs or increase revenues. An obvious way to increase revenues is to raise the price of the fitness drinks, if that option is realistic given the competitive nature of the marketplace.

15.6 Pro Forma Financial Statements

A firm's pro forma financial statements are similar to its historical financial statements except that they look forward rather than track the past. New ventures typically offer pro forma statements, but well-managed established firms also maintain these statements as part of their routine financial planning process and to help prepare budgets. The preparation of pro forma statements also helps firms rethink their strategies and make adjustments if necessary. For example, if the pro forma statements predict a downturn in profitability, a firm can make operational changes, such as increasing prices or decreasing expenses, to help prevent the decrease in profitability from actually happening.[22]

A firm's pro forma financial statements should not be prepared in isolation. Instead, they should be created in conjunction with the firm's overall planning activities. For example, it's often critical to have a good sense of how quickly a firm can raise money. Sometimes a firm has a good product or service, good demand, and knows how much capital it needs to maintain a sufficient cash flow, but it can't raise the money in time. This is what happened to Wise Acre Frozen Treats, as illustrated in this chapter's "What Went Wrong?" feature. The Wide Acre Frozen Treats case is a good example of how

Pro forma financial statements look forward rather than backwards. They help entrepreneurs establish budgets and plan for the future.

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WHAT WENT WRONG?

Be Careful What You Wish For: How Growing Too Quickly Overwhelmed One Company's Cash Flow

When Jim Picariello started Wise Acre Frozen Treats, no other company was making organic popsicles from unrefined sweeteners. Working out of a makeshift kitchen in 2006, Picariello developed his recipes using maple syrup and honey. He worked alone for a year and a half before hiring his first employee. About that time, his frozen popsicles really took off; by 2008, Wise Acre Frozen Treats had 15 employees, a 3,000-square-foot manufacturing facility, and was distributing its product to natural food stores and supermarkets across the East Coast. The company was awarded a contract to distribute to the West Coast. Then, abruptly, Wise Acre Frozen Treats failed. What went wrong?

Here's what happened. In its first year, Wise Acre Frozen Treats grew at a measured pace. It was filling orders for eight stores for a few hundred dollars each, nothing Picariello couldn't handle. Early in its second year, it won the "Most Innovative Product" award out of more than 2,000 products at a large food show called Expo East. That award increased Wise Acre Frozen Treats's profile, and it landed a contract with United National Foods, a huge national distributor, for freezer space in premier stores like Whole Foods and Wegmans. At that time, it seemed that things couldn't have worked out better.

Picariello knew he'd need to raise capital to cover the increased pace of activity. Operating expenses including labor, equipment, ingredients, packaging material, insurance, and design and marketing would all increase. Picariello obtained $300,000 from a local bank and $200,000 from an investment firm. But because Wise Acre Frozen Treats had so many orders to fill, it needed about $1 million to make things work. Picariello approached a local high-net-worth individual who agreed to invest $1 million, and who assured Picariello that he could put together the money quickly. Based on that promise, Picariello placed orders for the additional material and equipment Wise Acre Frozen Treats needed.

The timing of the investor's promise couldn't have been worse. In short order, the economy tanked and the investor reneged on his promise. At that point, Picariello characterized his life as a mad dash between running the company and meeting with potential investors. In regard to potential investors, Wise Acre Frozen Treats found itself in somewhat of a no-man's-land. Although its future was bright, the entrepreneurial venture wasn't big enough yet for investors to take notice. As time went on, serious cash flow difficulties kicked in. According to a blog post that Picariello wrote about Wise Acre Frozen Treats's failure, the company was burning through about $30,000 a month at its peak but didn't have the capital to back it up.

In retrospect, many things lined up well for Wise Acre Frozen Treats. It had a product that sold well, it had national distribution, and it had a business plan that indicated that it would take about two years for the company to break even. Its fatal flaw was that it didn't raise the money it needed before it hit major milestones, like getting the big orders. It literally went from eight stores to dozens to hundreds in a matter of months. From a cash standpoint, the firm lacked what it needed to keep up with its growth.

Questions for Critical Thinking

1. What lessons can be learned from Jim Picariello's agreement with the high-net-worth individual, who agreed to invest $1 million in Wise Acre Frozen Treats and then reneged on the agreement when the economy turned sour?
2. Why is it that a company can grow too fast? If Wise Acre Frozen Treats significantly increased its sales, why wouldn't its increased income provide more than enough cash to even out its cash flow?
3. Besides cash flow difficulties, what other problems can a firm experience by growing too quickly?
4. If Jim Picariello starts another company, make a list of the things you think he'll do differently as a result of his Wise Acre Frozen Treats experience.

Sources: J. Picariello, "My Company Grew Too Fast—and Went Out of Business," CBS Moneywatch, available at http://www.cbsnews.com/news/my-company-grew-too-fast-and-went-out-of-business/, posted on August 12, 2010, accessed on August 28, 2014; L. Petrecca, "Fast Growth Isn't Always Good: A Big Influx of Orders Can Be Overwhelming," *USA Today*, September 13, 2010, 1B.

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one aspect of financial management (i.e., raising money) can have a dramatic impact on another aspect of financial management (i.e., maintaining a sufficient cash flow).

The following sections explain the development of pro forma financial statements for New Venture Fitness Drinks.

15.6.1 Pro Forma Income Statement

Once a firm forecasts its future income and expenses, the creation of the **pro forma income statement** is merely a matter of plugging in the numbers. Table 15.6 shows the pro forma income statement for New Venture Fitness Drinks. Recall that net sales for New Venture Fitness Drinks are forecast to increase by 40 percent from 2014 to 2015 and by 25 percent from 2015 to 2016, and that its cost of sales has averaged 47.5 percent of net sales. In the pro forma income statement, the constant ratio method of forecasting is used to forecast the cost of sales and general and administrative expenses, meaning that these items are projected to remain at the same percentage of sales in the future as they were in the past (which is the mathematical equivalent of saying that they will increase at the same rate of sales). Depreciation, other income, and several other items that are not directly tied to sales are figured separately—using reasonable estimates. The most dramatic change is "other income," which jumps significantly from 2014 to 2015. New Venture Fitness Drinks anticipates a significant increase in this category as the result of the renegotiation of a licensing agreement for one of its fitness drinks that is sold by another company.

Table 15.6 Pro Forma Income Statement for New Venture Fitness Drinks, Inc.

	2014 Actual	2015 Projected	2016 Projected
Net sales	$586,600	$821,200	$1,026,500
Cost of sales	268,900	390,000	487,600
Gross profit	317,700	431,200	538,900
Operating expenses			
Selling, general, and administrative expenses	117,800	205,300	256,600
Depreciation	13,500	18,500	22,500
Operating income	186,400	207,400	259,800
Other income			
Interest income	1,900	2,000	2,000
Interest expense	(15,000)	(17,500)	(17,000)
Other income (expense), net	10,900	20,000	20,000
Income before income taxes	184,200	211,900	264,800
Income tax expense	53,200	63,600	79,400
Net income	131,000	148,300	185,400
Earnings per share	1.31	1.48	1.85

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15.6.2 Pro Forma Balance Sheet

The **pro forma balance sheet** provides a firm a sense of how its activities will affect its ability to meet its short-term liabilities and how its finances will evolve over time. It can also quickly show how much of a firm's money will be tied up in accounts receivable, inventory, and equipment. The pro forma balance sheet is also used to project the overall financial soundness of a company. For example, a firm may have a very aggressive set of pro forma income statements that project rapidly increasing growth and profitability. However, if this rapid growth and profitability push the firm's debt ratio to 75 percent (which is extremely high), investors may conclude that there is too much risk involved for the firm to be an attractive investment.

The pro forma balance sheet for New Venture Fitness Drinks is shown in Table 15.7. Note that the company's projected change in retained earnings each year is consistent with its projected net income for the same period on its pro forma income statements. The same approach was used to construct the pro forma balance sheets as the pro forma income statements. For each item listed under current assets and current liabilities, the item's historical percentage of sales was used to project its future percentage of sales. Several of the numbers were adjusted slightly upward, such as inventory levels and accounts payable, to reflect the potential impact of the opening of the second restaurant.

In regard to property, plant, and equipment, New Venture Fitness Drinks plans to invest \$100,000 in 2015 and \$275,000 in 2016. The pro forma balance sheet shows a corresponding increase in valuation in this category for 2015 and 2016, respectively. The company's projected long-term debt for 2015 and 2016 reflects changes resulting from principal reductions from cash flow and increased borrowing to fund the property, plant, and equipment purchases just mentioned. These transactions are reflected in the pro forma statement of cash flows for New Venture Fitness Drinks.

15.6.3 Pro Forma Statement of Cash Flows

The **pro forma statement of cash flows** shows the projected flow of cash into and out of the company during a specified period. The most important function of the pro forma statement of cash flows is to project whether the firm will have sufficient cash to meet its needs. As with the historical statement of cash flows, the pro forma statement of cash flows is broken into three activities: operating activities, investing activities, and financing activities. Close attention is typically paid to the section on operating activities because it shows how changes in the company's accounts receivable, accounts payable, and inventory levels affect the cash that it has available for investing and finance activities. If any of these items increases at a rate that is faster than the company's annual increase in sales, it typically raises a red flag. For example, an increase in accounts receivable, which is money that is owed to a company by its customers, decreases the amount of cash that it has available for investment or finance activities. If accounts receivable gets out of hand, it may jeopardize a company's ability to fund its growth or service its debt.

The pro forma consolidated statement of cash flows for New Venture Fitness Drinks is shown in Table 15.8. The figures appearing on the statement come directly, or are calculated directly, from the pro forma income statement and the pro forma balance sheet. The one exception is that the last line of each statement of cash flows, which reflects the company's cash balance at the end of the period, becomes the first line of the company's balance sheet for the next period. The pro forma statement of cash flows for New Venture

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Table 15.7 Pro Forma Balance Sheets for New Venture Fitness Drinks, Inc.

Assets	December 31, 2014	Projected 2015	Projected 2016
Current assets			
Cash and cash equivalents	$63,800	$53,400	$80,200
Accounts receivable, less allowance for doubtful accounts	39,600	57,500	71,900
Inventories	19,200	32,900	41,000
Total current assets	122,600	143,800	193,100
Property, plant, and equipment			
Land	260,000	260,000	360,000
Buildings and equipment	412,000	512,000	687,000
Total property, plant, and equipment	672,000	772,000	1,047,000
Less: accumulated depreciation	65,000	83,500	106,000
Net property, plant, and equipment	607,000	688,500	941,000
Total assets	729,600	832,300	1,134,100
Liabilities and shareholders' equity			
Current liabilities			
Accounts payable	30,200	57,500	71,900
Accrued expenses	9,900	12,000	14,000
Total current liabilities	40,100	69,500	85,900
Long-term liabilities			
Long-term debt	249,500	174,500	274,500
Total long-term liabilities	249,500	174,500	274,500
Total liabilities	289,600	244,000	360,400
Shareholders' equity			
Common stock (100,000 shares)	10,000	10,000	10,000
Retained earnings	430,000	578,300	763,700
Total shareholders' equity	440,000	588,300	773,700
Total liabilities and shareholders' equity	729,600	832,300	1,134,100

Fitness Drinks shows healthy cash balances at the end of each projected period and shows that investment activities are being funded more by earnings than by debt. This scenario reflects a company that is generating sufficient cash flow to fund the majority of its growth without overly relying on debt or investment capital.

In regard to dividends, the pro forma statement of cash flows shows that New Venture Fitness Drinks is not planning to pay a dividend to its stockholders in 2015 and 2016. Recall that New Venture Fitness Drinks is incorporated and has stockholders even though it is not traded on an organized exchange. If New Venture Fitness Drinks were planning to pay a dividend, the projected dividend payments would show up under financing activities and would reduce the amount of cash available for investing and financing activities. It is

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Table 15.8 Pro Forma Statement of Cash Flows for New Venture Fitness Drinks, Inc.

	December 31, 2014	Projected 2015	Projected 2016
Cash flows from operating activities			
Net income	$131,000	$148,300	$185,400
Changes in working capital			
Depreciation	13,500	18,500	22,500
Increase (decrease) in accounts receivable	9,300	(17,900)	(14,400)
Increase (decrease) in accrued expenses	1,900	2,100	2,000
Increase (decrease) in inventory	1,200	(13,700)	(8,100)
Increase (decrease) in accounts payable	(16,700)	27,300	14,400
Total adjustments	9,200	16,300	16,400
Net cash provided by operating activities	140,200	164,600	201,800
Cash flows from investing activities			
Purchase of building and equipment	(250,500)	(100,000)	(275,000)
Net cash flows provided by investing activities	(250,500)	(100,000)	(275,000)
Cash flows from financing activities			
Proceeds from increase in long-term debt	119,500	—	100,000
Principle reduction in long-term debt		(75,000)	
Net cash flows provided by financing activities			
Increase in cash	9,200	(10,400)	26,800
Cash and cash equivalents at the beginning of the year	54,600	63,800	53,400
Cash and cash equivalents at the end of the year	63,800	53,400	80,200

common for a new firm to invest the majority of its cash in activities that fund its growth, such as property, plant, and equipment purchases, rather than pay dividends.

15.6.4 Ratio Analysis

The same financial ratios used to evaluate a firm's historical financial statements should be used to evaluate the pro forma financial statements. This work is completed so the firm can get a sense of how its projected financial performance compares to its past performance and how its projected activities will affect its cash position and its overall financial soundness.

The historical financial ratios and projected ratios for New Venture Fitness Drinks are shown in Table 15.9. The profitability ratios show a slight decline from the historical period to the projected. This indicates that the projected increase in assets and corresponding sales will not produce income quite as efficiently as has been the case historically. Still, the numbers are strong, and no dramatic changes are projected.

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Table 15.9 Ratio Analysis of Historical and Pro Forma Financial Statements for New Venture Fitness Drinks, Inc.

	Historical			*Projected*	
Ratio	**2012**	**2013**	**2014**	**2015**	**2016**
Profitability ratios					
Return on assets	14.7%	18.7%	21.4%	19.0%	18.9%
Return on equity	24.9%	31.0%	35.0%	28.9%	27.2%
Profit margin	13.6%	17.9%	22.3%	18.1%	18.1%
Liquidity ratios					
Current	2.35%	2.26%	3.05%	2.07%	2.24%
Quick	1.96%	1.89%	2.58%	1.60%	1.78%
Overall financial stability ratios					
Debt	42.3%	37.4%	39.7%	29.3%	31.8%
Debt to equity	73.2%	59.8%	65.8%	41.5%	46.6%

The liquidity ratios show a consistently healthy ratio of current assets to current liabilities, suggesting that the firm should be able to cover its short-term liabilities without difficulty. The overall financial stability ratios indicate promising trends. The debt ratio drops from an actual of 39.7 percent in 2014 to a projected 31.8 percent in 2016. The debt-to-equity ratio shows an even more dramatic drop, indicating that an increasing portion of the firm's assets is being funded by equity rather than debt.

In summary, it is extremely important for a firm to understand its financial position at all times and for new ventures to base their financial projections on solid numbers. As mentioned earlier, regardless of how successful a firm is in other areas, it must succeed financially to remain strong and viable.

SUMMARY

15.1 To pursue an opportunity and to turn that pursuit into a viable venture, entrepreneurs require financial capital. Financial management deals with this reality. More specifically, financial management is concerned with two activities: raising money and managing a company's finances in a way that achieves the highest rate of return.

15.2 Profitability, liquidity, efficiency, and stability are the four main financial objectives of entrepreneurial firms. Profitability is the ability of a firm to earn a profit, liquidity is the ability of a company to meet or satisfy its short-term obligations, efficiency deals with how productively a firm uses its assets relative to its revenue and profits, and stability is the strength and vigor of the firm's overall financial standing.

15.3 The process of financial management includes the activities a firm takes to determine if its financial objectives are being met. Several documents are foundational to an entrepreneur's efforts to assess the degree to which a firm's financial objectives are being satisfied. These documents, as follows, are prepared regularly: (1) financial statements (a written report that describes a firm's health from a quantitative perspective), (2) forecasts

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(which are estimates of a firm's future income and expenses, based on its past performance, current situation, and its future plans), and (3) budgets (which are itemized forecasts of a firm's income, expenses, and capital requirements).

15.4 Historical financial statements reflect past performance. Typically, these documents are prepared on a quarterly and annual basis. The Securities and Exchange Commission (SEC) requires that publicly traded firms prepare and submit these documents. Pro forma financial statements are projections for expected performance in future periods. These projections are based on forecasts and are usually completed for two or three years into the future. Unlike historical financial statements, firms are not required to make their pro forma statements publicly available.

15.5 Historical financial statements include an income statement, a balance sheet, and a statement of cash flow. An income statement reflects the results of a firm's operations over a specified period of time. It records all the revenues and expenses for the given period and shows whether the firm is making a profit or is experiencing a loss. A balance sheet is a snapshot of a company's assets, its liabilities, and owners' equity. While income statements cover a specified period of time, a balance sheet is a snapshot of the firm at a specific point in time. A statement of cash flows summarizes the changes in a firm's cash position for a specified period of time and details why the changes occurred. This statement allows a firm to understand how much cash it has on hand and how its cash was used over a period of time.

15.6 Forecasts are predictions of a firm's future sales, expenses, income, and capital expenditures. A firm's forecasts provide the basis for its pro forma financial statements. When developed effectively, forecasts provide the foundation for a firm to prepare its future-oriented pro forma financial statements. Completely new firms typically base their forecasts on a good-faith estimate of sales and on industry averages (based on a percentage of sales) or the experiences of similar start-ups for cost of goods sold and other expenses. Once a firm has completed its sales forecast, it must forecast its costs of sales as well as the other items on its income statement. The most common way to do this is to use the percent-of-sales method, which is a method for expressing each expense item as a percentage of sales.

15.7 Pro forma financial statements are similar to historical financial statements except that they look forward rather than backward. Preparing pro forma statements helps entrepreneurs think about the quality of the strategies being implemented by their firm and to make adjustments to those strategies if necessary. Considered to be part of a firm's planning efforts, firms prepare a pro forma income statement, a pro forma balance sheet, and a pro forma statement of cash flows to help them anticipate and prepare for future activities and their anticipated outcomes.

KEY TERMS

10-K (p. 585)
accounts receivable (p. 582)
assumptions sheet (p. 594)
balance sheet (p. 588)
break-even point (p. 597)
budgets (p. 583)
constant ratio method of forecasting (p. 597)
cost of sales (p. 587)
current assets (p. 588)
current liabilities (p. 590)
current ratio (p. 590)
debt-to-equity ratio (p. 583)
efficiency (p. 583)
financial management (p. 581)
financial ratios (p. 583)
financial statement (p. 583)
financing activities (p. 592)
fixed assets, (p. 588)
forecasts, (p. 583)
historical financial statements (p. 585)
income statement (p. 587)
inventory (p. 582)

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investing activities (p. 592)
liquidity (p. 582)
long-term liabilities (p. 590)
net sales (p. 587)
operating activities (p. 592)
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owners' equity (p. 590)
percent-of-sales method (p. 596)
price-to-earnings (P/E) ratio (p. 588)
pro forma balance sheet (p. 602)
pro forma financial statements (p. 586)
pro forma income statement (p. 601)
pro forma statement of cash flows (p. 602)
profit margin (p. 588)
profitability (p. 582)
regression analysis (p. 596)
sales forecast (p. 595)
stability (p. 583)
statement of cash flows (p. 592)
working capital (p. 590)

REVIEW QUESTIONS

15.1 What are the two primary functions of the financial management of a firm?

15.2 What are the four main financial objectives of a firm?

15.3 Why is it important for a company to focus on its liquidity? What special challenges do entrepreneurial firms have in regard to remaining liquid?

15.4 What is meant by the term *efficiency* as it relates to the financial management of a firm?

15.5 What is meant by the term *stability* as it relates to the financial management of a firm?

15.6 What is the purpose of a forecast? What factors does a firm use to create its forecasts of future income and expenses?

15.7 On what factors or conditions do completely new firms base their forecasts?

15.8 What is the purpose of an income statement? What are the three numbers that receive the most attention when evaluating an income statement? Why are these numbers important?

15.9 How does a firm compute its profit margin? What is the significance of this ratio?

15.10 How does a firm compute its price-to-earnings ratio? Why does a high price-to-earnings ratio indicate that the stock market thinks the firm will grow?

15.11 What is the purpose of a balance sheet?

15.12 What are the major categories of assets and liabilities on a balance sheet? Briefly explain each category.

15.13 What is meant by the term *working capital*? Why is working capital an important consideration for entrepreneurial firms?

15.14 How does a firm compute its current ratio? Is this a relatively important or unimportant financial ratio? Explain your answer.

15.15 What is the purpose of a statement of cash flows?

15.16 What are the three separate categories of activities that are reflected on a firm's statement of cash flows? Briefly explain the importance of each activity.

15.17 What is the purpose of financial ratios? Why are financial ratios particularly useful in helping a firm interpret its financial statements?

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15.18 What is the purpose of an assumptions sheet?

15.19 Why is a firm's sales forecast the basis for most of its other forecasts?

15.20 What is meant by the percent-of-sales method as it relates to forecasts?

APPLICATION QUESTIONS

15.1 Kirsten, a friend of yours, plans to open a fashion boutique that will sell women's clothing and accessories. She told you that she leafed through several books on how to prepare forecasts and pro forma financial statements but that the books were geared toward existing firms that have several years of historical financial statements on which to base their projections. If Kirsten asked for your advice about how to prepare forecasts for a completely new women's fashion boutique, what would you tell her?

15.2 Suppose a friend of yours showed you the pro forma income statements for his startup and exclaimed excitedly that during the first three years of operations his firm will make a net income of $150,000 per year, which is just the amount of money ($450,000) the firm will need to pay off a three-year loan. Given your study of this chapter, why is it that your friend may not actually have $450,000 in cash, even though his pro forma income statements say that he will earn that amount of money?

15.3 Kate Snow just retired from a career with Walmart, cashing out a sizable retirement fund at the time of doing so. To start a second career, she is looking at the possibility of buying three different businesses. She has three years' historical financial statements for each business and has been pouring over the numbers. She was puzzled when she read the following statement in a book about small business financial management, "Be careful when looking at balance sheets to fully understand what you're looking at. In some respects balance sheets are very revealing, and in other respects they can be very deceiving." What do you think the author of the book meant by that statement?

15.4 Chipotle Mexican Grill is a publicly traded company. Calculate the firm's price-to-earnings ratio (P/E). What does Chipotle's P/E ratio tell you about investors' expectations regarding the company's growth? How do Chipotle's financial ratios compare to restaurant industry norms at the time of your analysis?

15.5 Jarrett Baker is the founder of an enterprise software company located in Chevy Chase, Maryland. By looking at the income statements for Jarrett's business over the past three years, you see that its working capital has declined from $42,400 in 2012 to $17,900 in 2013 to $3,100 in 2014. If this trend continues, in what ways could it jeopardize the future of Jarrett's business?

15.6 Jorge Martinez is thinking about buying an existing printing business and has been carefully studying the records of the business to get a good handle on its historical financial performance. Jorge heard that you are taking a class in entrepreneurship and asks you, "What suggestions do you have for me to make the best use of this financial information (i.e., three years of audited income statements, balance sheets, and statements of cash flow)?" What suggestions would you give Jorge for making the maximum use of the financial statements?

15.7 Casey Cordell is the owner of a digital photography service in Madison, Wisconsin. The company has been profitable every year of its existence. Its debt ratio is currently 68 per-

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cent, its current ratio is 1.1, and its debt-to-equity ratio is 72.2 percent. Do these financial numbers cause any reason to be concerned? Why or why not?

15.8 What items on the left side (or top) and what items on the right side (or bottom) of a firm's balance sheet should receive the greatest scrutiny? In regard to each of these items, what are the most important factors that a new venture should focus on to maintain its overall financial health?

15.9 Suppose a colleague of yours is gearing up to write a business plan for a business she intends to start. She told you she plans to prepare the financial statements first to get that job out of the way before she tackles the rest of the plan. What is the flaw in your colleague's logic as described to you?

YOU BE THE VC 15.1

COMPANY: Spindrift Soda

Business Idea: Make a specialty soda that is made entirely from just fresh-squeezed fruit juice, cane sugar, and carbonated water rather than sweetened syrup, juice concentrates, and preservatives.

Pitch: The knocks leveled against traditional sodas, like Coke and Pepsi, have created a market for small, specialty sodas such as Jones's and Boylan's. Still, most specialty sodas are made from sweetened syrups, and in many ways they are not that dissimilar from the major brands. Spindrift Soda provides a healthy and refreshing alternative. It is a carbonated beverage that is made from triple-purified sparkling water, fresh-squeezed fruit or berry puree (pulp and all), and cane sugar. Unlike almost every other soda on the market, it contains no syrups, no juice concentrates, no additives, and no preservatives. It's also light, bright, and tastes great.

Spindrift Soda is made every four to six weeks in small batches, and is shipped cold. It took nearly a year for Spindrift's founder, Bill Creelman, to figure out how to make it. Lots of people make fresh-squeezed juices on a small scale, and serve them to their families or sell them at a farmer's market. The challenge was to incorporate fresh-squeezed juices into a carbonated beverage at scale. Temperature-sensitive juices can't sit in vats the way syrups can. They have to be delivered in small jugs, stored properly, and then opened at the last minute and mixed in by hand. They're also hard to distribute to stores. Most sodas ship warm, like in the Coke or Pepsi trucks you see on the road. Spindrift Soda ships cold, which preserves its freshness. Creelman found distributors of fish, produce, and cheese willing to carry his product on their trucks. An added benefit of using fresh distributors is that they deliver daily, which allows them to quickly replenish Spindrift Soda inventories in stores when the stores are running low.

Spindrift's mission is to change how America experiences soda. Spindrift sodas come in six flavors including Blackberry, Sparking Orange Mango, Sparkling Lemonade, Sparkling Grapefruit, Cranberry Raspberry, and Half and Half. Spindrift also makes three flavors of bottled water including Tangerine, Lemon, and Raspberry Lime. Its beverages are truly fresh. For example, Spindrift Sparkling Grapefruit contains the following ingredients: triple-filtered sparkling water, fresh-squeezed juices (fresh pink grapefruit juice, fresh lemon juice), cane sugar, natural flavor, fruit, and vegetable juice for color. Now that's a list of ingredients that anyone can feel good about serving their family.

1. Based on the material covered in this chapter, what questions would you ask the firm's founders before making your funding decision? What answers would satisfy you?
2. If you had to make your decision on just the information provided in the pitch and on the company's website, would you fund this company? Why or why not?

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YOU BE THE VC 15.2

COMPANY: How Do You Roll?

Business Idea: Create a sushi restaurant that allows customers to "build their own sushi" by allowing them to select their own kind of wrap, rice, veggies, proteins, and toppings.

Pitch: People who like sushi have two choices. They can go to a fancy sushi restaurant and pay a fancy bill. Or they can go to a grocery store and buy sushi that is supposedly made daily. Now there is a third option. How Do You Roll? is a fast-casual sushi restaurant that combines the quality of a high-end restaurant with the convenience of a grocery store.

How Do You Roll? is the brainchild of two brothers, Yuen Yung and Peter Yung. Both grew up in the restaurant industry. Their parents had several Chinese restaurants, and at the tender age of eight or nine they both started working in their parents' restaurants. How Do You Roll? launched with a single store in Austin, Texas. It lets the customer be the chef by allowing customers to pick their own ingredients. The customer approaches a counter and is led through four steps:

Step 1 Choose Your Wrap: Traditional (seaweed) or modern (soy)

Step 2 Eat Your Veggies: Choose up to three healthy vegetables

Step 3 Stuff Your Roll: Choose one or more of our fresh meats

Step 4 Top It Off: Indulge in one or more of our specialty toppings or sides

Through this process customers personalize their sushi rolls. The meal, which consists of a six-piece sushi roll and a fountain drink, costs an average of $8 to $11. How Do You Roll's business model is also designed to make sushi accessible to people who won't touch raw ingredients or even fish. There is cooked chicken and beef available as substitutes. Along with sushi, each restaurant also sells miso soup, seaweed salad, and green tea ice cream. It is an experience that is totally unique in the sushi industry. It also provides fast-casual food patrons an alternative to the standard fare of burgers and chicken sandwiches.

How Do You Roll? is growing via franchising. It currently has eight franchise units and two company-owned stores. It has penned several development agreements, which may add up to 70 additional franchise units over the next 10 years. According to the company, it costs between $304,295 and $508,780 to open a How Do You Roll? restaurant. The initial franchise fee is $30,000, and the ongoing royalty is 7 percent of gross sales.

In spring 2013, Yuen Yung and Peter Yung pitched the business on the popular ABC show *Shark Tank*. Along with a $1 million investment from shark Kevin O'Leary, Yung said restaurant sales jumped 30 percent. In addition, he and his brother received more than 600 inquiries from potential franchisees interested in opening How Do You Roll? restaurants.

1. Based on the material covered in this chapter, what questions would you ask the firm's founders before making your funding decision? What answers would satisfy you?
2. If you had to make your decision on just the information provided in the pitch and on the company's website, would you fund this firm? Why or why not?

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CASE 15.1

Fundbox: Designed to Help Small Businesses Minimize Cash Flow Shortfalls

Introduction

Fundbox is an entrepreneurial start-up that offers 12-week loans to small businesses. The loans are tied to specific invoices that the businesses have outstanding. Payment for the loans (including principle, interest, and fees) is deducted from a company's bank account in 12 equal amounts on a weekly basis. Once the money for the invoice comes in, the loan can be paid in full. There is no penalty for early payment.

Fundbox was launched in 2012 by Yuval Ariav, Eyal Shinar, and Tomer Michael, who are technological innovators and financial professionals. The firm's mission is to offer small businesses a common-sense approach to cash-flow management.

The Problem

Almost all small businesses experience cash flow shortfalls. Think of how business works. Businesses often win a contract, purchase the materials and supplies that are needed to produce the firm's product or service, pay employees, and then have to wait 30 to 60 days to receive payment from the customer. This scenario causes even healthy businesses to be short on cash at times. There are two traditional solutions to the problem. The first is to maintain a line of credit at a bank. A line of credit allows a business to borrow up to a certain amount of money and pay it down when money comes in. The problem with this solution is that banks are increasingly reluctant to establish lines of credit for small businesses. Banks also don't like to make short-term loans for specific amounts. The second solution is invoice factoring. With invoice factoring, a company sells its invoices to a factoring company in exchange for a lump sum of money (say $4,500 for a $5,000 invoice). The factoring company then proceeds to collect the money from the company's customer. Many businesses don't like this alternative because it involves a third party having a direct relationship with their customer. If the factoring company becomes aggressive in trying to collect the invoice, it could affect the business's relationship with its customer.

To further complicate things, Days Sales Outstanding (DSO), or the time between when a business issues an invoice and the payment is received, has been increasing across the board in recent years.

Fundbox

Fundbox offers a novel solution to the problem. When an invoice comes in, it will issue a 12-week loan for the amount of the invoice. Because the loan is matched with a specific receivable, it prevents the repayment of the loan from creating a new cash flow problem for the business. The interest rate on the loan is tied to both the creditworthiness of the borrower and the company that owes the amount on the invoice. This practice encourages borrowers to borrow money on invoices that they are confident will be paid. For example, say a business does $10,000 of work for Home Depot. It knows Home Depot will pay the invoice, but Home Depot may operate on a net 30 or net 60 day payment schedule (meaning that it has 30 days or 60 days to make the payment). If the business has an account with Fundbox, it could get the $10,000 right away, minus Fundbox's fee. Weekly payments would start immediately. When Home Depot paid the invoice, the loan to Fundbox would be paid in full. This scenario allows a business to get its money sooner rather than later and avoid short-term gaps in its cash flow. The interest rate for Fundbox's service varies. According to a review published by the FitSmall Business blog, rates range from 0.7 percent to 3 percent per month, with the typical borrower at about 2 percent per month. About 40 percent of businesses that apply are accepted by Fundbox.

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Fundbox uses sophisticated data analytics to build a picture of a potential borrower's overall financial health and likelihood of repayment. Fundbox doesn't talk much about how this actually works. It is a core feature of their business and considered to be a trade secret.

Partnerships with Bookkeeping Companies

To make it easy for clients, Fundbox has established partnerships with many of the top online bookkeeping programs, including Quickbooks, Freshbooks, Xero, and Harvest. For Freshbooks, for example, once a businessperson creates a Fundbox account (sign-up is free), it can easily be tied to the business's Freshbooks account. When an invoice is entered into Freshbooks, Fundbox will analyze all pertinent data to see if a 12-week loan to cover the amount of the invoice can be made. The business will receive an e-mail message indicating whether a loan can be made. The business can then evaluate the terms of the loan and either accept or pass on the offer. If the offer is accepted, the funds will be deposited in the business's bank account, usually within a day. Fundbox only works with the borrower. In the Home Depot example provided above, if the borrower defaulted on Fundbox's loan, Fundbox would not try to collect the loan amount from Home Depot. Each borrower is given a maximum line of credit from Fundbox, so offers will not be made on all invoices.

B2B Players

Fundbox's loans are most suitable for business to business (B2B) companies. These are businesses that do work for other businesses and issue invoices for the work they do. Most business to consumer companies (B2C) are paid at the point of sale. For example, when you eat at a restaurant or buy a book from Amazon.com, you pay for it right away. The B2B category includes freelancers who do work for businesses. These are individuals who may benefit espe-

Fundbox has partnerships with many of the top online bookkeeping programs. If a business has a Freshbooks account, for example, it can easily be tied to the business's Fundbox's account.

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cially from Fundbox's service. For example, an independent software developer may spend 100 hours developing a mobile app for a small business and invoice the business $15,000. If the payment terms are net 60, the business will have 60 days to pay the bill. Via Fundbox, the independent software developer could get his money right away. For a freelancer, getting money sooner rather than later may make the difference in making rent or paying a mortgage on time.

Fundbox's Future

According to TechCrunch, Fundbox launched in stealth mode, presumably to test its service and work the bugs out. Since it has gone live, it has signed up thousands of active users (mostly small businesses) and clears tens of thousands of invoices daily in 42 states.

Fundbox is among a growing number of "alternative lenders" that small businesses are relying on, largely because banks have pulled back from small business lending. Firms offering services that are similar to those provided by Fundbox include Kabbage, OnDeck, and Lending Club. What is unique about Fundbox is that it connects loans to specific invoices, which helps small businesses minimize cash flow challenges.

The downside to using Fundbox as a fix for cash flow gaps is the costs involved. While the loans are short-term, an interest rate of between 0.7 percent and 3 percent per month, as reported above, results in a high annual APR. The best thing for any small business to do is to check with an accountant regarding the wisdom of using Fundbox or a similar product to minimize cash flow shortfalls.

Fundbox has raised $17.5 million from a collection of venture capitalists to fund and grow its operations.

Discussion Questions

1. Toward the beginning of this case, the following statement appears: "Almost all small businesses experience cash flow shortfalls." What is cash flow? Why is cash flow so critical to an entrepreneurial firm's success? Why do almost all small businesses experience cash flow shortfalls?

2. As explained in this chapter, a firm's statement of cash flows is divided into three separate activities. Which of the activities from the statement of cash flows would be affected by a firm's decision to use Fundbox's service? What are some of the potential effects of a small entrepreneurial firm's decision to use Fundbox on the components of that firm's statement of cash flows?

3. If Fundbox's co-founders (Yuval Ariav, Eyal Shinar, and Tomer Michael) were to ask your advice about the importance of pro forma statements to their firm's continuing success, what would you say to them? What pro forma statements would you recommend the co-founders develop and why?

4. As a young entrepreneur, what lessons about the financial management of a firm can you learn from the actions taken by the three co-founders of Fundbox?

Sources: L. Rao, "Lending Startup Fundbox Raises $17.5 from Khosla to Help SMBs Improve Cash Flow," TechCrunch, available at http://techcrunch.com/2014/04/10/lending-startup-fundbox-raises-17-5m-from-khosla-to-help-smbs-improve-cash-flow/, posted on April 10, 2014, accessed on August 29, 2014; M. Prosser, "Fundbox: An Alternative to Invoice Factoring or Discounting," FitSmallBusiness, available at http://fitsmallbusiness.com/fundbox/, posted on August 6, 2014, accessed on August 29, 2014; R. Shafaghi, "Meet: Fundbox—Turn Unpaid Invoices into Cash," available at http://www.freshbooks.com/blog/2014/05/28/meet-fundbox-turn-unpaid-invoices-into-cash/, posted on May 28, 2014, accessed on August 29, 2014.

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CASE 15.2

Dell Inc.: How Its Business Model Sweetens Its Financial Statements

Introduction

There are many reasons that Dell Inc. has, for the most part, been successful over the years. Two of the most compelling reasons are its direct sales model and its ultra-efficient global supply chain. While a start-up can't quickly emulate what Dell has done, there are lessons to be learned from Dell's experiences that any start-up can benefit from. Historically at least, Dell's approach to business made it the preferred computer brand for many businesses and consumers. Additionally, the business approach has sweetened Dell's financial statements and its ability to make money.

Dell's Hybrid Sales Approach (Combining Direct Sales and Retail Sales)

Dell was founded in 1988 touting a direct sales model. Rather than selling through stores like Sears and Best Buy, Dell sold direct, first over the phone and then via the Internet. Its business model not only allowed businesses and consumers to "customize" their computers, but also had profound positive effects on Dell's supply chain and financial activities. For a period of time after Dell launched its business model, other PC manufacturers, like Hewlett-Packard, had to forecast demand, build computers, ship them to retailers, hope they'd sell, and then wait 30 days or more for payment. Dell sidestepped all of this via its direct sales model. It received orders, built computers, and then shipped them to the buyers via UPS or FedEx. There was no "forecasting" of demand because demand was determined in real time, and Dell never got stuck with outdated computers because it maintained no inventory. Its customers also essentially financed its operations by paying in advance.

Dell maintained this business model from 1988 until 2007, when it shifted its sales strategy. Rather than selling exclusively directly, it decided to transition to a hybrid model, where it would continue to emphasize direct sales, but also sell a portion of its product line through retailers such as Best Buy, Staples, and Walmart. The main reason for the change was that Dell was shifting its emphasis from targeting businesses to targeting businesses, consumers, and international markets. The thinking was that it needed to have its computers side-by-side with its competitors in consumer channels if it hoped to become the preferred computer vendor for consumers along with businesses. It was also problematic to sell exclusively directly in some international markets.

Dell doesn't disclose the percentage of its sales that originate through its website or over the phone (its original direct-sales model) versus the percentage of its sales that come through retail outlets. It's clear, though, that a significant portion of its sales now occur online and over the phone and an increasing percentage of its sales are generated through retail outlets.

Dell's Supply Chain and Manufacturing Strategy

Dell's hybrid sales model has a significant impact on its supply chain and manufacturing strategy. It can produce computers in a highly efficient manner, because it does not have to forecast demand and keep excess inventory on hand for a large percentage of its sales. In fact, when Dell receives an order, via the Internet or on the phone, its suppliers are alerted in real time and, periodically throughout the day, deliver parts to Dell's assembly facilities where the computers are assembled, configured, and shipped. It also searches on a worldwide basis to find the best combinations of quality and cost for parts, which results in a complex yet highly efficient supply chain. In fact, in his 2005 book *The World Is Flat*, Thomas Friedman asked Dell to retrace the supply chain for his laptop computer, to determine where it was made,

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how many suppliers were involved, and how it reached his front door. The total supply chain for Friedman's Dell Inspiron 600m notebook computer, including suppliers of suppliers, involved about 400 companies in North America, Europe, and primarily Asia. The computer was codesigned in Austin, Texas, in Taiwan by a team of Dell engineers, and by a team of Taiwanese notebook designers (a globally distributed team can work 24 hours a day). Its final assembly was in a Dell factory in Penang, Malaysia. It was flown from Penang, Malaysia, to Nashville, Tennessee, on a China Airlines 747, the only 747 that lands in Nashville, other than when Air Force One is in town. It was delivered to Friedman's home via UPS.

To further increase efficiencies and reduce the amount of capital it must maintain, Dell is currently transitioning from this model and is relying increasingly on contract manufacturers.

Financial Advantages of Dell's Hybrid Sales Approach and Its Supply Chain and Manufacturing Strategy

There are direct financial benefits to Dell's hybrid sales approach and its approach to supply chain management and manufacturing. One of the biggest advantages is its inventory turnover. Dell turns its inventory over 31.4 times a year, compared to 13.9 times a year for Hewlett-Packard and 14.6 times a year for the S&P 500 average. Inventory turnover is determined by the following formula (the higher the number the better):

$$\text{Inventory Turnover} = \frac{\text{Cost of Goods Sold}}{\text{Average Inventories}}$$

A high inventory turnover means that a company is converting its inventory into cash quickly. Turning its inventory over quickly allows Dell to generate cash that's used to fund its growth, and to not get caught with out-of-date inventory. An often-told joke in the PC industry is that unsold inventory is like unsold vegetables—it spoils quickly. So maintaining a favorable inventory turnover ratio is critical.

Another ratio that's important is the asset turnover ratio. Asset turnover reflects the amount of sales generated for every dollar's worth of assets. It's calculated using the following formula (the higher the number the better):

$$\text{Asset Turnover} = \frac{\text{Sales}}{\text{Assets}}$$

Dell's asset turnover ratio is 1.26, compared to 1.06 for Hewlett-Packard and 0.34 for the S&P 500 average. Asset turnover denotes the amount of sales generated for every dollar's worth of assets. It's a measure of efficiency in regard to a firm's ability to use its assets to generate sales.

Along with crunching numbers, savvy managers assess the impact of their financial strategies on their overall goals and levels of customer satisfaction. Ultimately, it doesn't matter that a company has attractive-looking financial statements if its customers are starting to go elsewhere. Dell's hybrid sales approach and its supply chain and manufacturing strategy shine in this area too. Because it turns its inventory over quickly, it offers its customers the latest technologies rather than saddling them with products that likely will soon be outdated. It can also pass along the advantages of falling component costs quicker than its competitors can.

The Downside of Pushing Cost Savings Too Far

Although the majority of the decisions that Dell has made have both sweetened its financial statements and pleased its customers, Dell is learning the hard way that cost savings can be pushed too far. In the early 1990s, partly in response to the challenges imposed by its rapid growth, Dell started outsourcing the majority of its call center activities to low-wage countries in Asia and Central America. This strategy led to a chorus of growing complaints about

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long wait times for customer service calls and poor post-sales support. In response, Dell has spent over $100 million to revive its customer service, including an effort to increase the percentage of full-time Dell employees who staff customer service support lines and reduce its use of part-time and contract workers. The jury is still out on whether Dell has done enough to stem the tide of customer dissatisfaction. Another downside is that Dell pushes its suppliers hard. While most suppliers respond positively, it's hard to gauge the long-term impact in supplier relations by Dell's appearing to assume the role of "taskmaster" in its relationships with its suppliers.

It's also unclear how long Dell's hybrid sales approach will maintain an advantage. Although its inventory turnover number is still strong, it's not as outstanding as it was when Dell sold primarily online and over the phone. In 2004, Dell's inventory turnover was 107.1, but it is 31.4 today. Dell also has a formable competitor in Apple. Apple's inventory turnover is 63.0. It may be unfair to compare Dell directly to Apple, given that Apple is a more diversified company, but the comparison highlights the fact that Dell is no longer a trendsetter in inventory management efficiency. Another challenge that all computer manufacturers face is a global decline in personal computer sales. In slightly different words, global declines in computer sales is the reality of the day, even for premier firms like Dell, Hewlett-Packard, and Apple.

Discussion Questions

1. Investigate the financial ratio of inventory turnover. Find current information about Dell (www.hoovers.com is a good starting place) and report whether its inventory turnover is still as impressive as the number mentioned in the case. How does Dell's current inventory turnover ratio compare to that of some of its competitors such as Apple and Hewlett-Packard? Do the same for Dell's asset turnover ratio.
2. Locate Dell's most recent 10-K report and either locate or compute what you believe are the three most important financial ratios for Dell. Are the ratios impressive or do they provide you reason for concern?
3. If you were the CEO of Dell Inc., what expectations would you reflect when preparing a pro forma income statement for your company?
4. What lessons can a young entrepreneurial firm learn from Dell's experiences?

Sources: Dell 10-K report, available at www.sec.gov, for the fiscal year ending February 1, 2013; Financial data, including Inventory Turnover and Asset Turnover ratios, available at www.csimarket.com B. Breen, "Living in Dell Time," *Fast Company*, December 19, 2007.

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CHAPTER 16

Writing a *Business* Plan

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OPENING PROFILE

TEMPORUN: Proceeding on the Strength of a Winning Business Plan

In August of 2012 Josh Leider was on a run. He was listening to "Lose Yourself" by Eminem on his iPhone. The tempo of the song matched his running pace perfectly. Then "Lose Yourself" ended and another song started. The tempo was entirely different, throwing off Leider's run as a result. He thought, "Why can't you always run to the tempo of your music?" Hence, the idea of TempoRun, a smartphone app, was born.

Leider shared the idea with Benny Ebert-Zavos, a friend of his and a serious runner. Ebert-Zavos loved the idea, and the two of them decided to pursue it further. The pair found that there were apps on the market that adjust song tempos as a runner's pace changes, but none that did exactly what Leider and Ebert-Zavos envisioned, which was an app that categorized music according to tempo. Leider had worked on several business ideas and had a sense of how to proceed. He and Ebert-Zavos contacted the Computer Science department at Michigan State, the university they were attending, and a professor in the department hooked them up with two students, Adam Proschek and Phil Gatzen, who were good at coding and development. The group of four decided to form a business and build the app, using the name TempoRun for both.

One thing the partners did from the outset is utilize the resources of Michigan State. Leider was a marketing and economics major in the Eli Broad College of Business, while Ebert-Zavos was a student in the School of Hospitality Business. Both Proschek and Gatzen were in Computer Science. They wrote a business plan for TempoRun and, in December of 2012, entered the first Broad Pitch Competition, which was held in the college of business. Instead of wearing business attire, they pitched in running clothes, in part to show their passion for their business idea. Incredibly, they won the competition. The win included a $5,000 first prize and access to The Hatch, a student business accelerator in partnership with MSU's Entrepreneurship Network. The partners used the $5,000 and a grant from a campus businesses association to buy computers, trademark their idea, and create a limited liability company (LLC). They also utilized pro bono resources available through MSU's Entrepreneurship Network, such as interns who designed a logo and worked on TempoRun's marketing and legal efforts.

At the suggestion of a professor, in early 2013 they entered TempoRun in Student Startup Madness, a pitch competition for college digital projects at the South by Southwest Music and Media Conference in Austin, Texas. Michigan State funded the trip. They were competing against tech start-ups from universities across the country, including Stanford and Harvard, and ended up winning. Leider characterized the competition, and in particular the judging, as *Shark Tank* times 10. The judges were executives and well-known entrepreneurs from companies like Google, Square, and TechStars. Leider summed up the experience by saying that "We went into the competition thinking we knew everything but found that we knew very little." This was actually a positive comment on Leider's part. He was referring to the learning that took place as a result of the rigor of the judges' questions and their feedback. The South by Southwest win also netted TempoRun $5,000 in Google Cloud Platform credit and acquainted the entrepreneurs with people they would have had no way of coming into contact with otherwise. The nearby photo was taken just after the win at the South by Southwest competition. The team, from left to right, included Phil Gatzen, Benny Ebert-Zavos, Adam Proschek, and Josh Leider.

To gain visibility and prepare for launch, the TempoRun team sponsored a charity 5K at Michigan State in April of 2013. The proceeds went to support breast cancer research. The company formally launched in the Apple App Store in May 2013. The way the app works is that it helps users run at their preferred pace by categorizing the music on their iPhone from Level 1 (walking) to Level 10 (sprinting). It also incorporates music from a streaming Internet music station. The user selects a level, which can be changed with arrows on a simple interface. The app also keeps track of basic running analytics, such as distance run, pace, and calories burned. TempoRun, which charged a one-time download fee of $2.99 when it first launched, had 2,000 downloads its first day of launch. The company has experienced a steady pace of downloads since.

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Looking back, Leider credits the time his team spent in The Hatch, the Michigan State student accelerator, and the business plan and pitch competitions in which they participated as pivotal to their success. Leider says that the value of a business plan or pitch competition is that it "gets your ideas down on paper and causes you to ask questions of yourself that you would have never thought of before—questions about your business, your revenue streams, and more." Another ingredient to TempoRun's success is that Leider and Elbert-Zavos are very involved in the running community. Because they are consumers of their own product, they are able to make tweaks to the product based on their own observations and listen to suggestions from runners whom they know and who are also TempoRun users.

TempoRun is not yet a full-time job for the four founders, but they hope this will soon be the case. They envision extending TempoRun's basic approach to other sports, such as cycling and swimming.

This chapter discusses the importance of writing a business plan. Although some new ventures simply "wing it" and start doing business without the benefit of formal planning, it is hard to find an expert who doesn't recommend preparing a business plan. A **business plan** is a written narrative, typically 25 to 35 pages long, that describes what a new business intends to accomplish and how it intends to accomplish it. For most new ventures, the business plan is a dual-purpose document that is used both inside and outside the firm. Inside the firm, the plan helps the company develop a "road map" to follow to execute its strategies and plans. Outside the firm, it introduces potential investors and other stakeholders to the business opportunity the firm is pursuing and how it plans to pursue it.[1]

To begin this chapter, we discuss issues with which entrepreneurs often grapple when facing the challenge of writing a business plan. Topics included in the chapter's first section are reasons for writing a business plan, a description of who reads the business plan and what they're looking for, and guidelines to follow when preparing a written business plan. In the chapter's second section, we present an outline of a business plan with a description of the material in each section of the plan. The third section of the chapter deals with strategies for how to present the business plan to potential investors and others.

16.1 The Business Plan

Writing a business plan is the last activity completed in the step of the entrepreneurial process. It is a mistake to write a business plan too early. The business plan must be substantive enough and have sufficient details about the merits of the new venture in order to convince the reader that the new business is exciting and should receive support. Much of this detail is accumulated in the feasibility analysis stage of investigating the merits of a potential new venture.

In spite of conventional wisdom suggesting the need to do so, a relatively large percentage of entrepreneurs do not write business plans for their new ventures. In fact, a 2010–2012 study of 350 entrepreneurs found that of those that had successful exits (i.e., an IPO or sale to another firm), only about 30 percent started with a business plan.[2] That number is similar to the results of a 2011 survey by The Hartford. According to The Hartford's 2011 Small Business Success Study, which surveyed 2,000 business owners, only 35 percent of the owners said that they have a business plan.[3] Similarly, in a 2002 study, *Inc.* magazine asked the founders of the firms that make up the *Inc.* 500 that year whether they had written a formal business plan before they launched their companies. A total of 60 percent did not.[4] These statistics should not deter an entrepreneur from writing a

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business plan. Indeed, ample evidence supports the notion that writing a business plan is an extremely good investment of an entrepreneur's time and money.

16.1.1 Reasons for Writing a Business Plan

We show the two primary reasons to write a business plan in Figure 16.1. First, writing a business plan forces a firm's founders to systematically think through each aspect of their new venture.[5] This is not a trivial effort—it usually takes several days or weeks to complete a well-developed business plan—and the founders will usually meet regularly to work on the plan during this period. An example of how much work is sometimes involved, and how a well-planned new business unfolds, is provided by Gwen Whiting and Lindsey Wieber, the co-founders of The Laundress, a company that sells specially formulated laundry detergents and other fabric care products. Whiting and Wieber met at Cornell University while studying fabrics, and after graduating the pair decided to start a business together. The following vignette comes from an interview they gave to Ladies Who Launch, a website that highlights the accomplishments of female entrepreneurs:

> *Gwen:* Lindsey and I went to college and studied textiles at Cornell together and always wanted to be in business together. We knew it was going to happen. We always talked about ideas. We were talking about this concept, and it was the right time for us. The first thing we did was the business plan and then a cash flow analysis. We wanted to do as much research as possible before developing the products.
>
> *Lindsey:* We spent Memorial Day weekend (2003) doing our business plan. We spent the Fourth of July weekend doing our cash flow. After we had our ideas on paper, we went back to Cornell, met with a professor there, and had a crash course in chemistry. She worked with us on the formulation of the products.
>
> *Gwen:* I found a manufacturer on Columbus Day. Every piece of free time we had, we dedicated to the business. We weren't at the beach with our friends anymore.[6]

The payoff for this level of dedication and hard work, which involved the preparation of a formal business plan, is that Whiting and Wieber have now had a successful business for 10-plus years. Their products are sold through their website and in many stores.

Consistent with Whiting and Wieber's experience, writing a business plan forces a firm's founders to intently study every aspect of their business, a process that's hard to replicate in any other way. Imagine the following. Two friends are thinking about opening a seafood restaurant. They spend the next two months meeting four nights a week to hash out every detail of the business. They study the restaurant industry, identify their

Figure 16.1 Two Primary Reasons for Writing a Business Plan

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This group of young entrepreneurs plans to launch a website that features educational toys for children. Here, they are discussing how to integrate the results of their feasibility analysis into their business plan. A business plan is more compelling if it contains primary research conducted by the entrepreneurs launching the business.

Katarina Premfors/arabianEye/Corbis

target market, develop a marketing plan, settle on a hiring schedule, identify the type of people they want to employ, plan their facility, determine what their start-up expenses will be, and put together five years of pro forma (projected) financial statements. After 32 meetings and several drafts, they produce a 30-page business plan that explains every aspect of their business. Regardless of how conscientious the founders of a business are, it's difficult to discipline oneself to cover this level of detail absent writing a business plan. As stated earlier, writing a business plan forces a business's founders to systematically think through every aspect of their business and develop a concrete blueprint to follow.

The second reason to write a business plan is to create a selling document for a company. It provides a mechanism for a young company to present itself to potential investors, suppliers, business partners, key job candidates, and others. Imagine that you have enough money to invest in one new business.[7] You chat informally with several entrepreneurs at a conference for start-ups and decide that there are two new ventures that you would like to know more about. You contact the first entrepreneur and ask for a copy of his business plan. The entrepreneur hesitates a bit and says that he hasn't prepared a formal business plan but would love to get together with you to discuss his ideas. You contact the second entrepreneur and make the same request. This time, the entrepreneur says that she would be glad to forward you a copy of a 30-page business plan, along with a 10-slide PowerPoint presentation that provides an overview of the plan. An hour or two later, the PowerPoint presentation is in your e-mail in-box with a note that the business plan will arrive the next morning. You look through the slides, which are crisp and to the point and do an excellent job of outlining the strengths of the business opportunity. The next day, the business plan arrives just as promised and is equally impressive.

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Which entrepreneur has convinced you to invest in his or her business? All other things being equal, the answer is obvious—the second entrepreneur. The fact that the second entrepreneur has a business plan not only provides you with detailed information about the venture but also suggests that the entrepreneur has thought through each element of the business and is committed enough to the new venture to invest the time and energy necessary to prepare the plan. Having a business plan also gives an investor something to which s/he can react. Very few, if any, investors will free up time to "listen" to your idea for a new business, at least initially.

16.2 Who Reads the Business Plan—and What Are They Looking For?

There are two primary audiences for a firm's business plan. Let's look at each of them.

16.2.1 A Firm's Employees

A clearly written business plan, one that articulates the vision and future plans of a firm, is important for both the management team and the rank-and-file employees. Some experts argue that it's a waste of time to write a business plan because the marketplace changes so rapidly that any plan will become quickly outdated. Although it's true that marketplaces can and often do change rapidly, the process of writing the plan may be as valuable as the plan itself.

A clearly written business plan also helps a firm's rank-and-file employees operate in sync and move forward in a consistent and purposeful manner. The existence of a business plan is particularly useful for the functional department heads of a young firm. For example, imagine that you are the newly hired vice president for management information systems for a rapidly growing start-up. The availability of a formal business plan that talks about all aspects of the business and the business's future strategies and goals can help you make sure that what you're doing is consistent with the overall plans and direction of the firm.

16.2.2 Investors and Other External Stakeholders

External stakeholders who are being recruited to join a firm, such as investors, potential business partners, and key employees, are the second audience for a business plan. To appeal to this group, the business plan must be realistic and not reflective of overconfidence on the firm's part. Overly optimistic statements or projections undermine a business plan's credibility, so it is foolish to include them. At the same time, the plan must clearly demonstrate that the business idea is viable and offers potential investors financial returns greater than lower-risk investment alternatives. The same is true for potential business partners, customers, and key recruits. Unless the new business can show that it has impressive potential, investors have little reason to become involved with it.

Investors vary in terms of the reliance they place on formal business plans.[8] Initially, many investors ask for a PowerPoint deck or the executive summary of a business plan. A PowerPoint deck is a short set of PowerPoint slides that describe a business idea, and an executive summary is a one- to two-page overview of the full plan. If their interest is sufficiently peaked, in some cases investors will ask for a full business plan, and in other cases they won't. It's still necessary to have a business plan, however. If an investor commits, in

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most cases a business plan will be required during the due diligence phase. Due diligence refers to the process investors go through after they tentatively commit to an investment.[9] The commitment is based on a thorough investigation of the merits of the venture, whether any legal complications exist, and whether the claims made in the business plan are accurate and realistic.

A firm must validate the feasibility of its business idea and have a good understanding of its competitive environment prior to presenting its business plan to others. Sophisticated investors, potential business partners, and key recruits will base their assessment of a proposed firm's future prospects on facts, not guesswork or platitudes, as emphasized in Chapter 14. The most compelling facts a company can provide in its business plan are the results of its own feasibility analysis and the articulation of a distinctive and competitive business model. A business plan rings hollow if it is based strictly on an entrepreneur's predictions of a business's future prospects. Modify Watches, a retailer of customizable watches, is an example of a business that laid a firm foundation for its business plan via the feasibility analysis that it conducted very early on. Modify Watches is the focus of Case 14.1.

In addition to the previously mentioned attributes, a business plan should disclose all resource limitations that the business must address before it is ready to start earning revenues. For example, a firm may need to hire service people before it can honor the warranties for the products it sells. It is foolhardy for a new venture to try to downplay or hide its resource needs. One of the main reasons new ventures seek out investors is to obtain the capital needed to hire key personnel, further develop their products or services, lease office space, or fill some other gap in their operations. Investors understand this, and experienced investors are typically willing to help the firms they fund plug resource or competency gaps.

16.3 Guidelines for Writing a Business Plan

There are several important guidelines that should influence the writing of a business plan. It is important to remember that a firm's business plan is typically the first aspect of a proposed venture that an investor will see. If the plan is incomplete or looks sloppy, it is easy for an investor to infer that the venture itself is incomplete and sloppy.[10] It is important to be sensitive to the structure, content, and style of a business plan before sending it to an investor or anyone else who may be involved with the new firm. Table 16.1 lists some of the "red flags" that are raised when certain aspects of a business plan are insufficient or miss the mark.

16.3.1 Structure of the Business Plan

To make the best impression, a business plan should follow a conventional structure, such as the outline shown in the next section. Although some entrepreneurs want to demonstrate creativity in everything they do, departing from the basic structure of the conventional business plan format is usually a mistake. Typically, investors are very busy people and want a plan where they can easily find critical information. If an investor has to hunt for something because it is in an unusual place or just isn't there, he or she might simply give up and move on to the next plan.[11]

Many software packages are available that employ an interactive, menu-driven approach to assist in the writing of a business plan. Some of these programs are very helpful.[12] However, entrepreneurs should avoid a boilerplate plan that looks as though it came

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Table 16.1 Red Flags in Business Plans

Red Flag	Explanation
Founders with none of their own money at risk	If the founders aren't willing to put their own money at risk, why should anyone else?
A poorly cited plan	A plan should be built on hard evidence and sound research, not guesswork or what an entrepreneur "thinks" will happen. The sources for all primary and secondary research should be cited.
Defining the market size too broadly	Defining the market for a new venture too broadly shows that the true target market has not been clearly identified. For example, saying that a new venture will target the global pharmaceutical industry isn't helpful. The market opportunity needs to be better defined. Obviously, the new venture will target a segment or a specific market within the industry.
Overly aggressive financials	Many investors skip directly to this portion of the plan. Projections that are poorly reasoned or unrealistically optimistic lose credibility. In contrast, sober, well-reasoned statements backed by sound research and judgment gain credibility quickly.
Sloppiness in any area	It is never a good idea to make a reader wade through typos, balance sheets that don't balance, or sloppiness in any area. These types of mistakes are seen as inattention to detail and hurt the entrepreneur's credibility.

from a "canned" source. The software package may be helpful in providing structure and saving time, but the information in the plan should still be tailored to the individual business. Some businesses hire consultants or outside advisers to write their business plans. Although there is nothing wrong with getting advice or making sure that a plan looks as professional as possible, a consultant or outside adviser shouldn't be the primary author of the plan. Along with facts and figures, a business plan needs to project a sense of anticipation and excitement about the possibilities that surround a new venture—a task best accomplished by the creators of the business themselves.[13]

16.3.2 Content of the Business Plan

The business plan should give clear and concise information on all the important aspects of the proposed new venture. It must be long enough to provide sufficient information, yet short enough to maintain reader interest. For most plans, 25 to 35 pages (and typically closer to 25 than 35 pages) are sufficient. Supporting information, such as the résumés of the founding entrepreneurs, can appear in an appendix.

After a business plan is completed, it should be reviewed for spelling, grammar, and to make sure that no critical information has been omitted. There are numerous stories about business plans sent to investors that left out important information, such as significant industry trends, how much money the company needed, or how the money was going to be used. One investor even told the authors of this book that he once received a business plan that didn't include any contact information for the entrepreneur. Apparently, the entrepreneur was so focused on the content of the plan that he or she simply forgot to provide contact information on the business plan itself. This was a shame, because the investor was interested in learning more about the business idea.[14]

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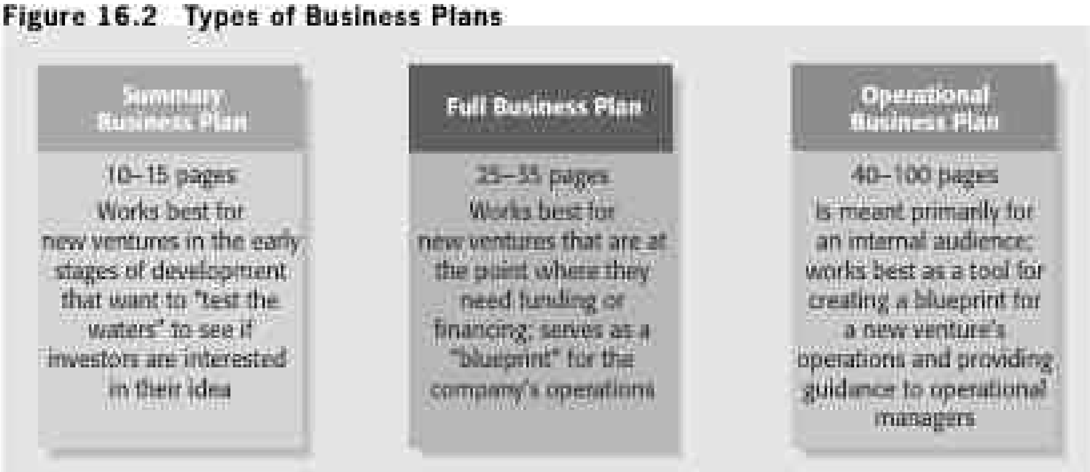
Style or Format of the Business Plan

The plan's appearance must be carefully thought out. It should look sharp but not give the impression that a lot of money was spent to produce it. Those who read business plans know that entrepreneurs have limited resources and expect them to act accordingly. A plastic spiral binder including a transparent cover sheet and a back sheet to support the plan is a good choice. When writing the plan, avoid getting carried away with the design elements included in word-processing programs, such as boldfaced type, italics, different font sizes and colors, clip art, and so forth. Overuse of these tools makes a business plan look amateurish rather than professional.[15]

One of the most common questions that the writers of business plans ask is, "How long and detailed should it be?" The answer to this question depends on the type of business plan that is being written. There are three types of business plans, each of which has a different rule of thumb regarding length and level of detail. Presented in Figure 16.2, the three types of business plans are as follows:

- **Summary plan:** A **summary business plan** is 10 to 15 pages and works best for companies that are very early in their development and are not prepared to write a full plan. The authors may be asking for funding to conduct the analysis needed to write a full plan. Ironically, summary business plans are also used by very experienced entrepreneurs who may be thinking about a new venture but don't want to take the time to write a full business plan. For example, if someone such as Drew Houston, the co-founder of Dropbox, was thinking about starting a new business, he might write a summary business plan and send it out to selected investors to get feedback on his idea. Most investors know about Houston's success with Dropbox and don't need detailed information. Dropbox, the subject of Case 13.1, is a free file hosting service that was founded in 2007 and is now being used by more than 200 million people across the world.
- **Full business plan:** A **full business plan** is typically 25 to 35 pages long. This type of plan spells out a company's operations and plans in much more detail than a summary business plan, and it is the format that is usually used to prepare a business plan for an investor.
- **Operational business plan:** Some established businesses will write an **operational business plan,** which is intended primarily for an internal audience. An operational business plan is a blueprint for a company's operations. Commonly running between 40 and 100 pages in length, these plans can obviously feature a great amount of detail that provides guidance to operational managers.

Figure 16.2 Types of Business Plans



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If an investor asks you for a PowerPoint deck or the executive summary of your business plan rather than the complete plan, don't be alarmed. This is a common occurrence. If the investor's interest is piqued, he or she will ask for more information. Most investors believe the process of writing a full business plan is important, even if they don't ask for one initially. This sentiment is affirmed by Brad Feld, a venture capitalist based in Boulder, Colorado, who wrote:

> Writing a good business plan is hard. At one point it was an entry point for discussion with most funding sources (angels and VCs). Today, while a formal business plan is less critical to get in the door, the exercise of writing a business plan is incredibly useful. As an entrepreneur, I was involved in writing numerous business plans. It's almost always tedious, time consuming, and difficult but resulted in me having a much better understanding of the business I was trying to create.[16]

A cover letter should accompany a business plan sent to an investor or other stakeholders through the mail. The cover letter should briefly introduce the entrepreneur and clearly state why the business plan is being sent to the individual receiving it. If a new venture is looking for funding, a poor strategy is to obtain a list of investors and blindly send the plan to everyone on the list. Instead, each person who receives a copy of the plan should be carefully selected on the basis of being a viable investor candidate.

Recognizing the Elements of the Plan May Change

A final guideline for writing a business plan is to recognize that the plan will usually change as it is being written and as the business evolves. New insights invariably emerge when entrepreneurs immerse themselves in writing the plan and start getting feedback from others. This process continues throughout the life of a company, and it behooves entrepreneurs to remain alert and open to new insights and ideas.

Because business plans usually change while being written, there is an emerging school of thought that opposes the idea of writing a business plan and advocates experimentation and trial-and-error learning gleaned through customer feedback over formal planning.[17] This approach, which is associated with the Lean Startup movement, espouses many excellent ideas, particularly in the area of soliciting feedback directly from prospective customers prior to settling on a business idea and business model to execute on the idea. In this book, we take the opposite position, arguing that a business plan, proceeded by a feasibility analysis, represents an important starting point for a new venture and serves many useful purposes. In this sense, those developing a business plan should understand that it is not intended to be a static document written in isolation at a desk. Instead, it is anticipated that the research conducted to complete the plan, and the preceding feasibility analysis, will place the founders in touch with potential customers, suppliers, business partners, and others, and that the feedback obtained from these key people will cause the plan to change as it's being written.[18] It's also anticipated that the business itself will iterate and change after it's launched, based on additional feedback. Some businesses will change more than others, based on the quality of their initial feasibility analysis and the newness and volatility of their industry. These issues and related ones are considered in the "Savvy Entrepreneurial Firm" feature.

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SAVVY ENTREPRENEURIAL FIRM

Know When to Hold Them, Know When to Fold Them

One of the challenges business owners have is determining how closely to stick to their business plan once the business is launched and they start receiving customer feedback. In almost all cases, some changes will need to be made to the firm's plan. But the degree to which business plans pan out as their founders envisioned varies. In some cases, a business plan is spot-on and the worst thing a founder could do is vary from the plan. In other cases, a plan needs to be significantly tweaked, and in still other cases it needs to be thrown out the window and the business needs to start over. The following are brief descriptions of businesses that have experienced these various outcomes.

Songkick—No Changes Needed

Songkick was founded in 2007 by Pete Smith, Michelle You, and Ian Hogarth. The problem the company solves is music lovers missing out on seeing their favorite bands because they didn't know they were in their area. Concertgoers try to avoid this problem by subscribing to venue e-mail lists, checking band websites, and surfing through generic concert newsletters. This is a clumsy process and doesn't ensure that music fans won't miss a concert they'd like to see. To solve this problem, Songkick indexes a large number of ticket vendors, venue websites, and local newspapers to create the most comprehensive database of upcoming concerts available. Its mission is to know about every concert that's happening in every location—from an indie band playing at a local nightclub to Beyoncé playing at Madison Square Garden. Users can track the performers they like, and Songkick will send them a personalized concert alert when those performers announce a tour date in their area. Songkick makes money by selling concert tickets on its website. While Songkick has enhanced its service offerings over the years, its business plan has remained unchanged. The site now has over 8 million users per month.

GrubHub—Minor Change Needed

GrubHub began in 2004 as a simple restaurant listing website. The idea was to set up a website that listed all the restaurants that deliver to a particular user's home or office address. The initial business plan was based on a "freemium" pricing model. GrubHub would list restaurants for free and make money by charging a subscription fee for restaurants that wanted to be placed in a premium position on its website. The idea was that the restaurants placed in a premium position would get more orders from existing customers, and would have a better chance being "discovered" by new customers. As time went on, the founders of GrubHub realized that restaurants loved what they were doing, but weren't comfortable with paying up front for sales that might or might not happen. Its customers were clear that they only wanted to pay GrubHub when a GrubHub user placed an order. These insights prompted GrubHub to revise its business plan. The company switched from a subscription pricing model, where they charged restaurants for a premium place, to a transactional model where they collected a commission for each order placed. After the change was made, GrubHub saw a dramatic increase in restaurants asking to be placed on its website.

Instagram—Major Changes Needed

Instagram almost wasn't Instagram at all. Before Instagram became the photo-sharing hit that it is, co-founders Kevin Systrom and Mike Krieger were working on a check-in-service called Burbn. Burbn was a location-based service similar to Foursquare. Users could check in to locations, earn points for hanging out with their friends, and share pictures inside the app. Systrom and Krieger worked on Burbn for over a year. It was completely done, had generated buzz, and had $500,000 in funding. The only problem—Systrom and Krieger didn't like it. To them it felt cluttered and overrun with features. They also worried about its competitiveness. Two similar services, Foursquare and Gowalla, already existed. They

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would have to fight it out with Foursquare and Gowalla for market share. So they stepped back and reconsidered. They concluded that the best approach was to pick a single feature and execute on it extremely well. So, they stripped Burbn down to the one group or feature they liked and felt they could contribute to the most. As it turned out, it was the photo-sharing, comment, and like capabilities. What was left was Instagram. Instagram is now a widely popular online photo-sharing, video-sharing, and social networking service that allows its users to take pictures and videos, and apply digital filters to them. Instagram was acquired by Facebook in 2012 for approximately $1 billion.

Questions for Critical Thinking

1. Despite all the changes that have happened with the Internet since 2007, when Songkick was founded, why do you think the company has been able to successfully stick with its original business plan?
2. What do you think would have happened to GrubHub if it hadn't changed its business plan?
3. Why do you think some start-ups find it difficult to change their business plan, even when presented with evidence that their current business plan isn't working?
4. Look at the "You Be the VC" features at the end of Chapter 14, which focus on August Smart Locks and Blue Apron, and the "You Be the VC" features at the end of this chapter, which focus on Buzzy and Flings Bins. From the information in the features and on each company's website, which company do you think will have the easiest time sticking to its original business plan? Which company do you think will have the hardest time? Explain your selections.

Sources: Songkick home page, www.songkick.com, accessed February 28, 2014; GrubHub home page, www.grubhub.com, accessed February 28, 2014; Instagram home page, http://instagram, accessed February 28, 2014; B. Barringer and R. D. Ireland, *Entrepreneurship: Successfully Launching New Ventures*, 3rd edition, 2010; M. G. Siegler, "A Pivotal Point," Techcrunch, available at http://techcrunch.com/2010/11/08/instagram-a-pivotal-point, accessed February 28, 2014.

16.4 Outline of the Business Plan

A suggested outline of the full business plan appears in Table 16.2. Specific plans may vary, depending on the nature of the business and the personalities of the founding entrepreneurs. Most business plans do not include all the elements introduced in Table 16.2; we include them here for the purpose of completeness.

16.4.1 Exploring Each Section of the Plan

Cover Page and Table of Contents

The cover page should include the company's name, address, and phone number; the date; the contact information for the lead entrepreneur; and the company's website address if it has one. The company's Facebook page and Twitter name can also be included. The contact information should include a land-based phone number, an e-mail address, and a smartphone number. This information should be centered at the top of the page. Because the cover letter and the business plan could get separated, it is wise to include contact information in both places. The bottom of the cover page should include information alerting the reader to the confidential nature of the plan. If the company already has a distinctive trademark, it should be placed somewhere near the center of the page. A table of contents should follow the cover letter. It should list the sections and page numbers of the business plan and the appendices.

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Table 16.2 Business Plan Outline

Cover Page

Table of Contents

I. Executive Summary

II. Industry Analysis
- Industry Size, Growth Rate, and Sales Projections
- Industry Structure
- Nature of Participants
- Key Success Factors
- Industry Trends
- Long-Term Prospects

III. Company Description
- Company History
- Mission Statement
- Products and Services
- Current Status
- Legal Status and Ownership
- Key Partnerships (if any)

IV. Market Analysis
- Market Segmentation and Target Market Selection
- Buyer Behavior
- Competitor Analysis
- Estimates of Annual Sales and Market Share

V. The Economics of the Business
- Revenue Drivers and Profit Margins
- Fixed and Variable Costs
- Operating Leverage and Its Implications
- Start-up Costs
- Break-Even Chart and Calculation

VI. Marketing Plan
- Overall Marketing Strategy
- Product, Price, Promotions, and Distribution
- Sales Process (or Cycle)
- Sales Tactics

VII. Design and Development Plan
- Development Status and Tasks
- Challenges and Risks
- Projected Development Costs
- Proprietary Issues (Patents, Trademarks, Copyrights, Licenses, Brand Names)

VIII. Operations Plan
- General Approach to Operations
- Business Location
- Facilities and Equipment

IX. Management Team and Company Structure
- Management Team (Including a Skills Profile)
- Board of Directors
- Board of Advisors
- Company Structure

X. Overall Schedule

XI. Financial Projections
- Sources and Uses of Funds Statement
- Assumptions Sheet
- Pro Forma Income Statements
- Pro Forma Balance Sheets
- Pro Forma Cash Flows
- Ratio Analysis

Appendices

Executive Summary

The **executive summary** is a short overview of the entire business plan; it provides a busy reader with everything she needs to know about the new venture's distinctive nature.[19] As mentioned earlier, in many instances an investor will first ask for a copy of a firm's PowerPoint deck or executive summary and will request a copy of the full business plan only if the PowerPoint deck or executive summary is sufficiently convincing. Thus, certainly when requested, the executive summary arguably becomes the most important section of the business plan.[20] The most critical point to remember when writing an executive summary is that it is not an introduction or preface to the business plan; instead, it is meant to be a summary of the plan itself.

An executive summary shouldn't exceed two single-spaced pages. The cleanest format for an executive summary is to provide an overview of the business plan on a section-by-section basis. The topics should be presented in the same order as they are presented in the business plan. Two identical versions of the executive summary should be

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prepared—one that's part of the business plan and one that's a stand-alone document. The stand-alone document should be used to accommodate people who ask to see the executive summary before they decide whether they want to see the full plan.

Even though the executive summary appears at the beginning of the business plan, it should be written last. The plan itself will evolve as it's written, so not everything is known at the outset. In addition, if you write the executive summary first, you run the risk of trying to write a plan that fits the executive summary rather than thinking through each piece of the plan independently.[21]

Industry Analysis

The main body of the business plan begins by describing the industry in which the firm intends to compete. This description should include data and information about various characteristics of the industry, such as its size, growth rate, and sales projections. It is important to focus strictly on the business's industry and not its industry and target market simultaneously. Before a business selects a target market, it should have a good grasp of its industry—including where its industry's promising areas are and where its points of vulnerability are located.

Industry structure refers to how concentrated or fragmented an industry is.[22] Fragmented industries are more receptive to new entrants than industries that are domi-

If you plan to start a company in the nursery and garden industry, it's important to document the health and future potential of the industry. A careful analysis of a firm's industry lays out what is realistically possible and what isn't realistically possible for a start-up to achieve.

Mike Kemp/Blend Images/Corbis

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nated by a handful of large firms. You should also provide your reader a feel for the nature of the participants in your industry. Issues such as whether the major participants in the industry are innovative or conservative and are quick or slow to react to environmental changes are the types of characteristics to convey. You want your reader to visualize how your firm will fit in or see the gap that your firm will fill. The key success factors in an industry are also important to know and convey. Most industries have 6 to 10 key factors in which all participants must establish competence as a foundation for competing successfully against competitors. Most participants try to then differentiate themselves by excelling in two or three areas.

Industry trends should be discussed, which include both environmental and business trends. The most important environmental trends are economic trends, social trends, technological advances, and political and regulatory changes. Business trends include issues such as whether profit margins in the industry are increasing or declining and whether input costs are going up or down. The industry analysis should conclude with a brief statement of your beliefs regarding the long-term prospects for the industry.

Company Description

This section begins with a general description of the company. Although at first glance this section may seem less critical than others, it is extremely important in that it demonstrates to your reader that you know how to translate an idea into a business.

The company history section should be brief, but should explain where the idea for the company came from and the driving force behind its inception. If the story of where the idea for the company came from is heartfelt, tell it. For example, the opening feature for Chapter 14 focuses on LuminAid, a solar light company that was started by Andrea Sreshta and Anna Stork, two Columbia University students. Sreshta and Stork's motivation to design the light was spurred by their concern for people affected by a major earthquake that took place in Haiti in 2010. They experienced firsthand how a disaster can negatively impact the lives of millions. One thing most disaster victims suffer from is a lack of light. Sreshta and Stork started LuminAid to solve this problem. The LuminAid solar light is unique in that it can be shipped flat, and inflates when used to produce a portable, renewable source of light. The company's goal is to make the LuminAid light a part of the supplies commonly sent as part of disaster relief efforts.

Sreshta and Stork's story is heartfelt and is one with which anyone can relate. It might even cause one to pause and think, "That is a fantastic idea. That's just the type of solution that people recovering from a natural disaster like an earthquake need."

A **mission statement** defines why a company exists and what it aspires to become.[23] If carefully written and used properly, a mission statement can define the path a company takes and act as its financial and moral compass. Some businesses also include a tagline in their business plan. A **tagline** is a phrase that a business plans to use to reinforce its position in the marketplace. For example, Wello's tagline is "Bye, Bye Gym Hello Convenience." Wello is an online platform that allows participants to arrange workouts with trainers via Skype or another online means, which avoids having to make a trip to a gym to receive the same service.

The products and services section should include an explanation of your product or service. Include a description of how your product or service is unique and how you plan to position it in the marketplace. A product or service's **position** is how it is situated relative to its rivals. If you plan to open a new type of smoothie shop, for example, you should explain how your smoothie shop differs from others and how it will be positioned in the market in terms of the products it offers and the clientele it attracts. This section is the ideal place for you to start reporting the results of your feasibility analysis. If the

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concept test, buying intentions survey, and library, Internet, and gumshoe research produced meaningful results, they should be reported here.

The current status section should reveal how far along your company is in its development. A good way to frame this discussion is to think in terms of milestones. A **milestone** is a noteworthy or significant event. If you have selected and registered your company's name, completed a feasibility analysis, developed a business model, and established a legal entity, you have already cleared several important milestones. The legal status and ownership section should indicate who owns the business and how the ownership is split up. You should also indicate what your current form of business ownership is (i.e., LLC, Subchapter S Corp., etc.) if that issue has been decided.

A final item a business should cover in this opening section is whether it has any key partnerships that are integral to the business. Many business plans rely on the establishment of partnerships to make them work. Examples of the types of partnerships that are common in business plans are shown in the "Partnering for Success" feature.

Market Analysis

The market analysis is distinctly different from the industry analysis. Whereas the industry analysis focuses on the industry in which a firm intends to compete (e.g., toy industry, fitness center industry, men's clothing industry), the **market analysis** breaks the industry into segments and zeroes in on the specific segment (or target market) to which the firm will try to appeal. As mentioned in Chapter 14, most start-ups focus on servicing a specific target market within an industry.

The first task that's generally tackled in a market analysis is to segment the industry the business will be entering and then identify the specific target market on which it will focus. This is done through **market segmentation**, which is the process of dividing the market into distinct segments. Markets can be segmented in many ways, such as by geography (city, state, country), demographic variables (age, gender, income), psychographic variables (personality, lifestyle, values), and so forth. Sometimes a firm segments its market based on more than one dimension in order to drill down to a specific segment that the firm thinks it is uniquely capable of serving. For example, in its market analysis, GreatCall, the cell phone service provided especially for older people, probably segmented the cell phone market by age and by benefits sought. Some start-ups create value by finding a new way to segment an industry. For example, before Tish Ciravolo started Daisy Rock Guitar, a company that makes guitars just for women, the guitar industry had not been segmented by gender. Daisy Rock Guitar's competitive advantage is that it makes guitars that accommodate a woman's smaller hands and build.

It's important to include a section in the market analysis that deals directly with the behavior of the consumers in a firm's target market. The more a start-up knows about the consumers in its target market, the more it can gear products or services to accommodate their needs. Many start-ups find it hard to sell products to public schools, for example, because purchase decisions are often made by committees (which draws out the decision-making process), and the funding often has to go through several levels of administrators before it can be approved. A **competitor analysis**, which is a detailed analysis of a firm's competitors, should be included.

The final section of the market analysis estimates a firm's annual sales and market share. There are four basic ways for a new firm to estimate its initial sales. If possible, more than one method should be used to complete this task. The most important outcome is to develop an estimate that is based on sound assumptions and seems both realistic and attainable. We show the four methods entrepreneurs can use to estimate sales in Table 16.3.

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PARTNERING FOR SUCCESS

Types of Partnerships That Are Common in Business Plans

Because new businesses are resource constrained, they often make partnering an essential part of their business plans. As illustrated throughout this book, effective partnering can help a start-up in many ways. The following are examples of the types of partnering scenarios that are common in business plans.

Smaller Companies Partnering with Larger Companies to Bring Their Products to Market

Because the cost of bringing a new drug to market is so high, biotech companies commonly partner with large pharmaceutical companies to bring their products to market. Biotech companies specialize in discovering and developing new drugs—it's what they're good at. In most cases, however, they have neither the money nor the experience to bring the products to market. In contrast, the large drug companies, like Merck and Pfizer, specialize in marketing and selling drugs and in providing information to doctors about them. It's what they're good at. As a result, most biotech firms' business plans plainly state that their mission is to discover, develop, and patent new drugs and that they'll partner with larger pharmaceutical companies to bring the products to market.

Smaller Companies Partnering with Larger Companies to Produce, Fulfill, and/or Ship Their Products

Many new firms, from the get-go, structure their business plans on the notion that partners will produce, fulfill, and ship their products. As a result, a start-up that develops a new type of board game may have the game made by a contract manufacturer in China, have it shipped from China to a warehouse and fulfillment company in the United States, and when an order is placed (by a retailer such as Barnes & Noble or Walmart) the warehouse and fulfillment company ships the product to the buyer. While there are costs involved at every step in the process, this arrangement frees the board game company to focus on designing and marketing products and reduces its initial capital requirements. A variation of this approach, for catalog and Web-based companies that sell other manufacturers' products, is a method called drop shipping. Drop shippers like eBags, which is an online retailer that sells luggage, backpacks, and similar items, do not warehouse anything they sell. Instead, when eBags receives an order it passes the order on to the original manufacturer (or distributor), which fulfills the order, often in an eBags box with an eBags packing list so it looks as though it came directly from eBags. This arrangement costs eBags money, but it is integral to eBags's business plan of offering a wide selection of products to customers at affordable prices and not getting caught with outdated merchandise.

Smaller Companies Outsourcing Human Resources Management Tasks

An increasingly common feature in business plans is to outsource human resource management tasks that are labor intensive and require specialized expertise. Some start-ups outsource only administrative tasks, such as payroll processing and benefits administration. These firms partner with payroll accounting firms such as Paychex or TriNet. Other start-ups outsource a broader range of their human resource management functions and partner with a company such as ADP or Administaff. These companies are called professional employer organizations (PEOs) and act as an off-site human resource department for a start-up or other firm. Along with doing everything that Paychex and TriNet does, PEOs can help a start-up with hiring, firing, training, regulatory compliance, and other more in-depth human resource–related issues. Outsourcing these tasks can minimize a firm's investment in human resources management personnel and support (such as software products) and frees a company to focus on other core activities.

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Questions for Critical Thinking

1. What factors in the business environment encourage firms to partner to compete?
2. What risks do small firms face when partnering with large, successful companies? What risks do large companies take when they partner with small start-ups?
3. Describe two reasons (that aren't mentioned in this feature) why a small firm would partner with another firm. Provide an example of a partnership that fits one of the reasons.
4. The "You Be the VC 16.1" feature focuses on Buzzy, a company that has created a device that helps relieve the pain and anxiety associated with getting a shot. What types of partnerships could Buzzy form to lower its capital requirements and allow its top management team to focus on its distinctive competencies?

Table 16.3 The Four Methods for Estimating a New Firm's Initial Sales

Method	Explanation
Utilize the Multiplication Method	There are two approaches that fit this category. Start-ups that plan to sell a product on a national basis normally use a top-down approach. This involves trying to estimate the total number of users of the product, estimate the average price customers pay, and estimate what percentage of the market your business will garner. Start-ups that plan to sell locally normally use more of a bottom-up approach. This approach involves trying to determine how many customers to expect and the average amount each customer will spend.
Find a Comparable Firm	Find a comparable firm and ask for an estimate of annual sales. For example, if you are planning to open a women's clothing boutique, try to find a boutique that is similar to yours (and is not in your trade area) and simply call the owner and ask for a chance to talk to him or her about the business. Once a relationship has been established, you can ask for an estimate of the business's annual sales.
Contact Industry Trade Associations	Contact the premier trade associations in your industry and ask if they track the sales numbers for businesses that are similar to your business. If the trade association doesn't track actual sales numbers for comparable businesses, ask if there are other rules of thumb or metrics that help new companies estimate sales. For example, many industries collect statistics such as "average sales per square foot" or "average sales per employee" for firms in their industry.
Conduct Internet Searches	Internet searches often reveal magazine and newspaper articles as well as blog entries that focus on firms in your industry. On occasion, these articles and blog entries will talk about the sales experiences of a similar early-stage firm. If you know of a firm that is comparable to your firm, target that firm first in your search. You may get lucky and find an article or entry that says, "XYZ firm earned gross revenues of $250,000 per year its first three years." If the source of this data is credible and XYZ firm is comparable to your firm, you've just found useful information.

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The Economics of the Business

This section begins the financial analysis of a business, which is further fleshed out in the financial projections. It addresses the basic logic of how profits are earned in the business and how many units of a business's product or service must be sold for the business to "break even" and then start earning a profit.

The major revenue drivers, which are the ways a business earns money, should be identified. If a business sells a single product and nothing else, it has one revenue driver. If it sells a product plus a service guarantee, it has two revenue drivers, and so on. The size of the overall gross margin for each revenue driver should be determined. The gross margin for a revenue driver is the selling price minus the cost of goods sold or variable costs. The **costs of goods sold** are the materials and direct labor needed to produce the revenue driver. So, if a product sells for $100 and the cost of goods sold is $40 (labor and materials), the gross margin is $60 or 60 percent. The $60 is also called the **contribution margin.** This is the amount per unit of sale that's left over and is available to "contribute" to covering the business's fixed costs and producing a profit. If your business has more than one revenue driver, you should figure the contribution margin for each. If you have multiple products in a given revenue driver category, you can calculate the contribution margin for each product and take an average. (For example, if you're opening an office supply store, you may have several different computer printers under the revenue driver "printers.") You can then calculate the weighted average contribution margin for each of the company's revenue drivers by weighing the individual contribution margin of each revenue driver based on the percentage of sales expected to come from that revenue driver.

The next section should provide an analysis of the business's fixed and variable costs. The variable costs (or costs of goods sold) for each revenue driver was figured previously. Add a projection of the business's fixed costs. A firm's **variable costs** vary by sales, while its **fixed costs** are costs a company incurs whether it sells something or not. The company's operating leverage should be discussed next. A firm's **operating leverage** is an analysis of its fixed versus variable costs. Operating leverage is highest in companies that have a high proportion of fixed costs relative to their variable costs. In contrast, operating leverage is lowest in companies that have a low proportion of fixed costs relative to variable costs. The implications of the firm's projected operating leverage should be discussed. For example, a firm with a high operating leverage takes longer to reach break-even; however, once break-even is reached, more of its revenues fall to the bottom line.

The business's one-time start-up costs should be estimated and put in a table. These costs include legal expenses, fees for business licenses and permits, website design, business logo design, and similar one-time expenses. Normal operating expenses should not be included.

This section should conclude with a break-even analysis, which is an analysis of how many units of its product a business must sell before it breaks even and starts earning a profit. In Chapter 15, we explained how to compute a break-even analysis.

Marketing Plan

The marketing plan focuses on how the business will market and sell its product or service. It deals with the nuts and bolts of marketing in terms of price, promotion, distribution, and sales. For example, GreatCall, a firm producing cell phones for older users, may have a great product, a well-defined target market, and a good understanding of its customers and competitors, but it still has to find customers and persuade them to buy its product.

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The best way to describe a company's marketing plan is to start by articulating its marketing strategy, positioning, and points of differentiation, and then talk about how these overall aspects of the plan will be supported by price, promotional mix and sales process, and distribution strategy. Obviously, it's not possible to include a full-blown marketing plan in the four to five pages permitted in a business plan for the marketing section, but you should hit the high points as best as possible.

A firm's **marketing strategy** refers to its overall approach for marketing its products and services. A firm's overall approach typically boils down to how it positions itself in its market and how it differentiates itself from competitors. GoldieBlox, the toy company introduced in Chapter 13, is positioning itself as a company that introduces girls to the field of engineering. Only about 10 percent of engineering jobs in the United States are held by women. Beginning with the assumption that storytelling will increase a young girl's connection with the act of building, the company has created a set of toys intended to be used to solve problems while reading about adventures. The ultimate goal is to connect girls with the art of building and encourage young women to pursue careers in engineering. As we see with the example of GoldieBlox, the marketing strategy sets the tone and provides guidance for how the company should reach its target market via its product, pricing, promotions, and distribution tactics. For example, it will invariably promote and advertise its products in places that young women and their parents are most likely to see. Similarly, it will most likely sell its products through specialty toy stores and its own website, along with mass merchandisers such as Toys"R"Us.

The next section should deal with your company's approach to product, price, promotion, and distribution. If your product has been adequately explained already, you can move directly to price. Price, promotion, and distribution should all be in sync with your positioning and points of differentiation, as described previously. Price is a particularly important issue because it determines how much money a company can make. It also sends an important message to a firm's target market. If GoldieBlox advertised its toys as high-quality toys that are both educationally sound and environmentally friendly but also charged a low price, people in its target market would be confused. They would think, "This doesn't make sense. Are GoldieBlox toys high quality or aren't they?" In addition, the lower price wouldn't generate the profits that GoldieBlox needs to further develop its toys. You should also briefly discuss your plans regarding promotions and distribution.

The final section should describe the company's sales process or cycle and specific sales tactics it will employ. It's surprising how many business plans describe a business's overall marketing strategies, but never comment on how a product or service will actually be sold.

Product (or Service) Design and Development Plan

If you're developing a completely new product or service, you need to include a section in your business plan that focuses on the status of your development efforts. Many seemingly promising start-ups never get off the ground because their product development efforts stall or the actual development of the product or service turns out to be more difficult than expected.

The first issue to address is to describe the present stage of the development of your product or service. Most products follow a logical path of development that includes product conception, prototyping, initial production, and full production. You should describe specifically the point that your product or service is at and provide a timeline that describes the remaining steps. If you are in the very early stages of your business and only have an idea, you should carefully explain how a prototype, which is the first

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physical depiction of a new product or service, will be produced. A **product prototype** is the first physical manifestation of a new product, often in a crude or preliminary form. The idea is to solicit feedback and then iterate. For example, a prototype of a product, like one of GoldieBlox's toys, might consist of a preliminary version of the product for users to test and then report their experiences. GoldieBlox would then modify or tweak the toy based on the users' experiences. Similarly, a prototype for a Web-based company might consist of a preliminary or beta version of the site, with sufficient functionality built into the site for users to test it and then provide feedback. In some instances a virtual prototype is sufficient. A **virtual prototype** is a computer-generated 3D image of a product or service idea. It displays the idea as a 3D model that can be viewed from all sides and rotated 360 degrees.

A section labeled "Challenges and Risks" should be included and disclose any major anticipated design and development challenges and risks that will be involved in bringing the product or service to market. While you want to remain upbeat, the last thing you want to do is paint an overly rosy picture of how quickly and effortlessly your design and development process will unfold. Experienced readers know that product and service development is an inherently bumpy and challenging process, and they will want insights into the challenges and risks you anticipate with your particular offering.

A final section should describe any patents, trademarks, copyrights, or trade secrets that you have secured or plan to secure relative to the products or services you are developing. If your start-up is still in the early stages and you have not taken action regarding intellectual property issues yet, you should get legal advice so you can, at a minimum, discuss your plans in these areas.

Operations Plan

The operations plan section of the business plan outlines how your business will be run and how your product or service will be produced. You have to strike a careful balance between adequately describing this topic and providing too much detail. Your readers will want an overall sense of how the business will be run, but they generally will not be looking for detailed explanations. As a result, it is best to keep this section short and crisp.

A useful way to illustrate how your business will be run is to first articulate your general approach to operations in terms of what's most important and what the make-or-break issues are. You can then frame the discussion in terms of "back stage," or behind-the-scenes activities, and "front stage," or what the customer sees and experiences. For example, if you're opening a new fitness center, the back-stage and the front-stage issues might be broken down as follows:

Back Stage (Behind-the-Scenes Activities)	Front Stage (What the Members See)
• Staff selection	• Member tours
• Operations manual	• Operating hours
• Relationships with suppliers	• Staff assistance
• Relationships with city government	• Fitness classes and programs
• Development of marketing materials	• Fitness machines
• Employee orientation and training	• Workshops
• Emergency plans	• Monthly newsletter

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Obviously you can't comment on each issue in the three to four pages you have for your operations plan, but you can lay out the key back-stage and front-stage activities and address the most critical ones.

The next section of the operations plan should describe the geographic location of your business. In some instances location is an extremely important issue, and in other instances it isn't. For example, one of the reasons Jeff Bezos decided to locate Amazon.com in Seattle is that this city is a major distribution hub for several large book publishers. By locating near these distribution facilities, Amazon.com has enjoyed a cost advantage that it wouldn't have had otherwise. On a more fine-grained level, for restaurants and retail businesses, the specific location within a mall or shopping center, or a certain side of a busy street, may make a dramatic difference.

This section should also describe a firm's facilities and equipment. You should list your most important facilities and equipment and briefly describe how they will be (or have been) acquired, in terms of whether they will be purchased, leased, or acquired through some other means. If you will be producing a product and will contract or outsource your production, you should comment on how that will be accomplished. If your facilities are nondescript, such as a generic workspace for computer programmers, it isn't necessary to provide a detailed explanation.

Management Team and Company Structure

Many investors and others who read business plans look first at the executive summary and then go directly to the management team section to assess the strength of the people starting the firm. Investors read more business plans with interesting ideas and exciting markets than they are able to finance. As a result, it's often not the idea or market that wins funding among competing plans, but the perception that one management team is better prepared to execute its idea than the others.

The management team of a new firm typically consists of the founder or founders and a handful of key management personnel. A brief profile of each member of the management team should be provided, starting with the founder or founders of the firm. Each profile should include the following information:

- Title of the position
- Duties and responsibilities of the position
- Previous industry and related experience
- Previous successes
- Educational background

Although they should be kept brief, the profiles should illustrate why each individual is qualified and will uniquely contribute to the firm's success. Certain attributes of a management team should be highlighted if they apply in your case. For example, investors and others tend to prefer team members who've worked together before. The thinking here is that if people have worked together before and have decided to partner to start a new firm, it usually means that they get along personally and trust one another.[24] You should also identify the gaps that exist in the management team and your plans and timetable for filling them. The complete résumés of key management team personnel can be placed in an appendix to the business plan.

If a start-up has a board of directors and/or a board of advisors, their qualifications and the roles they play should be explained and they should be included as part of your management team. A **board of directors** is a panel of individuals elected by a corporation's shareholders to oversee the management of the firm. A **board of advisors** is a panel of

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experts asked by a firm's management to provide counsel and advice on an ongoing basis. Unlike a board of directors, a board of advisors possesses no legal responsibility for the firm and gives nonbinding advice.[25] Many start-ups ask people who have specific skills or expertise to serve on their board of advisors to help plug competency gaps until the firm can afford to hire additional personnel. For example, if a firm is started by two Web designers and doesn't have anyone on staff with marketing expertise, the firm might place one or two people on its board of advisors with marketing expertise to provide guidance and advice.

The final portion of this section of your business plan focuses on how your company will be structured. Even if you are a start-up, you should outline how the company is currently structured and how it will be structured as it grows. It's important that the internal structure of a company makes sense and that the lines of communication and accountability are clear. Including a description of your company's structure also reassures the people who read the plan that you know how to translate your business idea into a functioning firm.

The most effective way to illustrate how a company will be structured and the lines of authority and accountability that will be in place is to include an organizational chart in the plan. An **organizational chart** is a graphic representation of how authority and responsibility are distributed within the company. The organizational chart should be presented in graphical format if possible.

Overall Schedule

A schedule should be prepared that shows the major events required to launch the business. The schedule should be in the format of milestones critical to the business's success, such as incorporating the venture, completion of prototypes, rental of facilities, obtaining critical financing, starting the production of operations, obtaining the first sale, and so forth. An effectively prepared and presented schedule can be extremely valuable in convincing potential investors that the management team is aware of what needs to take place to launch the venture and has a plan in place to get there.

Financial Projections

The final section of a business plan presents a firm's pro forma (or projected) financial projections. Having completed the previous sections of the plan, it's easy to see why the financial projections come last. They take the plans you've developed and express them in financial terms.

The first thing to include is a **sources and uses of funds statement,** which is a document that lays out specifically how much money a firm needs (if the intention of the business plan is to raise money), where the money will come from, and how the money will be used. The next item to include is an **assumptions sheet,** which is an explanation of the most critical assumptions on which the financial statements are based. Some assumptions will be based on general information, and no specific sources will be cited to substantiate the assumption. For example, if you believe that the U.S. economy will gain strength over the next three to five years, and that's an underlying assumption driving your sales projections, then you should state that assumption. In this instance, you wouldn't cite a specific source—you're reflecting a consensus view. (It's then up to your reader to agree or disagree.) Other assumptions will be based on very specific information, and you should cite the source for your assumptions. For example, if GoldieBlox has credible data showing that the educational segment of the children's toy industry is expected to grow at a certain percentage each year for the foreseeable future, and this

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figure plays a large role in its belief that it can increase its sales every year, then it should cite the sources of its information.

The importance of identifying the most critical assumptions that a business is based on and thoroughly vetting the assumptions is illustrated in the "What Went Wrong" feature. EventVue, the company that is the focus of the feature, failed largely because several of the key assumptions that business was based on turned out to be incorrect.

The **pro forma (or projected) financial statements** are the heart of the financial section of a business plan. Although at first glance preparing financial statements appears to be a tedious exercise, it's a fairly straightforward process if the preceding sections of your plan are thorough. The financial statements also represent the finale of the entire plan. As a result, it's interesting to see how they turn out.

A firm's pro forma financial statements are similar to the historical statements an established firm prepares, except they look forward rather than track the past. Pro forma financial statements include the pro forma income statement, the pro forma balance sheet, and the pro forma cash flow statement. They are usually prepared in this order because information flows logically from one to the next. Most experts recommend three to five years of pro forma statements. If the company you're writing your plan for already exists, you should also include three years of historical financial statements. Most business plan writers interpret or make sense of a firm's historical or pro forma financial statements through **ratio analysis.** Ratios, such as return on assets and return on sales, are computed by taking numbers out of financial statements and forming ratios with them. Each ratio has a particular meaning in regard to the potential of the business.

We presented a complete explanation of how to complete pro forma financial statements and ratio analysis in Chapter 15.

Appendix

Any material that does not easily fit into the body of a business plan should appear in an appendix—résumés of the top management team, photos or diagrams of product or product prototypes, certain financial data, and market research projections. The appendix should not be bulky and add significant length to the business plan. It should include only the additional information vital to the plan but not appropriate for the body of the plan itself.

Putting It All Together

In evaluating and reviewing the completed business plan, the writers should put themselves in the reader's shoes to determine if the most important questions about the viability of their business venture have been answered. Table 16.4 lists the 10 most important questions a business plan should answer. It's a good checklist for any business plan writer.

16.5 Presenting the Business Plan to Investors

If the business plan successfully elicits the interest of a potential investor, the next step is to meet with the investor and present the plan in person. The investor will typically want to meet with the firm's founders. Because investors ultimately fund only a few ventures, the founders of a new firm should make as positive an impression on the investor as possible.

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WHAT WENT WRONG?

What EventVue Learned the Hard Way About Making Assumptions

EventVue was a product that was intended to improve the experience of people who attend conferences. It started as a private social network that helped conference attendees network more effectively. It pivoted twice, once to roll out a widget that would bring more people to specific conferences, and then to an app that promised to be the best way for conference attendees to discuss what was taking place in real time. EventVue launched with promise but failed in early 2010. What went wrong?

Several things, all of which have to do with incorrect assumptions. The first assumption was that conference organizers would see EventVue as an invaluable asset. They didn't. While EventVue saw itself as essential, conference organizers saw it more as "a vitamin rather than a pain pill." It was something that event organizers said they liked, but none of them saw it as essential. It didn't make their lives easier, make them more money, reduce their costs, or boost the profile of an event. It was simply nice to have. Although EventVue's platform made it easier for conference attendees to network with one another, it wasn't clear what was in it for the organizers, who were the ones being asked to pay for it. What the founders of EventVue found was that conference organizers care first and foremost about one thing—selling tickets. Anything that doesn't sell tickets is a secondary consideration.

After disappointing initial results, EventVue pivoted to offer a widget that would help bring more people to conferences. This, the company founders assumed, would get the attention of conference organizers. The widget would let people know who was registered for an event. The idea was that if a prospective attendee saw that a friend or someone they admired was registered for a conference, they would be more likely to register for the event conference as well. Incredibly, the widget had the opposite effect. A rule of thumb for conferences is that the majority of sales come in the last two weeks before the conference is scheduled to take place. As a result, when people looked at the registration list—particularly if they looked at it more than two weeks out from the event—and saw that none of their friends or people that they admired were registered, they were less likely to register themselves. Therefore, rather than making conference organizers money, the EventVue widget actually cost them money. EventVue tried out several other ideas, but eventually ran out of ideas, persistence, and money.

There are two key takeaways from the EventVue story for business plan writers. First, a business should test its assumptions prior to launching. This lesson illustrates the need to complete a comprehensive feasibility analysis prior to writing a business plan and moving forward with a business idea, as illustrated in Chapter 14. Second, it's essential that a business understand its customers' needs. EventVue never found a way to help conference organizers sell more tickets. It found a way to help conference attendees better network with others, but conference attendees were not EventVue's customers.

Questions for Critical Thinking

1. Briefly map out the feasibility analysis that EventVue's founders should have conducted prior to launching the company. Of the four forms of feasibility analysis described in Chapter 14, which of the forms should have been emphasized the most? Explain your answer.
2. If EventVue had conducted a comprehensive feasibility analysis prior to launch, what do you think the company would have looked like?
3. Do some Internet research to see if there are companies that are providing social networks for conference attendees. If so, what are they doing differently than what EventVue tried to do? Try to discern why they have been able to stay in business while EventVue failed.
4. The "You Be the VC 14.1" feature focuses on August Smart Locks, a company that will enable users to control the locks on their homes or apartments via a smartphone. What are some of the main assumptions that August's business plan is based on?

Source: J. Fraser, "A Few Words About EventVue," Online Aspect, available at www/onlineaspect.com/2010/10/26/a-few-words-about-eventvue, accessed February 28, 2014.

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Table 16.4 The 10 Most Important Questions a Business Plan Should Answer

1. Is the business just an idea, or is it an opportunity with real potential?
2. Is the product or service viable? Does it add significant value to the customer? Has a feasibility analysis been completed? If so, what are the results?
3. Is the business entering an exciting, growing industry, and has the firm identified an attractive position within the industry?
4. Does the business have a well-defined target market?
5. Does the business have points of differentiation that truly separate it from its competitors? Are these points of differentiation sustainable?
6. Does the business have a sound marketing plan?
7. Is the management team experienced, skilled, and up to the task of launching the new firm?
8. Is the business's operations plan appropriate and sound?
9. Are the assumptions that the firm is basing its financial projections on realistic?
10. Are the financial projections completed correctly, and do they project a bright future for the firm?

The first meeting with an investor is generally very short, about one hour.[26] The investor will typically ask the firm to make a 15- to 20-minute presentation using PowerPoint slides and use the rest of the time to ask questions. If the investor is impressed and wants to learn more about the venture, the presenters will be asked back for a second meeting to meet with the investor and his or her partners. This meeting will typically last longer and will require a more thorough presentation.

16.5.1 The Oral Presentation of a Business Plan

When asked to meet with an investor, the founders of a new venture should prepare a set of PowerPoint slides that will fill the time slot allowed for the presentation portion of the meeting. The same format applies to most business plan competitions. The first rule in making an oral presentation is to follow instructions. If an investor tells an entrepreneur that he or she has one hour and that the hour will consist of a 20-minute presentation and a 40-minute question-and-answer period, the presentation shouldn't last more than 20 minutes. The presentation should be smooth and well-rehearsed. The slides should be sharp and not cluttered with material.

The entrepreneur should arrive at the appointment on time and be well prepared. If any audiovisual equipment is needed, the entrepreneur should be prepared to supply the equipment if the investor doesn't have it. These arrangements should be made prior to the meeting. The presentation should consist of plain talk and should avoid technical jargon. Start-up entrepreneurs may mistakenly spend too much time talking about the technology that will go into a new product or service and not enough time talking about the business itself. The most important issues to cover in the presentation and how to present them are shown in Table 16.5. This presentation format calls for the use of 12 slides. A common mistake entrepreneurs make is to prepare too many slides and then try to rush through them during a 20-minute presentation.

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Table 16.5 Twelve PowerPoint Slides to Include in an Investor Presentation

Topic	Explanation
1. Title slide	Introduce the presentation with your company's name, the names of the founders, and the company logo if available.
2. Problem	Briefly state the problem to be solved or the need to be filled.
3. Solution	Explain how your firm will solve the problem or how it will satisfy the need to be filled.
4. Opportunity and target market	Articulate your specific target market. Talk about business and environmental trends that are providing your target market momentum.
5. Technology	This slide is optional but is normally included. Talk about your technology or any unusual aspects of your product or service. Don't talk in an overly technical manner. Make your descriptions easy to understand and interesting.
6. Competition	Explain specifically the firm's competitive advantage in the market place and how it will compete against more established competitors.
7. Marketing and sales	Describe your overall marketing strategy. Talk about your sales process. If you've conducted primary research regarding how people feel about your product, report the results here.
8. Management team	Describe your existing management team. Explain how the team came together and how their backgrounds and expertise are keys to the success of your firm. If you have a board of advisors or board of directors, briefly mention the key individuals involved. If you have gaps in your team, explain how and when they will be filled.
9. Financial projections	Briefly discuss the financials. Stress when the firm will achieve profitability, how much capital it will take to get there, and when its cash flow will break even. Use additional slides if needed to properly display your information, but don't go overboard.
10. Current status	Describe the current status of your firm in the context of the milestones you've achieved to date. Don't diminish the value of your accomplishments.
11. Financing sought	Lay out specifically how much financing you're seeking and how you'll use the money.
12. Summary	Bring the presentation to a close. Summarize the strongest points of your venture and your team. Solicit feedback from your audience.

Source: B. Barringer, *Preparing Effective Business Plans: An Entrepreneurial Approach*, 1st Edition, © 2009, pp. 242–253. Adapted by permission of Pearson Education, Inc., Upper Saddle River, NJ.

16.5.2 Questions and Feedback to Expect from Investors

Whether in the initial meeting or on subsequent occasions, an entrepreneur will be asked a host of questions by potential investors. The smart entrepreneur has a solid idea of what to expect and is prepared for these queries. Because investors often come across as being very critical,[27] it is easy for an entrepreneur to become discouraged, particularly

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if the investor seems to be poking holes in every aspect of the business plan. The same dynamic typifies the question-and-answer sessions that follow presentations in business plan competitions. In fact, an investor who is able to identify weaknesses in a business plan or presentation does a favor for the entrepreneur. This is because the entrepreneur can take the investor's feedback to heart and use it to improve the business plan and/or the presentation.

In the first meeting, investors typically focus on whether a real opportunity exists and whether the management team has the experience and skills to pull off the venture. The investor will also try to sense whether the managers are highly confident in their own venture. The question-and-answer period is extremely important. Here investors are typically looking for how well entrepreneurs think on their feet and how knowledgeable they are about the business venture. Michael Rovner, a partner of Rob Adam's at AV Labs, put it this way: "We ask a lot of peripheral questions. We might not want answers—we just want to evaluate the entrepreneur's thought process."[28]

SUMMARY

16.1 A business plan is a written narrative that describes what a new business intends to accomplish and how it plans to achieve its goals. For most new businesses, the business plan is a dual-purpose document that is used both inside and outside the firm. Inside the firm, it helps the company develop a road map to follow in executing its strategies. Outside the firm, it acquaints potential investors and other stakeholders with the business opportunity the firm is pursuing and describes how the business will pursue that opportunity.

16.2 The two primary audiences for a firm's business plan are its employees and potential investors and other external stakeholders. There are different kinds of business plans. For example, a summary business plan is 10 to 15 pages and works best for companies in the early stages of development. These companies don't have the information needed for a full business plan but may put together a summary business plan to see if potential investors are interested in their idea. A full business plan, typically 25 to 35 pages, spells out a company's operations and plans in much more detail than a summary business plan and is the usual format for a business plan prepared for an investor. An operational business plan is usually prepared for an internal audience. It is 40 to 100 pages long and provides a blueprint for a company's operations.

16.3 Guidelines are available for those writing a business plan to follow. Adhering to these guidelines increases the probability that an entrepreneur will develop an effective business plan. The structure of the plan is the first guideline to consider. The advice here is that a conventional structure should be used to develop a business plan. Doing this allows business investors to focus on the parts of a plan that are critical to their decision-making process. Second, a business plan should be concise and clear in its development. All important aspects of the proposed venture should be included in the plan. Once written, the plan should be checked for grammar errors, spelling mistakes, and to verify that all vital information is in fact included. The plan's style and format are the issues around which the third guideline is framed. The plan's appearance should be carefully evaluated; however, it should be consistent with a conventional structure (as noted earlier) and should not suggest to the potential investor that a great deal of money was spent to prepare the plan itself.

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16.4 A business plan has multiple parts, the first of which is the executive summary. The executive summary is a quick overview of the entire business plan and provides busy readers with everything they need to know about the distinctive nature of the new venture. In many instances, an investor will ask for a copy of a firm's executive summary and will request a copy of the full business plan only when the executive summary is sufficiently convincing. The industry analysis, which is another part of the business plan, describes the industry a business will enter. The market analysis part of the plan breaks the industry analysis into segments and zeros in on the specific segments (or target markets) to which the firm will seek to appeal. The management team and company structure section of a business plan is critical. Many investors and others who read business plans look first at the executive summary and then go directly to the management team section to assess the strength of the people starting the firm. The sources and uses of funds statement is a document that lays out specifically how much money a firm needs (if it is raising money), where the money will come from, and what it will be used for. An assumptions sheet is an explanation of the most critical assumptions that a business's financial analysis is based on.

16.5 After writing the business plan, the entrepreneur must prepare to present it effectively to potential investors and possibly others as well. The oral presentation of a business plan typically consists of 20 minutes of formal remarks, accompanied by approximately 12 PowerPoint slides, and 40 minutes of questions and answers. The presentation should be smooth and well-rehearsed. The slides should be sharp and not cluttered with material.

KEY TERMS

assumptions sheet (p. 641)
board of advisors (p. 640)
board of directors (p. 640)
business plan (p. 621)
competitor analysis (p. 634)
contribution margin (p. 637)
costs of goods sold (p. 637)
executive summary (p. 631)
fixed costs (p. 637)
full business plan (p. 627)
market analysis (p. 634)
market segmentation (p. 634)
marketing strategy (p. 638)
milestone (p. 634)
mission statement (p. 633)
operating leverage (p. 637)
operational business plan (p. 627)
organizational chart (p. 641)
position (p. 633)
pro forma (or projected) financial statements (p. 642)
product prototype (p. 639)
ratio analysis (p. 642)
sources and uses of funds statement (p. 641)
summary business plan (p. 627)
tagline (p. 633)
variable costs (p. 637)
virtual prototype (p. 639)

REVIEW QUESTIONS

16.1 What is a business plan?

16.1 What are the advantages of preparing a business plan for a new venture?

16.3 When is the appropriate time to write a business plan?

16.4 What are the two primary reasons for those starting a new venture to write a business plan?

16.5 It is often argued that the process of writing a business plan is as important as the plan itself, particularly for the top management team of a young firm. Why is this so?

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16.6 Who reads the business plan and what are they looking for when doing so?

16.7 How will investors typically react if they think a business plan is based on estimates and predictions rather than on careful analysis and facts?

16.8 Why is it important for a business plan to follow a conventional structure rather than be highly innovative and creative?

16.9 What are the differences among a summary business plan, a full business plan, and an operational business plan?

16.10 Why should the executive summary, which is one of the first things that appears in a business plan, be written last?

16.11 What is the difference between the industry analysis section and the market analysis section of a business plan?

16.12 What is the difference between a concentrated and a fragmented industry?

16.13 What is the purpose of "The Economics of the Business" section of a business plan?

16.14 If you're developing a completely new product or service, what type of information should you include in your business plan regarding the status of the development efforts?

16.15 What is the purpose of the "Operations Plan" section of a business plan?

16.16 Why is the "Management Team and Company Structure" section of a business plan often touted as one of the most important sections?

16.17 What is the purpose of a sources and uses of funds statement?

16.18 What is the purpose of an assumptions sheet?

16.19 What are the differences between historical financial statements and pro forma financial statements?

16.20 What is the number-one rule in making an investor presentation?

APPLICATION QUESTIONS

16.1 Travis Ryan is one of four cofounders of a skateboard company. The cofounders have decided to write a business plan to obtain funding for their venture. During a recent meeting, Travis said, "I know that we're all really busy, so I'd like to volunteer to write our business plan. A friend of mine has a house on a lake near where we are going to school. If the three of you agree, I'll take my laptop to my friend's house for a couple of days and knock out our business plan. Any objections?" If you were one of Travis's cofounders, what would you say? What alternative approaches to writing a business plan would you propose and why?

16.2 A good friend of yours, Andrew Waters, has decided to leave his corporate job in order to launch a private SEO (search engine optimization) consulting firm. He is putting together a business plan for this venture and says the following to you: "I've read several books and articles about how to write a business plan, and there is a point about which I am still a bit confused. Is a business plan written more for learning and discovering or is it written more for pitching and selling?" What would you say to Andrew in response to his question?

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16.3 Kevin Andrews and Karen Platt are college seniors. They're in the process of launching an unsweetened, fruit-flavored bottle water start-up named Compete H2O. The start-up will be unique in that Compete H2O will be sold via small kisoks located in fitness centers. The university that Kevin and Karen attend hosts an annual business plan competition. Kevin is in favor of entering the competition. Karen is opposed to the idea, arguing that Compete H2O's business plan is complete and it is time to move forward. What advantages might Kevin and Karen gain by participating in the university's business plan competition?

16.4 Imagine you just received an e-mail message from a friend. The message reads: "Want to let you know that I just finished writing the business plan for my new venture. I'm very proud of what I've written. The plan is comprehensive and just a bit over 100 pages in length. The executive summary itself is 9 pages long. I intend to send my plan to investors beginning next week. Do you have any words of advice for me before I do this? Be honest. I really want to get funding!" How would you respond to your friend's request for feedback?

16.5 The entrepreneurship class you are taking meets for four hours once per week. A break of 10 minutes or so takes place after the first two hours of each class. During a recent break, you overhead one of your classmates say to another person that in her opinion, the teacher is overselling the importance to potential investors of a start-up's management team. "After all," the classmate says, "A good product outweighs any deficiency a firm may have in terms of managers and their abilities." Given what you have learned about business plans, what would you say to your classmate to convince her that she needs to rethink her view about potential investors' views about the quality of a proposed venture's management team?

16.6 d. light, which operates as a for-profit social enterprise, is the focus of Case 16.2. What, if any, special factors should be kept in mind when writing a business plan for a for-profit social enterprise?

16.7 Michael Graves and Jill Simpson just left their jobs with Microsoft to launch a business that will sell a new type of fax machine. They wrote a full business plan that they've asked you to review. When reading the plan, you noticed that several key sections begin with the phrase "We believe. . . ." Is any knowledgable person who reads this business plan going to know what "We believe . . ." really means? What is the problem with including the phrase "We believe . . ." to introduce key sections of a business plan?

16.8 Recently, Megan, Jennifer, and Mark, the cofounders of a medical products company, presented their business plan to a group of investors in the hopes of receiving funding for their venture. One of the investors asked the three, "How much of your personal money do each of you have invested in this firm?" Is this a legitimate question for the potential investor to ask? Why would an investor want to know how much of their own money each cofounder has committed to the proposed new venture?

16.9 Patty Carroll is thinking about opening a high-end fashion boutique in an affluent suburb of Minneapolis. She contacts an angel investor she knows has previously invested in this type of firm and asked if he would read her business plan. She received the following response from the angel investor: "I would be glad to read your plan. But you should know that when examining business plans for high-end fashion boutiques, the section I concentrate on with great intensity is called "The Economics of the Business." Why do you think the angel investor concentrates on this particular section of a business plan when studying proposals to launch a high-end fashion boutique? What specifically do you think the angel investor is interested in understanding when concentrating on this section?

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YOU BE THE VC 16.1

COMPANY: Buzzy

Business Idea: Create a device that helps relieve the pain and anxiety associated with getting a shot and other needle sticks like IV starts, blood draws, and finger pricks.

Pitch: While no one looks forward to getting a shot or finger prick, some people are so afraid of the experience that they are literally needle phobic. Needle phobic people are so fearful of getting a shot that it keeps them from donating blood, getting immunizations like flu shots, and receiving regular health care. Buzzy founder Amy Baxter, an emergency room physician and pain researcher, found herself dealing firsthand with this situation. Her son had a really bad shot experience and became needle phobic. She knew right away that she had to do something so her son would no longer be afraid to go to the doctor and receive appropriate treatments.

After some research and experimentation, and aided by a $1 million grant from the National Institutes of Health (NIH), Dr. Baxter invented Buzzy, a bee-shaped, palm-sized device. Buzzy operates on a pain management theory called gait control. Researchers have long suspected that various kinds of sensory simulation could actually interrupt pain signals traveling up the spinal cord, before they reach the brain. After experimenting with different kinds of stimulations, Dr. Baxter settled on a combination of cold temperature with high-speed vibration. The cold and the vibration crowds out the pain caused by a shot by literally sending stronger motion and temperature sensations up the nerve pathways than are produced by the pain. It's kind of like rubbing a cut under cold water or the dentist jiggling your check before giving you a shot. The vibrating bee attaches to thin ice packs that look like wings. The device is then placed between the injection site and the brain to block the pain from the injection. It also blocks the burning sensation that some medications cause after a shot is administered.

Buzzy's efficacy has been verified by independent testing and research. Along with helping people who get an occasional shot, Buzzy is particularly beneficial for people who must receive regular shots as the result of a chronic condition. Buzzy is sold to doctors' offices, hospitals, and clinics. A fully FDA-compliant version is also available for home use and is priced at $39.95. The home version can be used by people who inject themselves as part of a physician-supervised home health care regime, or can be taken to the doctor's office when the need for a shot is anticipated. The Buzzy device is reusable.

1. Based on the material covered in this chapter, what questions would you ask the firm's founders before making your funding decision? What answers would satisfy you?

2. If you had to make your decision on just the information provided in the pitch and on the website, would you fund this company? Why or why not?

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YOU BE THE VC 16.2

COMPANY: Flings Bins

Business Idea: Create a pop-up, disposable trash bin that makes the process of recycling and collecting trash, particularly at parties and events that are held away from everyday garbage and recycling receptacles, simpler, cleaner, and more fun.

Pitch: Most people want to do what is "right" when it comes to handling trash and recycling, but obstacles get in their way. Trash bags are often flimsy and hard to deal with. Recycling containers can quickly get dirty and unsightly. And handling trash and recycling can be difficult at parties and events that are held away from a person's home or business. These types of complications cause many people angst. Imagine throwing a party at a park, a beach, or a facility that you're not familiar with. It's easy for soda cans and beer bottles to pile up and for garbage cans to overflow. Even if you're throwing a party in your own home, household garbage cans and recycling containers are often too small to handle the job.

Flings Bins were created to address these problems. Flings is a freestanding pop-up container and trash bag in one. You can set up several Flings containers around the house and not have to worry about taking out trash in the middle of the party. They are portable and can be brought outdoors to picnics, campsites, and tailgating parties where there is no trash can nearby. They are disposable and 100 percent biodegradable, but are sturdy enough to be emptied and used again if the trash inside wasn't particularly messy. They also dress up a party or event rather than create an eyesore, as is the case with most trash containers. They are available in many different colors and patterns, such as patriotic colors for a Fourth of July party, red and white gingham for a barbeque, or confetti and balloons for a New Year's Eve party. While people don't normally think of impressing their guests with their trash or garbage containers, Flings Bins are quite stylish. Flings Bins are also available that are completely covered in the recycle symbol and are labeled "Please Recycle Here." There are boxes that can be checked with a marker or sharpie that say "cans," "plastics," "glass," and so on, so a host can opt to set up recycling bins for different purposes.

Flings containers come flat and pop up for use. As a result, they are easy to transport and store. As the company says, "Pop it! Fill it! Toss it! Or Recycle and Reuse!" Each bin has a 13-gallon capacity (which holds about 60 cans or bottles), and a drawstring that makes them easy to close and carry.

1. Based on the material covered in this chapter, what questions would you ask the firm's founders before making your funding decision? What answers would satisfy you?
2. If you had to make your decision on just the information provided in the pitch and on the company's website, would you fund this company? Why or why not?

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CASE 16.1

Birchbox: Leveraging the College Experience to Write a Business Plan and Launch a Winning Start-up

Introduction

Katie Beauchamp and Hayley Barna met on their first day at Harvard Business School. They volunteered to co-coordinate a spring holiday for themselves and 50 of their classmates. Through the experience they realized that they worked well together as a team, but at that time, they had no thought of co-founding a business. That all changed just over a year later, when Beauchamp and Barna launched Birchbox, a beauty samples subscription service that now has over 400,000 monthly subscribers.

The College Experience

Beauchamp and Barna quickly became friends. They were also in the same MBA cohort and took many of their classes together. The idea for Birchbox emerged gradually. One class was particularly instrumental. It was a class on disruptive innovation taught by Harvard professor Clayton Christensen. The class challenged the students to think of a big idea that's an industry game changer. Beauchamp and Barna's first idea concerned the beauty industry, which hadn't experienced significant innovation for many years. A personal dynamic also nudged them towards a business idea in the beauty industry. Barna's best friend, Mollie Chen, was a beauty editor. Beauchamp would notice that Barna always had the best beauty products, and when asked where she got them, she would always say that Chen (the beauty editor) had recommended them. It got Beauchamp and Barna thinking "wouldn't every woman like to have a best friend that was a beauty editor and could recommend beauty products to them?"

Birchbox Co-founders Hayley Barna and Katie Beauchamp

Birchbox

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Beauchamp and Barna's thoughts coalesced in the last semester of their two-year MBA program. For the first time, they were thinking about starting a business together. They saw a void in the marketplace ripe to be filled. Companies had come up with great ways to sell many products online, including fashion, but not beauty products. Beauty products are tough to sell online because they have a touch, try, and feel element to them. To capitalize on the opportunity of selling beauty products online, and get around the hesitation that people have for buying beauty products without touching and seeing them first, Beauchamp and Barna's idea was an online monthly subscription service that consisted of a small box of beauty product samples that qualified customers could try out. They would then offer full-sized versions of the samples on their website for sale. The major brands were already making samples that they handed out in stores. Beauchamp and Barna decided to call their business Birchbox.

Last Semester at Harvard—A Testing Ground for Birchbox

Rather than let the clock run out on their college experience and then try to launch Birchbox, Beauchamp and Barna did everything they could to leverage their college status. They negotiated with their professors so their final project in each class would be Birchbox. They also used their student status as a way of getting their foot in the door with suppliers and customers. For Birchbox to work, Beauchamp and Barna had to answer three fundamental questions. First, would beauty brands work with them, in regard to providing samples? Second, would women pay for curated boxes of samples? And third, would samples drive full-sized purchases? The only way, they figured, to answer these questions was to go straight to the sources. First, they built a prototype of the box in which they would send the monthly samples and determined how the samples would be presented in the box. They then thought through the rest of the business. Each month, the box would contain five beauty product samples. Information would be put on their website and YouTube channel about each product, so the customer could learn more about them. They would then offer full-sized versions of the products for sale. To get buy-in, they "cold-called" beauty and cosmetics companies. They never hid the fact that they were still in college. Instead, they framed it as an advantage (they had a readymade audience of their target market right in their classes). Incredibly,

Each monthly Birchbox for Women includes a small collection of high-quality beauty, grooming, and lifestyle product samples. The product samples are similar to the ones shown here.

Christopher Hall/Shutterstock

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several of the companies, including Benefits, Nars, and Keihl's signed on. Second, they created a beta version of their website and incented 200 subscribers to pay them $20 a month to test their concept. They used feedback from the users to improve the original Birchbox in several key areas. At this point, Beauchamp and Barna had more than an idea. They had suppliers, a preliminary list of potential customers, results, and data.

After completing these steps, Beauchamp and Barna entered Birchbox into the HBS business plan competition. They won second place, which further bolstered their confidence. The competition provided tremendous exposure for Birchbox and for Beauchamp and Barna as nascent entrepreneurs. They met people who became advisers and mentors. The competition was judged by venture capitalists, and several of them offered the pair money. They passed on the offers, thinking it would be best to keep Birchbox lean.

Birchbox officially launched in September 2010. At the outset, it remained lean and reflected a college student's lifestyle. After graduation, Beauchamp and Barna moved Birchbox to Brooklyn to be closer to their suppliers. Their first office was unpretentious and had IKEA furniture. Beauchamp and Barna learned many lessons the hard, and sometimes fun, way. For example, when they made their first product video they tried to recruit volunteers in Union Square (a popular area in Manhattan). They soon found that it's impossible to get busy New Yorkers to volunteer, so they, along with a couple of early employees, dressed up and starred in the video themselves. By the end of 2010, Birchbox had 10,000 subscribers.

Birchbox Today

Birchbox today is operating on all cylinders. The company has 400,000 monthly subscribers. Its monthly subscription service for women, which costs $10 per month, is much the same as it was when the company originally launched, except that subscribers now fill out a beauty profile and several versions of the monthly box are sent out. In 2012, the company launched Birchbox Man, a $20 box filled with men's grooming supplies and lifestyle products. It also started testing a limited edition "home box" for $58 a month that will include home décor products and items such as seasonal napkins and decorations. In September 2012, Birchbox acquired JolieBox, a Paris-based competitor. The acquisition will allow Birchbox to more effectively enter European markets. Along the way the company has grown to 140 employees and raised almost $12 million in funding.

The company's performance metrics are also strong. The number of monthly subscribers in all of its categories continues to grow. More than half of its monthly subscribers make purchases from the firm's e-commerce store, and the e-commerce store now represents a quarter of its revenue. Birchbox's online store even attracts business from nonsubscribers. About 15 percent of the company's orders come from customers who don't get the monthly box of sample products.

Birchbox's model is also working out for its suppliers. Traditionally, beauty suppliers have tried to acquire customers by handing out samples at their counters and in other parts of stores and malls. Birchbox's customers, in stark contrast, actually pay to be acquired through the monthly subscription service. They in effect opt-in and explicitly want to be sampled. When Birchbox sells a full-sized version of something that was sampled through its subscription service, it shares the revenue with the supplier.

Challenges Ahead

Despite its success, Birchbox has significant challenges. It may at some point plateau in terms of subscribers for its staple women's subscription service. New markets may be more difficult to grow. For example, the number of products and product samples made for men's grooming and lifestyle supplies is much lower than those made for women. It may also be difficult to find as large a following for products like home décor as for women's beauty suppliers.

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Another challenge Birchbox faces is growing competition. A number of start-ups have replicated Birchbox's monthly subscription service for beauty product samples for women. While Birchbox remains the clear leader in this space, the number of competitors it is attracting is somewhat worrisome. Interestingly, while it doesn't directly impact Birchbox's business, the company has also inspired a wave of companies selling monthly boxed products in almost every conceivable area, including fishing, food, crafts, kids' toys, products for dogs, and wine.

Discussion Questions

1. How effectively do you think Katie Beauchamp and Hayley Barna used their time in college to advance their business idea?
2. In what ways is Birchbox's business approach a win-win for both its suppliers and its customers?
3. How was writing a business plan and preparing for a business plan competition helpful to Katie Beauchamp and Hayley Barna while Birchbox was still in the planning, testing, and prototyping stage?
4. Going forward, what are the most serious challenges facing Birchbox? Which of these challenges do you believe is the most threatening to the firm's success? Why?

Sources: Birchbox home page, www.birchbox.com, accessed March 1, 2014; A. Groth, "Exclusive Q&A: Birchbox Co-Founder on HSB and the Advice They Got from Investors," Business Insider, www.businessinsider.com, accessed March 1, 2014; A. Dizik, "MBA Entrepreneurs Think Outside the Box for Beauty Business," *Financial Times*, March 3, 2013; T. Baldwin, "Entrepreneur's Corner: Birchbox," *The Wharton Journal*, February 28, 2014.

CASE 16.2

d.light: How Bringing Its Business Plan to Life Helped a Social Enterprise Get Off to a Strong Start

Introduction

Imagine the following. You're in the audience of a business plan competition. The next team up to present is d.light, a for-profit social enterprise that plans to bring light to people without access to reliable electricity. Two young men introduce themselves as the founders of d.light, and say they're going to start their presentation with a demonstration. The lights go out. In a few seconds, you see a dim light at the front of the room, and smell smoke and burning kerosene. After about 30 seconds, your eyes start to water and it becomes slightly uncomfortable to breathe. The lights switch back on and the smoke clears. The young men apologize for the lack of light and the smoke, but say the demonstration was staged to illustrate a point. Around 1.6 billion people, or more than one fifth of the world's population, have no access to electricity, and about a billion more have an unreliable or intermittent supply. A large share of these people use kerosene to light their homes at night. Kerosene fumes are extremely unhealthy, even fatal. In fact, the United Nations estimates that kerosene fumes kill 1.5 million people per year, and cause countless health complications for others.

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Sam Goldman and the Origins of d.light

The scene described here actually took place—several times. It's the way Sam Goldman and Ned Tozun, the co-founders of d.light, introduced the company at business plan competitions and when they pitched investors. d.light is an international consumer products company serving "base of the pyramid" consumers who don't have access to reliable electricity. Although d.light technically started in a class at Stanford University, its beginning can be traced to Sam Goldman's youth and early adulthood. Growing up, Goldman's parents worked for the United States Agency for International Development (USAID), a government agency that provides economic and humanitarian assistance in countries across the globe. Goldman lived in Pakistan, Peru, India, Canada, and several other countries. As a young adult, while working for the Peace Corps, he lived for four years in a West African village that had no electricity. A neighbor boy was badly burned in a kerosene fire, an event that deeply impacted Goldman. At one point during his time in the village, Goldman was given a battery-powered LED headlamp, and was struck by the dramatic difference that simply having light at night can make in a person's life. He could now cook, read, and do things at night that were unimaginable without the benefits reliable lighting provides.

Impacted by this experience, Goldman sought out a graduate program that would provide him the opportunity to start thinking about creating a business to take light to people without access to reliable electricity. He landed at Stanford, which was starting a program in social enterprise. A pivotal class was Jim Patelli's 2006–2007 Entrepreneurial Design course. The class was divided into teams, and each team was challenged to address a significant issue in the developing world. Goldman was teamed up with Ned Tozun, a business classmate, and two engineering students, Erica Estrade and Xian Wu. The team tackled the problem of light for people without access to reliable electricity, and developed a rough prototype of a portable LED light that could be recharged via solar power. That spring, the team traveled to Burma for the purpose of going into villages that didn't have access to electricity to introduce their device. Villagers told them they spent up to 40 percent of their income on kerosene. When shown how their crude prototype could provide light at night and be recharged during the day simply by deploying small solar panels on their homes, the villagers were so taken that one woman actually wept. According to one account of the team's trip, in one village the local police confiscated the prototypes. They, too, needed light at night.

Design and Distribution

After completing the Entrepreneurial Design course, the teammates headed their separate directions for the summer. In the fall, they reunited, determined to continue to work on their business concept. The concept of using solar power to recharge portable lights in poor rural areas wasn't new. In fact, it had been tried many times. The problem, in Goldman and his team's estimation, was a combination of design and distribution. Previous models relied either on NGOs and governments "giving" fairly expensive lights to people without access to electricity, which they couldn't afford to replace when used up or if broken, or commercial enterprises buying extremely inexpensive lights in China and exporting them to Africa and elsewhere, where they performed poorly. It was clear to Goldman that neither of these models was sustainable.

So Goldman and his team, driven by the possibility of changing literally millions of people's lives throughout the world, recruited talented engineers and distribution experts, who worked on a near pro bono basis, to help with the project. The goal was to produce a solar-powered portable LED light that was exactly what rural villagers needed—nothing more and nothing less. It also had to be cheap enough that villagers could afford it yet capable of being produced in a way that yielded sufficient margins for d.light to be profitable. The

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decision was made early on that d.light would be a for-profit company. The company's goal was not to impact 100,000 people or a million people but to impact hundreds of millions of people. Goldman and his team knew that their lofty ambitions would take cash and additional R&D efforts, which would require private-sector investment capital.

During this period, which covered the summer of 2007 until early 2008, Goldman and his co-founders continued traveling to remote areas for the purpose of obtaining feedback about their prototype. During Christmas break, instead of traveling home to see his family, Goldman was in the middle of Myanmar doing research. The team thinned some in early 2008, with Goldman, Tozan, and Wu continuing. d.light was now up-and-running and opened its first international offices in India, China, and Tanzania.

Business Plan Competitions and Investor Presentations

One thing Goldman stresses during talks about d.light is the instrumental role that the company's business plan played in helping the company take shape and in raising investment capital. Early on, d.light entered several business plan competitions. In the spring of 2007, it took second place in the University of California, Berkley's Social Venture Competition and won first prize at Stanford's Social E-Challenge. A big breakthrough happened in May 2007, when the team claimed the $250,000 first prize in the prestigious Draper Fisher Jurvetson Venture Challenge competition. This money provided seed funding for much of the work that was completed during the summer and fall of 2007.

What's particularly interesting is Goldman's reflections about why d.light was so successful in business plan competitions and eventually with investor presentations. These reflections are instructive for entrepreneurs as they think about how to design and then successfully launch their ventures. As shown in the nearby table, there are six reasons that account for d.light's success, specifically with business plan competitions. Collectively, the attributes shown in the table present d.light as an organization with a compelling idea, a strong management team, large markets to serve, an intense product focus, and a coherent, resolute, and extremely admirable vision for the future.

d.light Today

Today, d.light is having the impact that its founders envisioned it could. The nearby chart shows the numbers on d.light's social impact dashboard, which is updated frequently. These numbers reflect the impact of the availability of light, produced by d.light solar lanterns, for people who didn't previously have access to reliable electricity and light. The numbers are remarkable, particularly in terms of lives empowered, school-aged children reached with solar lighting, and savings in energy-related expenses. The numbers reflect the good that a well-managed social enterprise can create.

d.light's Social Impact Dashboard

Number	Category
28,785,844	Lives empowered
7,196,461	School-aged children reached with solar lighting
$905,549,027	Saved in energy-related expenses
9,276,143,334	Productive hours created for working and studying
2,125,754	Tons of CO_2, offset
37,590,326	kWh generated from renewable energy source

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Indian mother of three with her d.light solar-powered lamp.

Archivo particular GDA Photo Service/Newscom

d.light sells its product through a number of channels in more than 30 countries. One strategy that has worked well is to employ "rural entrepreneurs" to sell the product. d.light likes to employ indigenous personnel, who know the local customs, people, and language, to sell its product on a commission basis. It also has partnerships with NGOs, microfinance organizations, and social enterprise start-ups that are producing solar lanterns to achieve the same goals it is striving towards. In 2013, d.light entered into a major partnership with Total, a French oil and gas company that sells d.light's products as part of the "Access to Energy Program" throughout Africa. As a result of the Total partnership, and its initiatives across the world, d.light now makes more than 500,000 of its solar lanterns per month. The first few years of its existence, d.light's production was more in the neighborhood of 20,000 to 30,000 units per month. d.light has funded its operations and growth through both investment capital and earnings. d.light is also continually updating its products. For example, its newest design incorporates a smartphone charger, knowing smartphones are the lifeline of many small business owners and others in developing countries.

Challenges Ahead

As it continues to grow, d.light faces a host of challenges. The problem it is trying to solve, to provide a reliable source of light to people without access to electricity, is as large as ever. The United Nations now estimates that over 2 billion people in the world do not have access to reliable electricity. Incredibly, that number is higher than when d.light was founded in 2007. Its for-profit status is also periodically challenged. A d.light lantern costs the equivalent

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Six Key Reasons d.light Was Successful in Business Plan Competitions

Told Stories and Showed Pictures	While many teams enter business plan competitions with impressive PowerPoint slides and bullet points, d.light focused on telling stories and showing pictures. The company's founders showed photographs of rural villagers using their device, and shared their testimonials. In one interview, Goldman remarked that no matter how many plans or pitches a group of judges or investors heard during a day, he was confident they remembered d.light's presentation.
All In	The founders were fully committed to d.light. They passed on corporate jobs and focused on d.light full time. Along with "talking the talk," they also "walked the walk." Instead of saying that they planned to travel to remote villages to test their device, they just went out and did it. Some of the trips came before the business plan presentations.
Right Team	d.light put together a strong team, with a balance of business and engineering expertise. The team was well-suited for launching a global initiative. Goldman had lived overseas the majority of his life, in places like India and Pakistan. Other team members had demonstrated that they had no inhibitions about traveling to remote villages to talk about their device.
Big Market	d.light was tackling a large market, which investors like. To make their financials work, the team would have to scale the business and sell millions of units. While the challenge was great, so was the potential payoff.
Product Focus	The company iterated its device multiple times before settling on its first solar-powered portable LED light, called the Nova. The Nova sold for a U.S. equivalent of around $25. Early feedback indicated that the price was still too high, so more iterations took place.
Strong Vision	Although d.light was a social enterprise, it unashamedly presented itself as a for-profit venture. The team was resolute that getting to scale could only be accomplished via private-sector capital. d.light also measured its success by the number of families it positively impacted. This sense of purpose and vision permeated the organization.

of 30 U.S. dollars, an amount that remains beyond the reach of many people in underdeveloped countries. Some observers believe that companies like d.light should be nonprofits and give their lanterns away. d.light's counter to this argument is that the only way to effectively tackle the worldwide shortage of reliable lighting is to stimulate business activity through the private sector. How can an entrepreneur in Kenya, the company argues, make a living selling solar lights if a nearby NGO is giving them away for free?

d.light also continues to face the challenge of convincing hesitant customers with a little extra income to invest in unfamiliar technology. Although kerosene has many harmful side effects, it is an integral part of many villagers' lives. It often takes an influential person in a village buying a d.light lantern for others to follow suit. d.light is also continually trying to lower the price point of its basic lanterns.

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d.light's efforts have clearly made a difference in the lives of millions of people. The firm has received numerous awards to recognize what it has accomplished. One particularly nice distinction is its place in the British Museum's History of the World in 100 Objects. d.light's basic lantern, the S250, is object number 100 in the collection.

d.light's stated goal is to impact the lives of at least 100 million people by 2020. It appears to be well on its way to achieving the goal.

Discussion Questions

1. Why is the problem of bringing light to people who don't have access to reliable electricity not being tackled in a meaningful way by a large lighting company, such as GE (General Electric) or Philips?
2. What qualities do Sam Goldman and his team have that will help them solve the problem of providing light to the billions of people in the world who lack access to reliable electricity?
3. Why does Sam Goldman go out of his way to talk about the importance of d.light's business plan? In what ways do you think having a meticulously created business helped d.light in its launch efforts?
4. If you were one of d.light's founders, what would your marketing strategy be? How would you go about educating people in remote areas of the world about your product and the benefits associated with purchasing it?

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CHAPTER 17

Managing the Business Enterprise

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A CRISIS FOR THE 787 DREAMLINER

On January 7, 2013, the lithium-ion batteries in a brandnew Boeing 787 Dreamliner owned by Japan Airlines caught fire while the plane was parked at Boston's Logan Airport. Then, on January 16, an All Nippon Airways Dreamliner made an emergency landing after pilots noticed a burning smell. Passengers exited the plane on emergency slides. As a result of these two incidents, the U.S. Federal Aviation Administration (FAA) grounded all 787s until the cause of the problem could be identified and fixed (the first time since 1979 that the FAA had taken such an action). The grounding order meant that the eight airlines that had purchased the plane had to cancel hundreds of flights, and that reduced their revenues. It also meant that Boeing couldn't deliver dozens of already-built Dreamliners until the FAA ban was lifted. The problem is one of Boeing's biggest crises in years and could cost the company a lot of money, including penalty payments to buyers who do not receive their planes on time.

Jim McNerney—the CEO of Boeing—immediately took action to deal with the crisis. He sent handwritten apologies to the leaders of the two Japanese airlines, and persuaded General Motors and General Electric to lend their electrical experts to help find the cause of the problem. He also met with officials at the FAA to brief them on what Boeing was doing to deal with the crisis. McNerney's strategy was to work behind the scenes to deal with the crisis rather than to get involved in a lot of public relations activity with the media. In a meeting with Boeing's Chief Technology Officer, McNerney pointed out in strong terms that the problem wasn't simply about electrochemistry in a battery, but about safety and the confidence of the general public in Boeing's plane. But McNerney took flak for not being more forthcoming with investors and the public about the nature of the problem.

At a press conference on January 30, McNerney talked about fourth-quarter financial results and told investors and financial analysts that the company was planning to increase 787 production from five to ten planes a month. He said he couldn't answer questions about the battery problems because the company was in the middle of an investigation. Investors were nervous because they didn't know how much the problem would cost to fix.

On February 22, FAA officials met with Boeing managers and reviewed a proposal to get the Dreamliner flying again, but the FAA representatives said they wouldn't let the plane back in service until they were convinced that the safety risks with the lithium-ion batteries had been addressed. Both Japanese and U.S. investigators agreed that the batteries had caught fire after short circuits caused thermal reactions among the battery cells

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which then produced temperatures that were high enough to melt metal. But they disagreed over what caused the short circuits. Japanese investigators from GS Yuasa Corp. (the company that makes the batteries) felt that a power surge that originated outside the battery was the cause of the problem. They therefore suggested that a voltage regulator be installed to prevent electrical current from flowing to the batteries if a problem developed. By contrast, Boeing's investigators proposed stronger and better separated battery cells, as well as a fireproof container for the batteries. One of the reasons for this disagreement is that investigators didn't have much experience with the use of lithium-ion batteries on commercial jetliners. But the disagreement meant that Boeing was facing the possibility that the root cause of the problem might be very difficult to identify.

On March 12, the FAA gave initial approval to Boeing's proposed fix-ups to the batteries. This meant that flight tests could begin to see if the problem had really been solved. But test flights are a lengthy process, and it appeared that commercial flights might not be able to resume until May 2013.

The negative publicity about the problems with the 787 created a public relations challenge for Boeing, because it had to convince passengers that the airplane was really safe to fly. Boeing responded to the crisis with various initiatives. For example, when curious web users Googled search terms such as "Dreamliner fire," the first item they saw was a sponsored link that directed them to a page where they could read details of Boeing's changes to the plane's batteries. Boeing also downplayed the severity of the battery fires by noting that there had been thousands of instances over the years where batteries in airplanes malfunctioned. A top executive at Boeing also said that he would be on the first 787 flight after the FAA lifted its grounding order.

The crisis also grounded the pilots who fly the Dreamliner. They passed the time by practising on flight simulators and giving lectures to school-children. One Air India 787 pilot made a rap video for YouTube lamenting his lack of flight time.

On April 25, 2013, the FAA approved the changes to the battery system that Boeing proposed, and the Dreamliner was cleared for flights carrying passengers once again.

How Will This Help Me?

From the perspective of a *manager*, after reading this chapter you will have a clearer understanding of how to effectively carry out various management responsibilities. From the perspective of a *consumer* or *investor*, you'll be better able to assess and appreciate the quality of management in various companies.

Questions for Discussion

1. How well do you think Boeing CEO Jim McNerney handled the Dreamliner crisis? Explain.
2. Use the steps in the rational decision-making process that are presented in this chapter to describe the progression of events that occurred in the 787 Dreamliner crisis.

17.1 Who Are Managers?

Managers are the people who plan, organize, lead, and control the operations of an organization. All businesses depend on effective management. Regardless of the type of organization they work in, managers perform many of the same basic functions, are responsible for many of the same tasks, and have many of the same responsibilities. Although our focus is on managers in business settings, management is important for all kinds of organizations, including charities, religious organizations, community organizations, educational institutions, and government agencies. The prime minister of Canada, the president of the University of Toronto, the executive director of the United Way, the dean of your business school, and the chief administrator of your local hospital are all managers. Regardless of the nature and size of an organization, managers are among its most important resources.

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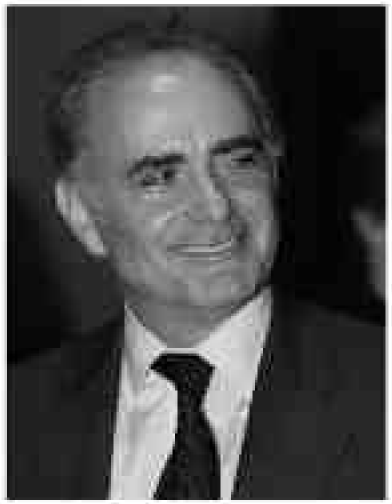
As top managers, (a) Marjorie Scardino (former CEO of Pearson PLC), (b) Colin Rovinescu, president and CEO of Air Canada, and (c) James Sinegal (co-founder and CEO of Costco) are important resources for their companies. They set the strategic direction for their companies and provide leadership to other managers. They are also accountable to shareholders, employees, customers, and other key constituents for the performance and effectiveness of their businesses.

ADRIAN DENNIS/AFP/Getty Images



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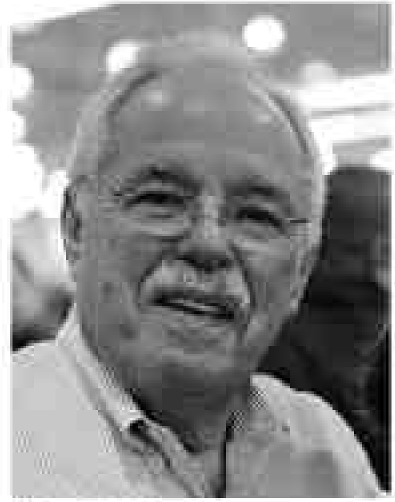

AP Photo/Paul Sakuma

17.2 | The Management Process

Management is the process of planning, organizing, leading, and controlling an enterprise's financial, physical, human, and information resources to achieve the organization's goals. There are two important overall points to keep in mind when thinking about the management process. First, the planning, organizing, leading, and controlling aspects of a manager's job are interrelated. This means that a manager is likely to be engaged in all these activities during the course of any given business day.

Second, there is a difference between management effectiveness and management efficiency. **Efficiency** means achieving the greatest level of output with a given amount of input. **Effectiveness**, on the other hand, means achieving organizational goals that have been set. Thus, efficiency means doing things right, while effectiveness means doing the right things. A manager who focuses on being effective will likely also be efficient, but a manager who focuses on being efficient may or may not be effective.

17.2.1 Planning

Planning is the process of determining the firm's goals and developing a strategy for achieving those goals. The planning process involves five steps:

- In Step 1, goals are established for the organization. A commercial airline, for example, may set a goal to fill 90 percent of the seats on each flight.
- In Step 2, managers identify whether a gap exists between the company's desired and actual position. For example, the airline may analyze load data and find that only 73 percent of the seats on the average flight are filled.
- In Step 3, managers develop plans to achieve the desired objectives. For example, the airline may reduce fares on heavily travelled routes in order to increase the percentage of the seats that are filled.

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- In Step 4, the plans that have been decided upon are implemented. For example, the fare from Toronto to Montreal may be reduced by 10 percent.
- In Step 5, the effectiveness of the plan is assessed. The airline would measure the percentage of seats that were filled after the change was implemented to determine whether the goal was reached.

McDonald's experience in Canada over the past decade demonstrates the importance of the planning process. Until 2002, McDonald's was the largest fast-food chain in Canada. But then it was overtaken by Tim Hortons. In response to this development, McDonald's set a goal to reinvent itself and begin to grow again (Step 1). The gap between where McDonald's was and where it wanted to be (Step 2) was obvious, so McDonald's top managers developed a strategic plan (called "Plan to Win") in order to achieve the new objective (Step 3). This involved developing many new menu items (like the Angus Burger, new salads, and snack wraps), renovating restaurants to look more like contemporary cafés or bistros (with polished stone tabletops and fireplaces), letting franchisees target local tastes with their menus (like the McLobster sandwich in the Maritimes), and staying open longer (60 percent of McDonald's restaurants are now open 24 hours a day). These plans were implemented beginning in 2003 and 2004 (Step 4). The effectiveness of the plan has now been assessed (Step 5). Sales were $2.9 billion in 2008 (a record) and $3 billion in 2009 (another record).[1] These sales levels were achieved in spite of the recession of 2008 to 2009. In 2011, McDonald's announced that it planned to spend $1 billion on further interior and exterior renovations to its restaurants.[2]

A Hierarchy of Plans

Plans can be made on three general levels, with each level reflecting plans for which managers at that level are responsible. These levels constitute a hierarchy because implementing plans is practical only when there is a logical flow from one level to the next. **Strategic plans** reflect decisions about resource allocations, company priorities, and the steps needed to meet strategic goals, and are usually set by top management. In 2010, Maple Leaf Foods developed a five-year strategic plan which was designed to increase its earnings by more than 75 percent by 2015.[3] When organizations like Bell Canada make strategic plans, they must take into account certain technological developments that affect their business (see the boxed insert entitled "Should You Say Goodbye to Traditional Land Lines?")

By contrast, **tactical plans** are shorter-range plans concerned with implementing specific aspects of the company's strategic plan. They typically involve upper and middle management. Coca-Cola's decision to increase sales in Europe by building European bottling facilities is an example of tactical planning. **Operational plans**, developed by middle and lower-level managers, set short-term targets for daily, weekly, or monthly performance. McDonald's, for example, establishes operational plans when it explains precisely how Big Macs are to be cooked, warmed, and served.

17.2.2 Organizing

Organizing involves mobilizing the resources that are required to complete a particular task. The importance and complexity of the organizing function can be seen by considering the restructuring that has taken place at Hewlett-Packard in recent years. HP had long prided itself on being a corporate confederation of individual businesses. Each business made its own decisions quickly and efficiently, and the competition kept each

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E-BUSINESS AND SOCIAL MEDIA SOLUTIONS

Should You Say Goodbye to Traditional Land Lines?

Older Canadians remember the days when telephone operators and telephone cords were an integral part of everyday conversations. Today, consumers use words like VoIP and Skype, and they use tools like smartphones and tablets. In the past two decades, there has been a steady decline of land-line usage and an increase in wireless communication. And pay phones, which were once a powerful revenue source for phone companies, were available in numerous locations, such as local restaurants, malls, and street-corner stand-alone phone booths. But it's getting tougher and tougher to spot these relics of the past. Your home land-line phone may be next.

Part of the transition is due to the introduction and tremendous growth of VoIP (which stands for Voice-over-Internet Protocol). When you think of VoIP, you may think of pure play companies like Vonage or even a firm like Magic Jack, but it also includes computer-based options like Skype and Google Voice. The big name cable companies like Rogers are also in on the action, but they tend to charge much higher prices than pure VoIP organizations. It is projected that by 2015 this category will account for over 68 percent of the market. This number should be reached and quickly surpassed partly because of some new regulations. A recent ruling gives consumers the ability to transfer their regular phone numbers to new VoIP service accounts if they decide to leave their current provider. In early 2013, NetTalk jumped on the opportunity and was actively encouraging consumers to transfer their service and save money.

There is another trend that threatens traditional phone companies. According to Convergence Consulting Group Ltd., one in five Canadians (an estimated 21.6 percent in 2013) are cancelling their home phone line altogether. This is up from about 14 percent two years earlier. This is happening because:

- Mobile plans are getting cheaper as new competition drives down prices.
- Competition has led to more favourable unlimited plans.
- Younger consumers who grew up with mobile phones are feeling no need to sign up to a land-line service when they leave their parents' home.

The net result is that wireless is seen as the only way to go for a large number of Canadians. You can't really blame companies like Bell for wishing things would stay the same (land lines and mobiles for everyone), but they have already started to respond to the mobile market. As the communications industry continues to change, all the players will need to adapt or risk becoming as irrelevant as the lonely phone booth.

Critical Thinking Questions

1. Do you have a traditional home line? A VoIP line? Are you one of the growing number of people that are part of the wireless-only generation?
2. What can traditional phone and wireless providers do to keep your business or regain your loyalty? Think of solutions beyond just pricing.

unit on its toes. This structure served the firm well for many years. But as time passed, HP somehow lost its competitive edge. The decision was then made to centralize company activities and develop an integrated, organization-wide internet strategy. A reorganized HP then bounced back, at least for a few years.[4] But when HP began again to experience profitability problems in its PC division in 2005, then-CEO Carly Fiorina decided to combine the PC and printing divisions in order to increase hardware sales to customers. When Fiorina left HP shortly thereafter, her successor (Mark Hurd) undid

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Managers are needed in all kinds of business firms, including professional sports teams. A head coach is a first-line manager who is responsible for the day-to-day success of the team.

her changes. When Hurd left the firm a few years later, the new CEO, Meg Whitman, once again combined the two divisions.[5]

17.2.3 Leading

Leading (or directing) involves the interactions between managers and their subordinates as they both work to meet the firm's objectives. Legendary leaders like Sam Walton (Walmart), Clive Beddoe (WestJet), and Steve Jobs (Apple) were able to unite their employees in a clear and targeted manner, and motivate them to work in the best interests of the company. While managers have the power to give orders and demand results, leading goes beyond merely giving orders. Leaders must also have the ability to motivate their employees to set challenging goals and to work hard to achieve them. This means that employees will respect their leaders, trust them, and believe that by working together, both the company and its employees will benefit.

17.2.4 Controlling

Controlling is the process of monitoring a firm's performance to make sure that it is meeting its goals. Managers at WestJet and Air Canada, for example, focus relentlessly on numerous indicators of performance that they can measure and adjust. Everything, from on-time arrivals to baggage-handling errors to the number of empty seats on an airplane to surveys of employee and customer satisfaction, are regularly and routinely monitored. If on-time arrivals start to slip, managers focus on the problem and get it fixed. No single element of the firm's performance can slip too far before it is noticed and fixed.

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Figure 17.1 The Control Process

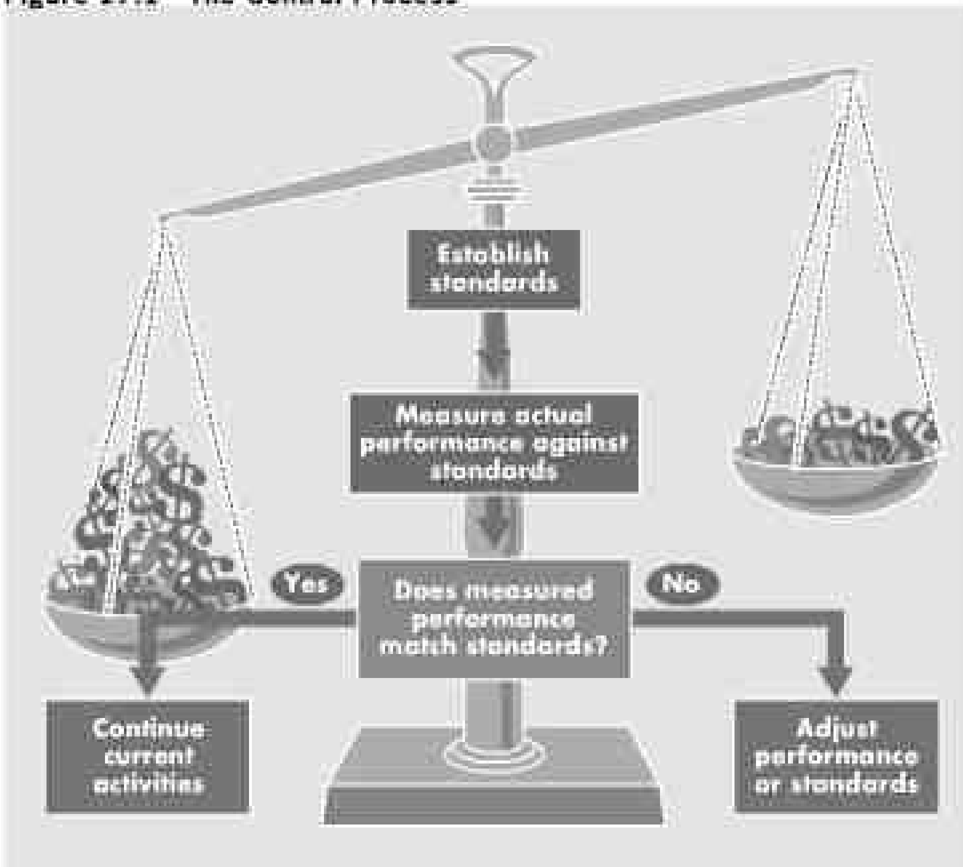

Figure 17.1 illustrates the control process, which begins when management establishes standards (often for financial performance). If, for example, a company sets a goal of increasing its sales by 20 percent over the next five years, an appropriate standard to assess progress toward the 20 percent goal might be an increase of about 4 percent a year. Managers then measure actual performance each year against standards. If the two amounts agree, the organization continues along its present course. If they vary significantly, however, one or the other needs adjustment. If sales have increased 3.9 percent by the end of the first year, things are probably fine. But if sales have dropped 1 percent, some revision in plans is needed.

Consider how controlling applies to the courses that you are now taking. The instructor first indicates the knowledge areas where you must show competence and the level of competence you must show. Next, the instructor measures your performance, usually through assignments and exams. The instructor then determines whether your performance meets the standard. If your performance is satisfactory (or unsatisfactory), you receive feedback in the form of a passing (or failing) grade in the course.

Control can also show where performance is better (or worse) than expected and can serve as a basis for providing rewards or reducing costs. For example, when the distributor of the surprise hit movie *The March of the Penguins* saw how popular the movie was becoming, the firm was able to increase advertising and distribution, making the niche movie into a major commercial success. In contrast, when the sales of the Chevrolet Super Sport Roadster (a classic, late-1940s pickup-style vehicle with a two-seat roadster design) were much lower than expected, production of the vehicle was suspended.

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17.2.5 Management Roles vs. Management Functions

Describing managers' jobs by referring to functions like planning, organizing, leading, and controlling gives us a good *general* picture of what managers do, but it may not give a clear idea of the *specific* activities that managers are involved in. The answer to the question "What do managers actually do?" is that they play a variety of roles in organizations. The work of Henry Mintzberg of McGill University illustrates the roles approach to management. In a now-classic work, Mintzberg conducted a detailed study of the work of five chief executive officers and found that (1) they worked at an unrelenting pace, (2) their activities were characterized by brevity, variety, and fragmentation, (3) they preferred "live" action and emphasized work activities that were current, specific, and well defined, and (4) they were attracted to verbal media.[6]

Mintzberg believes that a manager's job can be described as 10 roles (in three general categories) that must be performed. The manager's formal authority and status give rise to three *interpersonal roles*: (1) figurehead (duties of a ceremonial nature, such as attending a subordinate's wedding), (2) leader (being responsible for the work of the unit), and (3) liaison (making contact outside the vertical chain of command). These interpersonal roles give rise to three *informational roles*: (1) monitor (scanning the environment for relevant information), (2) disseminator (passing information to subordinates), and (3) spokesperson (sending information to people outside the unit).

The interpersonal and informational roles allow the manager to carry out four *decision-making roles*: (1) entrepreneur (improving the performance of the unit), (2) disturbance handler (responding to high-pressure disturbances, such as a strike at a supplier), (3) resource allocator (deciding who will get what in the unit), and (4) negotiator (working out agreements on a wide variety of issues, such as the amount of authority an individual will be given).

17.3 | Types Of Managers

Although all managers plan, organize, lead, and control, not all managers have the same degree of responsibility for each activity. Moreover, managers differ in the specific application of these activities. Thus, we can differentiate between managers based on their level of responsibility and their area of responsibility.

17.3.1 Levels of Management

The three basic levels of management are top, middle, and first-line management. As Figure 17.2 shows, in most firms there are more middle managers than top managers and more first-line managers than middle managers. Moreover, as the categories imply, the authority of managers and the complexity of their duties increase as we move up the pyramid.

Top Managers

The executives who guide the fortunes of companies are **top managers**. Common titles for top managers include president, vice-president, chief operating officer (COO), chief executive officer (CEO), and chief financial officer (CFO). Top managers are responsible to the board of directors and shareholders of the firm for its overall performance and effectiveness. They set general policies, formulate strategies, oversee significant

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Figure 17.2 Organizations Have Three Basic Levels of Management

(Top to Bottom) © Trains and Planes/Alamy; © Photos 12/Alamy; Scott Houston/Polaris/Newscom

decisions, and represent the company in its dealings with other businesses and government.[7] While top managers have a lot of authority, they also have something of an image problem. A 2012 study ranked CEOs very low on the "trust" dimension, and this means that some of Canada's most successful people have low credibility.[8]

Middle Managers

Although below the ranks of the top executives, **middle managers** still occupy positions of considerable autonomy and importance. Titles such as plant manager, operations manager, and division manager are typical of middle-management positions. The producer of a Lion's Gate film, like *Precious*, is a middle manager. In general, middle managers are responsible for implementing the strategies, policies, and decisions made by top managers. For example, if top management decides to bring out a new product in 12 months or to cut costs by 5 percent, middle management will have to decide to increase the pace of new product development or to reduce the plant's workforce.

First-Line Managers

First-line managers spend most of their time working with and supervising the employees who report to them. Common titles include supervisor, office manager, and group leader. A transit supervisor who monitors bus schedules, passenger safety, and the behaviour of bus drivers is a first-line supervisor. So is the flight-services manager for a specific Air Canada flight. Table 17.1 summarizes the duties of the three basic levels of management.

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TABLE 17.1 The Three Levels of Management

Top managers	President, vice president, treasurer, chief executive officer (CEO), chief financial officer (CFO)	• Responsible for the overall performance and effectiveness of the firm • Set general policies, formulate strategies, and approve all significant decisions • Represent the company in dealings with other firms and with government bodies
Middle managers	Plant manager, operations manager, division manager, regional sales manager	• Responsible for implementing the strategies of and working toward the goals set by top managers
First-line managers	Supervisor, office manager, project manager, group leader, sales manager	• Responsible for supervising the work of employees who report to them • Ensure employees understand and are properly trained in company policies and procedures

17.3.2 Areas of Management

Within any large company, the top, middle, and first-line managers work in a variety of areas, including human resources, operations, information, marketing, and finance.

Human Resource Managers

Human resource managers can be found in most companies; they hire employees, train them, evaluate their performance, decide how they should be compensated, and deal with labour unions (if the workforce is unionized). Large firms may have several human resource departments, each dealing with specialized activities. Imperial Oil, for example, has separate departments to deal with recruiting and hiring, wage and salary levels, and labour relations. Smaller firms may have a single department, while very small organizations may have a single person responsible for all human resource activities.

Operations Managers

Operations managers are responsible for a company's system for creating goods and services. This includes production control, inventory control, and quality control, among other duties. Manufacturing companies like Steelcase, Bristol Aerospace, and Sony need operations managers at many levels. Such firms typically have a vice-president for operations (top), plant managers (middle), and supervisors (first-line). In recent years, sound operations management practices have also become increasingly important to service-producing organizations like hospitals, the government, and colleges and universities.

Information Managers

Dramatic increases in both the amount of information available to managers and the ability to manage it have led to the emergence of **information managers**. These managers are responsible for designing and implementing various systems to gather, process,

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and disseminate information. Federal Express, for example, has a chief information officer. Middle managers engaged in information management help design information systems for divisions or plants. Computer systems managers within smaller businesses or operations are first-line managers.

Marketing Managers

Marketing includes the development, pricing, promotion, and distribution of products and services. **Marketing managers** are responsible for getting these products and services to buyers. Marketing is especially important for firms producing consumer products, such as Procter & Gamble, Coca-Cola, and Sun Ice. These firms may have large numbers of marketing managers at various levels. For example, a large firm will probably have a vice-president for marketing (top manager), regional marketing managers (middle managers), and several district sales managers (first-line managers).

Financial Managers

Management of a firm's finances is extremely important to its survival. Nearly every company has **financial managers** to plan and oversee its financial resources. Levels of financial management may include a vice-president for finance (top), division controller (middle), and accounting supervisor (first-line). For large financial institutions, effective financial management is the company's reason for being.

Other Managers

Some firms have more specialized managers. Chemical companies like CIL have research and development managers, for example, whereas companies like Petro-Canada and Apple have public relations managers. The range of possibilities is almost endless, and the areas of management are limited only by the needs and imagination of the company.

17.4 Basic Management Skills

The degree of success that people achieve in management positions is determined by the skills and abilities they possess. Effective managers must have several skills, including technical, human relations, conceptual, time management, and decision-making skills.

17.4.1 Technical Skills

Technical skills allow managers to perform specialized tasks. A secretary's ability to type, an animator's ability to draw a cartoon, and an accountant's ability to audit a company's records are all technical skills. People develop their technical skills through education and experience. The secretary, for example, probably took an office systems technology course and has had many hours of practice both on and off the job. The animator may have had training in an art school and probably learned a great deal from experienced animators on the job. The accountant earned a university degree and a professional certification.

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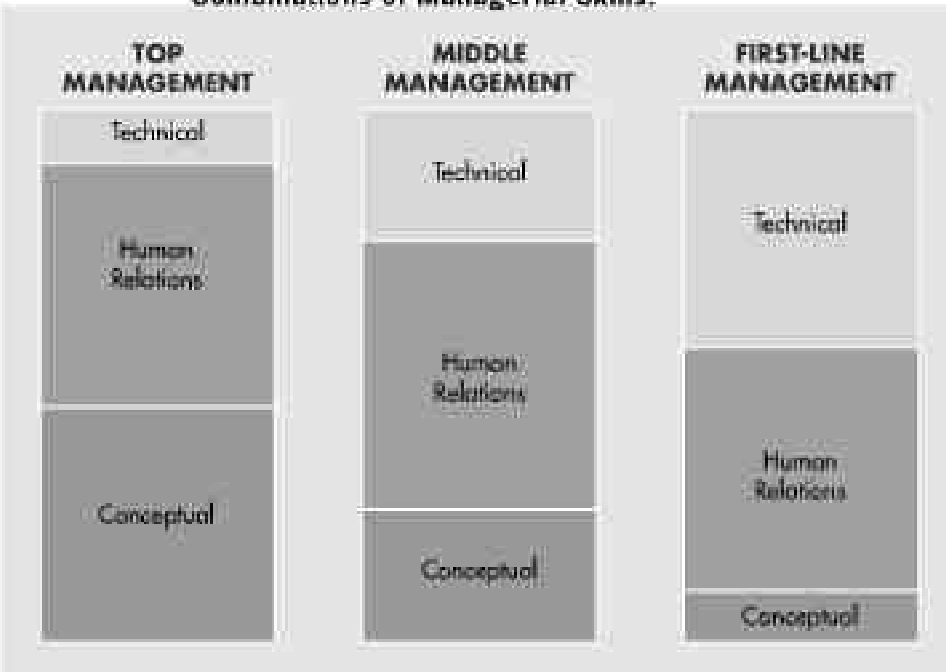
Figure 17.3 Different Levels in an Organization Require Different Combinations of Managerial Skills.



As Figure 17.3 shows, technical skills are especially important for first-line managers. Most first-line managers spend considerable time helping employees solve work-related problems, monitoring their performance, and training them in more efficient work procedures. Such managers need a basic understanding of the jobs they supervise. As a manager moves up the corporate ladder, however, technical skills become less and less important. Top managers, for example, often need only a general familiarity with the mechanics of basic tasks performed within the company. A top manager at Disney, for example, probably can't draw Mickey Mouse or build a ride for Disney World.

17.4.2 Human Relations Skills

Human relations skills help managers lead, motivate, communicate with, and get along with their subordinates. Managers with poor human relations skills will likely have conflicts with subordinates, cause valuable employees to quit or transfer, and contribute to poor morale. Figure 17.3 shows that human relations skills are important at all levels of management. This is true because all managers in the hierarchy act as "bridges" between their bosses, their subordinates, and other managers at the same level in the hierarchy. A study by DDI Canada found that the top reason for managerial failure was poor people skills,[9] and a study by Google found that technical expertise ranked last among a list of eight "Habits of Highly Effective Google Managers." At the top of the list were even-tempered bosses who made time for one-on-one meetings, and who helped subordinates work through problems.[10]

To improve their insights into employee needs and company operations, some managers work alongside lower-level employees on a temporary basis. For example, the CEO of ING Direct sits beside call centre agents and personally answers caller inquiries.[11] When the CEO of 7-Eleven (Joseph De Pinto) worked undercover at a 7-Eleven outlet, he discovered how hard the people worked and why the location was selling so much

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coffee. Larry O'Donnell, the CEO of Waste Management, did jobs like sorting trash, picking up paper at a landfill, and cleaning portable toilets. The experience taught him the pressure for production that employees had to cope with, and he introduced changes based on what he had learned on the job.[12]

17.4.3 Conceptual Skills

Conceptual skills refer to a person's ability to think in the abstract, to diagnose and analyze various situations, and to see beyond the present situation. Conceptual skills help managers recognize new market opportunities and threats. For example, in e-commerce businesses, conceptual skills help managers foresee how a particular business application will be affected by, or can be translated to, the internet. Figure 17.3 shows that top managers depend most on conceptual skills, and first-line managers least, but some conceptual skills are needed in almost any management job.

17.4.4 Time Management Skills

Time management skills refer to the productive use that managers make of their time. Effective time management is particularly important for highly paid top managers. For example, in 2010 Aaron Regent, CEO of Barrick Resources, was paid a total of $24 217 040.[13] Assuming that he worked 50 hours a week and took two weeks' vacation, Regent earned about $9686 per hour, or about $161 per minute. Any time that Regent wastes represents a large cost to Barrick and its stockholders.

To manage time effectively, managers must address four leading causes of wasted time:

- *Paperwork.* Some managers spend too much time deciding what to do with letters and reports. Most documents of this sort are routine and can be handled quickly. Managers must learn to recognize those documents that require more attention.
- *The telephone.* Experts estimate that managers are interrupted by the telephone every five minutes. To manage time more effectively, they suggest having a secretary screen all calls and setting aside a certain block of time each day to return the important ones.
- *Meetings.* Many managers spend as much as four hours per day in meetings. To help keep this time productive, the person handling the meeting should specify a clear agenda, start on time, keep everyone focused on the agenda, and end on time.
- *Email.* With the introduction of devices like the BlackBerry, managers are relying more heavily on email and other forms of electronic communication. But many email messages are not important, and some are downright trivial. As the number of electronic messages grows, the potential time wasted also increases.

17.4.5 Decision-Making Skills

Decision-making skills help managers define problems and select the best course of action. It is a critical management skill because decision making affects all the functions of management. The Alternative Board (TAB) is devoted to improving management decision making and has 1000 peer groups around North America. These peer groups—attended by managers looking for solutions to problems they are experiencing—provide a forum for discussions among managers who have had similar problems.[14]

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The Rational Decision-Making Process

Table 17.2 shows the steps in the rational decision-making process. The key elements of each step are described below.

Recognizing and Defining the Decision Situation The first step in rational decision making is recognizing that a decision is necessary. There must be some stimulus or spark to initiate this process. For example, when equipment malfunctions, managers must decide whether to repair it or to replace it. The stimulus for a decision may be either a problem or an opportunity. A manager facing cost overruns on a project is faced with a problem decision, while a manager who is trying to decide how to invest surplus funds is faced with an opportunity decision.

Understanding precisely what the problem or opportunity is comes from careful analysis and thoughtful consideration of the situation. Consider the international air travel industry. Because of the growth of international travel related to business, education, and tourism, global carriers like Singapore Airlines, KLM, JAL, British Airways, and American Airlines need to increase their capacity for international travel. Because most major international airports are already operating at or near capacity, adding a significant number of new flights to existing schedules is not feasible. As a result, the most logical alternative is to increase capacity on existing flights. Thus, Boeing and Airbus, the world's only manufacturers of large commercial aircraft, recognized an important opportunity and defined their decision situation as how best to respond to the need for increased global travel capacity.[15]

TABLE 17.2 Steps in the Rational Decision-Making Process

1.	Recognizing and defining the decision situation	Some stimulus indicates that a decision must be made. The stimulus may be positive or negative.	The plant manager sees that employee turnover has increased by 5 percent.
2.	Identifying alternatives	Both obvious and creative alternatives are desired. In general, the more important the decision, the more alternatives should be generated.	The plant manager can increase wages, increase benefits, or change hiring standards.
3.	Evaluating alternatives	Each alternative is evaluated to determine its feasibility, its satisfactoriness, and its consequences.	Increasing benefits may not be feasible. Increasing wages and changing hiring standards may satisfy all conditions.
4.	Selecting the best alternative	Consider all situational factors and choose the alternative that best fits the manager's situation.	Changing hiring standards will take an extended period of time to cut turnover, so increase wages.
5.	Implementing the chosen alternative	The chosen alternative is implemented into the organizational system	The plant manager may need permission from corporate headquarters. The human resource department establishes a new wage structure.
6.	Following up and evaluating the results	At some time in the future, the manager should ascertain the extent to which the alternative chosen in step 4 and implemented in step 5 has worked.	The plant manager notes that six months later, turnover dropped to its previous level.

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After a long decision-making process, Airbus decided to design its own new jumbo jet. Boeing, meanwhile, went through a similar decision-making process, but concluded that the risks were too great to gamble on such an enormous project. Instead, the company decided to modify its existing 747 design and develop a new fuel-efficient aircraft called the 787.

© Hero Images Inc./Alamy

Identifying Alternatives Once the need for a decision has been recognized and defined, the second step is to identify possible alternative courses of effective action. In general, the more important the decision, the more attention is directed to developing alternatives. If the decision involves a multimillion-dollar relocation, a great deal of time and expertise should be devoted to identifying alternatives, but if the decision involves choosing a name for the company softball team, many fewer resources should be devoted to the task (although there may be a lot of arguing about what the name should be!).

Managers must accept that factors such as legal restrictions, moral and ethical norms, and available technology can limit their alternatives. For example, after assessing the question of how to increase international airline capacity, Boeing and Airbus identified three alternatives: They could independently develop new large planes, they could collaborate in a joint venture to create a single new large plane, or they could modify their largest existing planes to increase their capacity.

Evaluating Alternatives Once alternatives have been identified, they must be thoroughly evaluated to increase the chance that the alternative finally chosen will be successful. During its analysis of alternatives, Airbus concluded that it would be at a disadvantage if it tried to simply enlarge its existing planes, because the competitive Boeing 747 is already the largest aircraft being made and could readily be expanded. Boeing, meanwhile, was seriously concerned about the risk inherent in building a new and even larger plane, even if it shared the risk with Airbus as a joint venture.

Selecting the Best Alternative Choosing the best available alternative is a key activity in decision making. Even though many situations do not lend themselves to objective mathematical analysis, managers and leaders can often develop subjective estimates for choosing an alternative. Decision makers should also remember that finding multiple acceptable alternatives may be possible, so selecting just one alternative and rejecting all the others might not be necessary. For example, Airbus proposed a joint venture with Boeing, but Boeing decided that its best course of action was to modify its existing 747 to increase its capacity. Airbus then decided to proceed on its own to develop and manufacture a new jumbo jet

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called the A380. Meanwhile, Boeing decided that, in addition to modifying its 747, it would also develop a new plane (the 787).

Implementing the Chosen Alternative After an alternative has been selected, managers must implement it. In the case of an acquisition, for example, managers must decide how to integrate the activities of the new business into the firm's existing organizational framework. One of the key considerations during implementation is employee resistance to change. The reasons for such resistance include insecurity, inconvenience, and fear of the unknown. Managers must also recognize that even when all alternatives have been evaluated as precisely as possible and the consequences of each alternative have been weighed, unanticipated consequences are still likely. For example, both Boeing and Airbus have experienced unexpected delays in bringing their new planes to market.

Following Up and Evaluating the Results The final step in the decision-making process requires managers to evaluate the effectiveness of their decision—that is, they should make sure that the chosen alternative has served its original purpose. If an implemented alternative appears not to be working, they can respond in several ways. One possibility is to adopt an alternative that had previously been discarded. Or they might recognize that the situation was not correctly defined to begin with and start the process all over again. In the Boeing–Airbus case, both companies have gotten some feedback about whether or not they made a good decision. For example, increasing fuel prices mean that the 787 was the best decision because it is so fuel efficient.

Behavioural Aspects of Decision Making

Most managers try to be logical when they make decisions. But even when they try, they may not succeed. When Starbucks opened its first coffee shops in New York, it relied on scientific marketing research, taste tests, and rational deliberation in making a decision to emphasize drip over espresso coffee. However, that decision proved wrong when it became clear that New Yorkers strongly preferred the same espresso-style coffees that were Starbucks' mainstays in the west. Hence, the firm had to reconfigure its stores hastily to meet customer preferences.

To complicate matters, non-logical and emotional factors often influence managerial decision making. These factors include *organizational politics, intuition, escalation of commitment*, and *risk propensity*.

Organizational Politics The term **organizational politics** refers to the actions that people take as they try to get what they want. These actions may or may not be beneficial to the organization, but they do influence decision making, particularly if the person taking the action is a powerful manager. A study of 293 Canadian office workers found that 71 percent believed that office politics was at least somewhat necessary in order to get ahead in their organization.[16]

Intuition Managers sometimes decide to do something because it "feels right" or they have a "hunch." **Intuition** is usually based on years of experience and practice in making decisions in similar situations. Such an inner sense may actually help managers make an occasional decision without going through a rational sequence of steps. For example, the New York Yankees once contacted three major sneaker manufacturers—Nike, Reebok, and Adidas—and informed them that they were interested in signing a sponsorship deal. While Nike and Reebok were carefully and rationally assessing the possibilities, managers at Adidas quickly responded to the idea and ended up hammering out a contract while the competitors were still analyzing details.[17] These occasional successes can be very dramatic, but they should not cause managers to rely too heavily on intuition.

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Escalation of Commitment When a manager makes a decision and then remains committed to its implementation in spite of clear evidence that it was a bad decision, **escalation of commitment** has occurred.[18] A good example of this is Expo '86, the world's fair that was held in British Columbia. When the project was first conceived, the deficit was projected at about $56 million. Over the next few years, the projected deficit kept rising until it was over $300 million. In spite of that, the project went forward. Managers can avoid over-commitment by setting specific goals ahead of time that deal with how much time and money they are willing to spend on a given project. These goals make it harder for managers to interpret unfavourable news in a positive light.

Risk Propensity **Risk Propensity** refers to how much a manager is willing to gamble when making decisions. Managers who are very cautious when making decisions are more likely to avoid mistakes, and they are unlikely to make decisions that lead to big losses (or big gains). Other managers are extremely aggressive in making decisions and are willing to take risks.[19] They rely heavily on intuition, reach decisions quickly, and often risk big money on their decisions. These managers are more likely than their conservative counterparts to achieve big successes, but they are also more likely to incur greater losses.[20] The organization's culture is a prime ingredient in fostering different levels of risk propensity.

17.5 Strategic Management: Setting Goals and Formulating Strategy

Strategic management is the process of effectively aligning the organization with its external environment. The starting point in strategic management is setting goals that a business wants to achieve. Every business needs goals. Remember, however, that deciding what it intends to do is only the first step for an organization. Managers must also make decisions about what actions will and will not achieve company goals. Decisions cannot be made on a problem-by-problem basis or merely to meet needs as they arise. In most companies, a broad program underlies those decisions. That program is called a **strategy**—the broad set of organizational plans for implementing the decisions made for achieving organizational goals.

17.5.1 Setting Business Goals

Goals are performance targets, the means by which organizations and their managers measure success or failure at every level. Goals indicate *what* results are desired, while plans indicate *how* these goals are to be achieved. Managers must understand the purposes of goal setting and the kinds of goals that need to be set.

The Purposes of Goal Setting

There are four main purposes in organizational goal setting:

1. *Goal setting provides direction, guidance, and motivation for all managers.* Toyota set a goal to sell 200 000 vehicles in Canada in 2012. That was a 25 percent increase over actual sales in 2011.[21] WestJet's goal is to challenge Air Canada for the top spot in domestic air travel by 2016.[22]

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2. *Goal setting helps firms allocate resources.* Areas that are expected to grow will get first priority. Thus, 3M allocates more resources to new projects with large sales potential than it allocates to mature products with low growth potential.
3. *Goal setting helps to define corporate culture.* General Electric's goal is to have each of its divisions be #1 or #2 in its industry. The result is a competitive, often stressful, environment and a culture that rewards success and has little tolerance for failure.
4. *Goal setting helps managers assess performance.* At Port Metro Vancouver, the goal for container "dwell time"—the time containers sit on the dock—is three days (the North American standard). In January 2010, the dwell time was 3.7 days, but by November 2011, it had been reduced to 2.5 days. Setting specific goals like this helps managers assess their performance.[23]

Goal setting is effective for individuals as well as organizations. When students set goals, they achieve higher grades, lower their chance for dropping out of school, and experience greater well-being as adults. Unfortunately, less than half of the students aged 10 to 18 are aggressively pursuing goals.[24]

Kinds of Goals

Goals differ from company to company, depending on the firm's vision and mission. Every organization has a **vision (or purpose)** that indicates why it exists and what kind of organization it wants to be. For example, businesses seek profit, universities discover and transmit new knowledge, and government agencies provide services to the public. Most organizations also have a **mission statement**—a statement of how they will achieve their purpose. DaimlerChrysler's mission statement emphasizes "delighted customers," while Atco Ltd.'s mission is to provide products and services to the energy and resource industries and to invest in energy-related assets in North America. Mission statements often include some statement about the company's core values and its commitment to ethical behaviour.

Two business firms can have the same vision—for example, to sell watches at a profit—yet have very different missions. Timex sells low-cost, reliable watches in outlets ranging from department stores to corner drugstores. Rolex, on the other hand, sells high-quality, high-priced fashion watches through selected jewellery stores. Regardless of a company's purpose and mission, it must set long-term, intermediate, and short-term goals.

- **Long-term goals** relate to extended periods of time—typically five years or more into the future. American Express, for example, might set a long-term goal of doubling the number of participating merchants during the next 10 years.
- **Intermediate goals** are set for a period of one to five years into the future. When Kazuo Hirai became CEO of Sony in 2012, he was determined to improve the performance of the consumer electronics company. He therefore set a sales target of US$105 billion for the division that makes medical equipment and electric car batteries. The goal is to be achieved in two years. He also set a goal to triple revenue in the mobile phone division.[25]
- Like intermediate goals, **short-term goals**—which are set for one year or less—are developed for several different areas. Increasing sales by 2 percent this year, cutting costs by 1 percent next quarter, and reducing turnover by 4 percent over the next six months are all short-term goals.

Whatever the time frame of the goals that are set, research shows that managers who set **SMART goals** (goals that are Specific, Measurable, Achievable, Relevant, and

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Time-framed) have higher performance than managers who don't. The boxed insert entitled "Extending the Logic of Goal Setting" describes the importance of setting goals that take the environment into account.

17.5.2 Formulating Strategy

After a firm has set its goals, it must develop a strategy for achieving them. In contrast to planning, strategy is wider in scope and is a broad program that describes how a business intends to meet its goals, how it will respond to new challenges, and how it will meet new needs. For example, Brookfield Asset Management's strategy is to buy high-quality assets at less than replacement cost.[26] **Strategy formulation** involves three basic steps: (1) setting strategic goals, (2) analyzing the organization and its environment, and (3) matching the organization and its environment (see Figure 17.4).

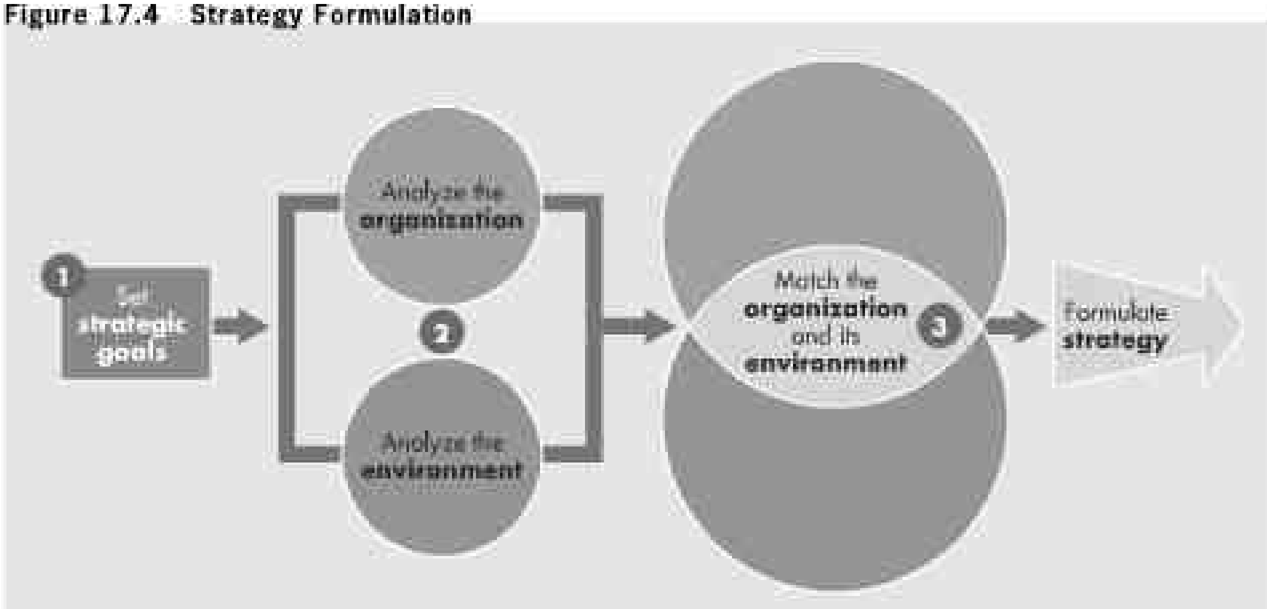
Setting Strategic Goals

Strategic goals are long-term goals derived directly from the firm's mission statement. General Electric, for example, is pursuing four strategic goals to ensure continued success for the company: an emphasis on quality control, an emphasis on selling services and not just products, concentrating on niche acquisitions, and global expansion.

Analyzing the Organization and Its Environment

After strategic goals have been set, managers assess both their organization and its environment using a **SWOT analysis**. This involves identifying organizational Strengths and Weaknesses, and identifying environmental Opportunities and Threats. Strengths and weaknesses are factors internal to the firm, and are assessed using **organizational analysis**. Strengths might include surplus cash, a dedicated workforce, an ample supply of managerial talent, technical expertise, or weak competitors. For example, Pepsi's strength in beverage distribution through its network of soft-drink distributors was successfully extended to distribution of its Aquafina brand of bottled water. Weaknesses

Figure 17.4 Strategy Formulation



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THE GREENING OF BUSINESS

Extending the Logic of Goal Setting

The logic of goal setting is being extended to make businesses greener. Green goals may be developed by managers, or they may be imposed on companies by external groups. Consider the following:

- Scotiabank set a goal to be in the top 10 percent of the companies listed on the Dow Jones Sustainability World Index.
- Employees on different floors of the Air Miles building in Toronto compete to see who can reduce energy usage the most in a specific month.
- Ford Motor Co. has set a goal of tripling its production of electric vehicles and hybrids by 2013.
- Co-operators Life Insurance Co. has set a goal to reduce emissions from business travel and climate control by 50 percent by 2014.
- Dillon Consulting Ltd. (Toronto) has a goal to invest 1 percent of revenue into social, environmental, and community initiatives.
- DuPont Canada has a goal to double investment in research and development programs with quantifiable environmental benefits.

For some organizations, their entire mission is being green. For example, the mission of B.C.–based Greener Footprints (a non-profit organization) is to reduce the use of plastic bags in Canada. For other organizations, the setting of green goals is closely tied to the success of their business. For example, the CEO of Honda, Takeo Fukui, recognized that Toyota's popular Prius hybrid automobile outsold Honda's hybrid car by a wide margin during the last decade, so he set a goal to make Honda the greenest company in the automobile industry. Honda has set a goal to sell 500 000 hybrid automobiles each year (Toyota's goal is 1 million). In 2008, Honda introduced its Clarity FCX, which was powered by a hydrogen fuel cell that generates no pollution at all. Honda also launched a new gas-electric hybrid in 2009 and plans to launch several other hybrids by 2015.

Rona Inc., the home renovation chain, has set a goal of doing business only with suppliers who address environmental sustainability and do not contribute to deforestation. The goal for 2009 was to have all the plywood panels Rona sells made only from lumber that comes from forests that have been certified as sustainable. By 2010, the same goal applied to spruce, pine, and fir. By 2012, Rona's goal was to have 25 percent of its total wood sales come from forests that are certified by the Forest Stewardship Council.

Critical Thinking Questions

1. What are the advantages of setting green goals? Are there disadvantages? Explain.
2. What difficulties might Rona encounter as it tries to reach the goal of having 25 percent of its total wood sales come from forests that are certified by the Forest Stewardship Council?

might include a cash shortage, aging factories, and a poor public image. Garden.com's reliance on the internet-based e-tailing model became its downfall when the dot-com bubble burst.

Opportunities and threats are factors external to the firm and are assessed using **environmental analysis.** Opportunities include things like market demand for new products, favourable government legislation, or shortages of raw materials that the company is good at producing. For example, when Pepsi managers recognized a market opportunity for bottled water, they moved quickly to launch their Aquafina brand and to position it for rapid growth. Threats include new products developed by competitors, unfavourable government regulations, and changes in consumer tastes. For example, in 2010, the Province of Ontario proposed new legislation that sharply reduced the revenue that pharmacies would receive for dispensing prescription drugs. Some external threats are unpredictable, like the volcanic eruption in Iceland in 2010 that halted air travel in Europe for a week.

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THERE'S AN APP FOR THAT!

1. **SWOT Chart** >>> **Platforms:** *Apple, Android, BlackBerry*
   Source: K. Kaleeswaran
   Key Features: Strategic planning method used to evaluate the Strengths, Weaknesses, Opportunities, and Threats.
2. **Goal Tracker: SmartGoals**
   >>> **Platforms:** *Android*
   Source: MSurf Lab.
   Key Features: A tool to help you set SMART (specific, measurable, achievable, relevant, and time-framed) goals.
3. **Strategy + Business Magazine**
   >>> **Platforms:** *Apple, Android*
   Source: Booz and Company
   Key Features: In-depth feature stories, leader interviews, and strategic commentaries.

App Discovery Exercise

Since APP availability changes, conduct your own search for "Top 3" Management APPS and identify the key features.

Commercial airlines lost hundreds of millions of dollars of revenue, while alternative service providers like trains saw demand for their services soar.

Matching the Organization and Its Environment

The final step in strategy formulation is matching environmental threats and opportunities with corporate strengths and weaknesses. Matching companies with their environments lays the foundation for successfully planning and conducting business. Over the long term, this process may also determine whether a firm typically takes risks or behaves more conservatively. Just because two companies are in the same industry does not mean that they will use the same strategies. The Toronto-Dominion Bank, for example, aggressively expanded into the U.S. retail banking industry by acquiring U.S. banks, but the Royal Bank of Canada has been much less aggressive in this area.[27]

17.5.3 Levels of Strategy

There are three levels of strategy in a business firm (see Figure 17.5). A **corporate-level strategy** identifies the various businesses that a company will be in and how these businesses will relate to each other. A **business-level (competitive) strategy** identifies the ways a business will compete in its chosen line of products or services. **Functional strategies** identify the basic courses of action that each department in the firm will pursue so that it contributes to the attainment of the business's overall goals.

Corporate-Level Strategies

There are several different corporate-level strategies that a company might pursue, including concentration, growth, integration, diversification, and investment reduction.

Concentration A **concentration strategy** involves focusing the company on one product or product line that it knows very well. Organizations that have successfully pursued a concentration strategy include McDonald's and Canadian National Railway.

Growth Companies have several growth strategies available to them, including **market penetration** (boosting sales of present products by more aggressive selling in the firm's

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Figure 17.5 Hierarchy of Strategy

Source: Based on Thomas L. Wheelen and J. David Hunger, *Strategic Management and Business Policy,* 8th edition. (Upper Saddle River, NJ: Prentice Hall, 2002), 14.

current markets), **geographic expansion** (expanding operations in new geographic areas), and **product development** (developing improved products for current markets). These three strategies focus on internal activities that will result in growth.

Integration There are two basic integration strategies. **Horizontal integration** means acquiring control of competitors in the same or similar markets with the same or similar products. For example, Hudson's Bay owns Home Outfitters (Deco Decouverte in Quebec), and U.S.-based Target acquired many Zellers stores as it prepared to enter the Canadian market. **Vertical integration** means owning or controlling the inputs to the firm's processes and/or the channels through which the products or services are distributed. Oil companies like Shell not only drill and produce their own oil, but also sell it through company-controlled outlets across Canada. These two strategies focus on external activities that will result in growth.

Diversification **Diversification** helps the firm avoid the problem of having all of its eggs in one basket by spreading risk among several products or markets. *Related diversification* means adding new, but related, products or services to an existing business. For example, Maple Leaf Gardens Ltd., which already owned the Toronto Maple Leafs, acquired the Toronto Raptors basketball team. *Conglomerate diversification* means diversifying into products or markets that are not related to the firm's present businesses. Eastman Kodak was the leader for many years in the film-based photography business, but it fell on hard times when digital cameras were introduced (Kodak invented the digital camera in the 1970s, but somehow never capitalized on the idea). Kodak then adopted a diversification strategy in an attempt to survive (and tried to reinvent itself as a printing and graphics company), but it fell into bankruptcy anyway.[28]

Investment Reduction **Investment reduction** means reducing the company's investment in one or more of its lines of business. One investment-reduction strategy is *retrenchment*, which means the reduction of activity or operations. For example, Federal Industries was formerly a conglomerate with interests in trucking, railways, metals, and other product lines, but it has now retrenched and focuses on a more limited set of products and customers. *Divestment* involves selling or liquidating one or more of a firm's businesses. For example, BCE sold its Yellow Pages and White Pages for $4 billion.

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Target used a horizontal integration strategy when it entered the Canadian market. It purchased over 200 Zellers stores and then remade them in the Target style.

© Jonathan Larsen/Diadem Images/Alamy

The boxed insert entitled "Will This Strategy Fly?" describes corporate-level strategic thinking at Bombardier.

Business-Level (Competitive) Strategies

Whatever corporate-level strategy a firm decides on, it must also have a competitive strategy. A competitive strategy is a plan to establish a profitable and sustainable competitive position.[29] Michael Porter identifies three competitive strategies. **Cost leadership** means becoming the low-cost leader in an industry. Walmart is the best-known industry cost leader. Montreal-based Gildan Activewear is dedicated to achieving the lowest possible costs in producing its T-shirts. The company has captured 29 percent of the U.S. imprinted T-shirt market with this strategy.[30] A firm using a **differentiation strategy** tries to be unique in its industry along some dimension that is valued by buyers. For example, Caterpillar emphasizes durability, Volvo stresses safety, Apple stresses user-friendly products, and Mercedes-Benz emphasizes quality. A **focus strategy** means selecting a market segment and serving the customers in that market niche better than competitors. Before it was acquired by Nexfor, Fraser Inc. focused on producing high-quality, durable, lightweight paper that is used in bibles.

Functional Strategies

Each business's choice of a competitive strategy (cost leadership, differentiation, or focus) is translated into supporting functional strategies for each of its departments to pursue. A functional strategy is the basic course of action that each department follows so that the business accomplishes its overall goals. To implement its cost-leadership

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MANAGING IN TURBULENT TIMES

Will This Strategy Fly?

Montreal-based Bombardier is a world leader in the production of commercial jets, business jets, and trains. Bombardier's fortunes are often influenced by political decisions made by governments, so developing corporate strategy is difficult. For example, Bombardier and Brazil-based Embraer have repeatedly charged each other with violating World Trade Organization rules about receiving government subsidies from their home governments.

Bombardier's corporate strategy involves aggressively pursuing customers in two distinct markets: business jets and commercial jets. In the *business jet* market, Bombardier's current product offering is the Global Express XRS high-end jet. But in order to compete with U.S. rival Gulfstream Aerospace, Bombardier is planning to spend more than $1 billion to develop two new, ultra-luxurious, long-range business jets that are derivatives of the Global Express. The Global 7000, which is slated for delivery in 2016, will be 20 percent wider than Gulfstream's G650 (but the G650 will come on the market in 2012). The Global 8000 is designed to compete on distance and will fly slightly faster than the G650. In the *commercial jet* market, Bombardier is developing the CSeries jet, which is designed to compete in the 100- to 150-seat segment of the market. The new jet will have advanced avionics, new wings made of composite materials, and a fuselage made of a lithium-aluminum alloy. There are actually two planes in the series: the CS100 (which seats 100 to 124 people) and the CS300 (which seats 120 to 145 people). With its new entries, Bombardier feels that it can successfully compete against planes made by Airbus and Boeing, the two giants in the industry. But developing a new product is risky because of the complexity of the product, the long time frame needed for its development, and the high cost of each unit (for example, the new CSeries jets will sell for about $65 million each).

At the 2011 Paris Air Show, executives of both Boeing and Airbus conceded that aircraft manufacturers in Canada, Russia, Brazil, and China are going be competitive with Boeing and Airbus. AirInsight, an aviation consultancy company, released a report showing that the CSeries aircraft will have advantages over both the Airbus A319neo and the Boeing 737. But Boeing and Airbus could also respond to the CSeries threat by lowering prices on their planes. Since they are much larger companies, Bombardier could probably not meet their prices.

If Bombardier's strategy succeeds, it will mean huge sales revenues and profits for the company, but Bombardier also has to worry about other competition, which will come from China's C919 aircraft, which is being developed by Commercial Aircraft Corp. of China (also known as Comac). Ryanair, Europe's biggest discount carrier, is working together with Comac, so that could make it difficult for Bombardier to sell any planes to Ryanair. New planes are also being developed by Embraer (Brazil) and Sukhoi (Russia).

Critical Thinking Questions

1. What are the various levels of strategy that exist in a business firm?
2. What corporate-level strategy is Bombardier pursuing? Explain your reasoning.

of satellite-based warehousing that ultimately drove distribution costs down below those of its competitors.

17.6 Contingency Planning and Crisis Management

Business environments are often difficult to predict because unexpected events may occur. Two common methods of dealing with the unforeseen are *contingency planning* and

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Commercial airlines have contingency plans to deal with problems like major snowstorms. These contingency plans involve making sure that planes are not stranded at airports that are experiencing snow delays.

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17.6.1 Contingency Planning

Contingency planning means identifying in advance changes that might occur that would affect a business and developing a plan to respond to such changes. For example, airlines know that snowstorms at, say, Toronto's Pearson International Airport are likely, so they develop contingency plans for coping with that eventuality. These plans typically involve rescheduling flights into neighbouring airports and providing passengers with ground transportation into Toronto. Assessing the costs and benefits of these and other options ahead of time helps managers cope with problems when they arise.

17.6.2 Crisis Management

Crisis management means dealing with an emergency that demands an immediate response. Crisis management plans outline who will be in charge in different kinds of circumstances, how the organization will respond, and the plans that exist for assembling and deploying crisis-management teams.

Business crises are more common than you might think. For example, as we saw in the opening case, Boeing faced a crisis when batteries in the 787 Dreamliner caught fire. BP also faced a crisis when an explosion at a drilling rig in the Gulf of Mexico resulted in the death of 11 workers and caused a huge oil spill. Toyota faced a crisis when consumers claimed that some models of its cars were accelerating out of control. Carnival Corp. faced a crisis when one of its cruise ships lost power and stranded 4000 passengers at sea for four days with no working toilets. Maple Leaf Foods was confronted with a crisis when listeria (tainted meat) was discovered at one of its processing plants. Maple Leaf quickly recalled 686 000 kilograms of meat (an action that cost the company $19 million). CEO Michael

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Crisis management involves an organization's methods for dealing with emergencies. Here, Red Cross volunteers organize and file paperwork submitted by Hurricane Katrina victims.

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McCain publicly apologized at news conferences and in television commercials and assured consumers that the company would solve the problem.[31] A few months later, a survey revealed that 78 percent of respondents had recently purchased a Maple Leaf product (that was up from only 20 percent right after the crisis occurred).[32]

17.7 | Management and the Corporate Culture

Just as every individual has a unique personality, every company has a unique identity. This is its **corporate culture**—the shared experiences, stories, beliefs, and norms that characterize it. Here are some examples:

- At ING DIRECT, the culture encourages employees to challenge the status quo, both within the company and the banking industry.[33]
- The culture of the Toronto Blue Jays organization is designed to make employees feel like they are part of a family. To facilitate the culture, employees have "snacks with the president" so they can talk about how the organization is operating.
- Google creates a culture of "yes" in order to encourage innovation. Employees focus on what is right with a new idea rather than what is wrong with it.[34]
- Magna International, a large Canadian producer of auto parts, is a firm with a strong culture. Its founder, Frank Stronach, is well known for his views about employees, working conditions, daycare centres, unions, the free enterprise system, and profit distribution.[35]
- Four Seasons Hotels and Resorts has a different, but equally strong, culture. Managers are judged by deeds, not words, and act as role models; employees take their cues from the managers.[36]

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The founder or CEO of a business plays a major role in shaping the company's culture. For example, the late Steve Jobs, co-founder and former CEO of Apple, helped establish an informal and laid-back culture at the company, which featured casual business attire and an open-door policy. That culture helps Apple continue to attract and retain talented people.

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Companies that focus largely on one type of product (for example, Starbucks Coffee Company) may have a fairly homogeneous culture throughout the organization. But companies with many different divisions and many different types of customers (for example, the Royal Bank of Canada) are likely to have several different subcultures because the various divisions pursue different goals and because different types of people are found in the different divisions.

A strong corporate culture guides everyone to work toward the same goals and helps newcomers learn accepted behaviours. In a strong culture where financial success is the key issue, newcomers quickly learn that they are expected to work long, hard hours and that the "winner" is the one who brings in the most revenue. But if quality of life is more fundamental to the culture, newcomers learn that it's acceptable to balance work and non-work activities. Cameron Herold—a Vancouver entrepreneur who has had a string of successes in franchising, including College Pro Painters, Boyd Autobody, and 1-800-GOT-JUNK—says that a cult-like culture is crucial for attracting great employees. He says what's needed is a culture that is "more than a business and slightly less than a religion."[37]

Each year, Waterstone Human Capital conducts in-depth interviews with senior managers at many different Canadian companies and asks them which corporate cultures they admire most. The 2011 winners included Agrium Inc., CIBC, Coast Capital Savings Credit Union, and ING Direct Canada.[38] Although many companies do not systematically monitor their corporate cultures, Starbucks is one company that does. Once every

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18 months, employees fill out a Partner View Survey containing questions that are designed to help the company determine whether it is making progress toward one of its key values—providing a work environment where people treat one another with respect and dignity. The survey is voluntary, but about 90 percent of employees fill it out (on company time). One reason the participation rate is so high is that the company actually pays attention to what employees say in the survey. For example, when one survey showed that employees were not clear about career progression possibilities in the company, Starbucks held career fairs in several Canadian cities, where company managers spoke with employees about management opportunities at Starbucks.[39]

17.7.1 Communicating the Culture and Managing Change

Managers must carefully consider the kind of culture they want for their organization, then work to nourish that culture by communicating with everyone who works there. Walmart, for example, assigns veteran managers to lead employees in new territories. Starbucks Coffee surveys employees every 18 months regarding several aspects of its culture. Royal Bank of Canada and Four Seasons Hotels and Resorts also survey their employees to determine how well they are progressing toward their corporate culture goals.[40]

Communicating the Culture

To use a company's culture to full advantage, its managers must accomplish several tasks, all of which hinge on effective communication. First, managers themselves must have a clear understanding of the culture. Second, they must transmit the culture to others in the organization. Communication is a key aim in training and orienting newcomers. A clear and meaningful statement of the organization's mission is also a valuable communication tool. Finally, managers can maintain the culture by rewarding and promoting those who understand it and work toward maintaining it.

Managing Change

Organizations must sometimes change their cultures. Ontario Hydro, for example, had an "engineering" culture for many years. That meant that everything was planned and analyzed down to the last detail before any action was taken. But Ontario Hydro's culture has changed to a more consumer-oriented, risk-taking culture as it tries to cope with large debt and changes in its markets.

Changing an organization's culture can be difficult, so just because someone recognizes the need for cultural change does not mean that it will actually be implemented. For example, when several RCMP officers alleged that there were problems with senior management, lawyer David Brown was appointed by the government to look into the matter. His report concluded that the Commissioner had exercised absolute power, that no one questioned his management style, and that there was a "tone" at the top of the organization that resulted in little respect for employees. The report also said that whistle-blowers within the RCMP were punished when they pointed out that there were problems. The report concluded that the culture and management structure at the RCMP were "horribly broken."[41] These developments are discouraging because just a few years earlier the RCMP had completed a "visioning" process that resulted in a new mission statement, a new set of core values, and a commitment to the communities where it worked. At that time, it was reported that the culture of the RCMP was quite different than it had been in the days when military tradition dominated the organization, but subsequent events suggested that the culture had not actually changed much.

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SUMMARY

1. **Describe the four activities that constitute the *management process.*** Management is the process of planning, organizing, leading, and controlling an organization's financial, physical, human, and information resources to achieve the organization's goals. *Planning* means determining what the company needs to do and how best to get it done. *Organizing* means determining how best to arrange a business's resources and the necessary jobs into an overall structure. *Leading* means guiding and motivating employees to meet the firm's objectives. *Controlling* means monitoring the firm's performance to ensure that it is meeting its goals.
2. **Identify *types of managers* by level and area.** Managers can be differentiated in two ways: by level and by area. By level, *top managers* set policies, formulate strategies, and approve decisions. *Middle managers* implement policies, strategies, and decisions. *First-line managers* usually work with and supervise employees. By area, managers focus on *marketing, finance, operations, human resource,* and *information.* Managers at all levels may be found in every area of a company.
3. **Describe the five basic *management skills.*** Most managers agree that five basic management skills are necessary for success. *Technical skills* are needed to perform specialized tasks ranging from typing to auditing. *Human relations skills* are needed to understand and get along with other people. *Conceptual skills* allow managers to think in the abstract, to diagnose and analyze various situations, and to see beyond present circumstances. *Decision-making skills* allow managers to define problems and to select the best course of action. *Time management skills* refer to managers' ability to make productive use of the time available to them.
4. **Explain the importance of *goal setting* and *strategic management* in organizational success.** *Goals*—the performance targets of an organization—can be *long term, intermediate,* and *short term.* They provide direction for managers, they help managers decide how to allocate limited resources, they define the corporate culture, and they help managers assess performance. *Strategic management* involves three major activities: setting strategic goals, analyzing the organization and its environment, and matching the organization and its environment. The strategies that are decided upon are then translated into *strategic, tactical,* and *operational* plans.
5. **Discuss *contingency planning* and *crisis management* in today's business world.** To deal with crises or major environmental changes, companies develop contingency plans and plans for crisis management. *Contingency planning* tries to identify in advance the important aspects of a business or its markets that might change and how the company will respond if such changes actually occur. *Crisis management* means developing methods and actions for dealing with an emergency that requires an immediate response. To prepare for such emergencies, organizations develop crisis plans.
6. **Explain the idea of *corporate culture* and why it is important.** *Corporate culture* is the shared experiences, stories, beliefs, and norms that characterize an organization. A strong, well-defined culture can help a business reach its goals and can influence management styles. Culture is determined by several factors, including top management, the organization's history, stories and legends, and behavioural norms. If carefully communicated and flexible enough to accommodate change, corporate culture can be managed for the betterment of the organization.

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QUESTIONS AND EXERCISES

Questions For Analysis

1. How are the four *functions* of management related to the five *skills* of management? Use examples to clarify your answer.
2. What is the relationship between Mintzberg's *roles* of management and the more traditional *functions* of management? Use examples to clarify your answer.
3. Identify the managers by level and area at your college or university.
4. Can you identify any organizations where the technical skills of top managers are more important than human relations or conceptual skills? Can you identify organizations where conceptual skills are not important?
5. What differences might you expect to find in the corporate cultures of a 100-year-old manufacturing firm based in Winnipeg and a five-year-old e-commerce firm based in Ottawa?
6. Consider the various corporate-level strategies discussed in the text (concentration, growth, integration, diversification, investment, reduction). What is the relationship between these various strategies? Are they mutually exclusive? Are they complementary? Explain.

Application Exercises

7. Interview a manager at any level of a local company. Identify the manager's job according to level and area. Explain what planning, organizing, directing, and controlling mean in terms of the manager's job. Give examples. Also indicate which management skills are most important for the manager's job.
8. Review the example of the decisions made by Airbus and Boeing regarding new large aircraft. Then research the most current information on the status of the two planes. Which company seems to have made the better decision?
9. Interview an administrator at your college or university. Ask the administrator to give his or her views on the school's strengths and weaknesses and on the threats and opportunities the school is facing. Then use this information to write up a SWOT analysis for the school.
10. Select any organization of which you are a member (your company, your family, your place of worship, or a club). Explain the relevance of the management functions of planning, organizing, directing, and controlling for that organization.

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TEAM EXERCISES: BUILDING YOUR BUSINESS SKILLS

Speaking With Power

Goal

To encourage students to appreciate effective speaking as a critical human relations skill.

Background

A manager's ability to understand and get along with supervisors, peers, and subordinates is a critical human relations skill. At the heart of this skill, says Harvard University professor of education Sarah McGinty, is the ability to speak with power and control. McGinty defines "powerful speech" in terms of the following characteristics:

- the ability to speak at length and in complete sentences
- The ability to set a conversational agenda
- The ability to deter interruption
- The ability to argue openly and to express strong opinions about ideas, not people
- The ability to make statements that offer solutions rather than pose questions
- The ability to express humour

Taken together, says McGinty, "all this creates a sense of confidence in listeners."

Method

Step 1 Working alone, compare your own personal speaking style with McGinty's description of powerful speech by taping yourself as you speak during a meeting with classmates or during a phone conversation.

(Tape both sides of the conversation only if the person to whom you are speaking gives permission.) Listen for the following problems:

- Unfinished sentences
- An absence of solutions
- Too many disclaimers ("I'm not sure I have enough information to say this, but . . .")
- The habit of seeking support from others instead of making definitive statements of personal conviction (saying, "As Emily stated in her report, I recommend consolidating the medical and fitness functions," instead of, "I recommend consolidating the medical and fitness functions.")
- Language fillers (saying, "you know," "like," and "um" when you are unsure of your facts or uneasy about expressing your opinion)

Step 2 Join with three or four other classmates to evaluate each other's speaking styles.

- Have a 10-minute group discussion on the importance of human relations skills in business.
- Listen to other group members, and take notes on the "power" content of what you hear.
- Offer constructive criticism by focusing on what speakers say rather than on personal characteristics (say, "Bob, you sympathized with Paul's position, but I still don't know what you think," instead of, "Bob, you sounded like a weakling.").

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Follow-Up Questions

1. How do you think the power content of speech affects a manager's ability to communicate? Evaluate some of the ways in which effects may differ among supervisors, peers, and subordinates.
2. How do you evaluate yourself and group members in terms of powerful and powerless speech? List the strengths and weaknesses of the group.
3. Do you agree or disagree with McGinty that business success depends on gaining insight into your own language habits? Explain your answer.
4. In our age of computers and email, why do you think personal presentation continues to be important in management?
5. McGinty believes that power language differs from company to company and that it is linked to the corporate culture. Do you agree, or do you believe that people express themselves in similar ways no matter where they are?

EXERCISING YOUR ETHICS

Clean Up Now or Clean Up Later?

The Situation

The top management team of a medium-sized manufacturing company is on a strategic planning "retreat" where it is formulating ideas and plans for spurring new growth in the company. As one part of this activity, the team, working with the assistance of a consultant, has conducted a SWOT analysis. During this activity, an interesting and complex situation has been identified. Next year, the federal government will be issuing new—and much more stringent—pollution standards for the company's industry. The management team sees this as a potential threat in that the company will have to buy new equipment and change some of its manufacturing methods in order to comply with the new standards.

The Dilemma

One member of the team, James Smith, has posed an interesting option—not complying. His logic can be summarized as follows:

1. The firm has already developed its capital budgets for the next two years. Any additional capital expenditures will cause major problems with the company's cash flow and budget allocations.
2. The company has a large uncommitted capital budget entry available in three years; those funds could be used to upgrade pollution control systems at that time.
3. Because the company has a spotless environmental record so far, James Smith argues that if the company does not buy the equipment for three years, the most likely outcomes will be (a) a warning in year 1; (b) a small fine in year 2; and (c) a substantial fine in year 3. However, the total amounts of the years 2 and 3 fines will be much lower than the cost of redoing the company budgets and complying with the new law next year.

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Team Activity

Assemble a group of four students and assign each group member to one of the following roles:

- Management team member
- Lower-level employee at the company
- Company customer
- Company investor

Action Steps

1. Before hearing any of your group's comments on this situation and from the perspective of your assigned role, decide whether James Smith's suggestion regarding ignoring pollution standards is a good one. Write down the reasons for your position.
2. Before hearing any of your group's comments on this situation and from the perspective of your assigned role, determine what the underlying ethical issues are in this situation.
3. Gather your group together and reveal, in turn, each member's comments on James Smith's suggestion. Next, reveal the ethical issues listed by each member.
4. Appoint someone to record main points of agreement and disagreement within the group. How do you explain the results? What accounts for any disagreement?
5. From an ethical standpoint, what does your group conclude is the most appropriate action that should be taken by the company in this situation?
6. Develop a group response to the following question: What are the respective roles of profits, obligations to customers, and obligations to the community for the firm in this situation?

BUSINESS CASE 17.1

The Overtime Pay Controversy

Under the terms of the Canada Labour Code, individuals in supervisory roles are not entitled to overtime pay for work beyond 40 hours per week. But this provision is now being challenged. It all started in 2003, when Sharon Michalowski, a manager at Nygard International Ltd., filed a complaint with the Manitoba Labour Board arguing that she should have been paid overtime for the extra hours that she was required to work. Nygard took the position that since Michalowski was a manager, that she was required to work whatever hours were necessary to do the job. But the Board ruled in Michalowski's favour and awarded her $10 000 in overtime pay. Nygard appealed the case to the Supreme Court of Canada, but lost. Soon after, the province of Manitoba fell into line with other provinces and passed legislation that exempted managers from overtime pay rules in its labour laws. But that didn't end the debate.

In 2010, a $250 million overtime class action lawsuit was launched by 1500 first-line supervisors at Canadian National Railway who oversee the movement of trains and the maintenance of track. The supervisors said they had to work 50 hours a week on average, and sometimes as much as 90 hours per week. The lawsuit was certified (approved to go to trial) by the Ontario Superior Court. An important issue in this case was whether a person who is designated as a "supervisor" can claim overtime, that is, the case hinges on whether first-line

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supervisors at CN are properly classified as "managers" and whether they actually have managerial duties. In June 2012, the Ontario Court of Appeals denied certification of the CN case and concluded that it wouldn't work as a class action because it depended on the definition of "manager" and "employee," and that would have to be determined on a case-by-case basis. The Appeals Court decision means that individual first-line supervisors at CN will have to decide whether to pursue an appeal or not.

It is not just groups of employees who are filing lawsuits. Massimo Sanago, the executive chef at the Glendale Golf and Country Club in Hamilton, had the responsibility of managing kitchen operations. But because of staff shortages, he spent over half his time cooking. He also had to work long hours to finish all his other work. Glendale gave him a $5000 bonus in recognition of his efforts, but he felt that was insufficient, so he filed a claim for overtime pay with the Ministry of Labour. Glendale disputed the claim, arguing that Sanago's job was managerial and that he, therefore, did not qualify for overtime pay. The company said that his core job was managerial in nature, and that he performed cooking duties only on an emergency basis. But the Ontario Labour Relations Board ruled that the company had to pay him overtime.

Cases like those above should not be confused with overtime class-action lawsuits that have been filed by *non-management* workers. In 2008, for example, a $360 million class-action lawsuit was filed against CIBC World Markets Inc. by salaried stock analysts, financial advisors, and investment bankers who claimed they had not been compensated for overtime work they had done. Early in 2012, a judge quashed the lawsuit, saying that some employees who are classified as "analysts" are actually managers and do not qualify for overtime. A similar class action overtime lawsuit was filed by bank tellers at the CIBC. The Ontario Divisional Court ruled that CIBC's overtime policy didn't violate the law, but it also ruled that there were not enough common issues among the 31 000 tellers at CIBC to warrant a class-action lawsuit. But in June 2012, the Ontario Court of Appeal overturned the earlier rulings and decided that the case could go forward.

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In 2010, non-management workers at the Bank of Nova Scotia also filed a class-action lawsuit claiming that they were not paid for overtime that they had worked. The bank appealed a judge's ruling that the case could go to trial, but in 2011, the Ontario Divisional Court rejected the bank's appeal and concluded that there was evidence of systemic wrongs in Scotiabank's overtime policy. In June 2012, the Ontario Court of Appeal agreed with the Divisional Court and certified the class action suit. Note that such certification does not mean that the judge agrees with the plaintiff; rather, it simply means that the plaintiffs can be included in a single case for a single trial. The two banks may now appeal the ruling to the Supreme Court of Canada.

The threat of lawsuits has influenced other companies to take action. For example, KMPG was sued by employees who claimed that the company forced them to work as much as 90 hours a week in order to complete their work. While the lawsuit was still before the courts, KPMG agreed to fix the problem, and it may have to spend up to $10 million to do so.

Class action suits against employers are partly the result of the way labour laws are written. For example, unless a person's occupation is specifically excluded by legislation, that person is entitled to overtime pay for each hour they work beyond the provincial maximum (in Ontario, that is 44 hours per week). In Ontario, occupations such as lawyers, accountants, dentists, veterinarians, farmers, salespeople, gardeners, janitors, taxi drivers, and IT professionals are excluded. Critics of the legislation argue that the first five occupations make some sense because they require independent work, but it makes little sense to exclude the latter four occupations.

QUESTIONS FOR DISCUSSION

1. Identify the positive and negative implications of not paying managers for overtime. Do the same for non-management workers.
2. Consider the following statement: *Managers should not expect to be paid overtime. They are highly paid, and they should focus on getting the job done, rather than on how many hours it takes to complete the job. People who don't have a "get-the-job-done" attitude shouldn't be managers.* Do you agree or disagree with the statement? Defend your answer.

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APPENDIX A

Compound Interest Factors for Discrete Compounding, Discrete Cash Flows

Taken from *Engineering Economics: Financial Decision Making for Engineers*, Fifth Edition by Niall M. Fraser and Elizabeth M. Jewkes.

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$i = 0.5\%$ Discrete Compounding, Discrete Cash Flows

	SINGLE PAYMENT		UNIFORM SERIES				
	Compound Amount Factor	Present Worth Factor	Sinking Fund Factor	Uniform Series Factor	Capital Recovery Factor	Series Present Worth Factor	Arithmetic Gradient Series Factor
N	*(F/P,i,N)*	*(P/F,i,N)*	*(A/F,i,N)*	*(F/A,i,N)*	*(A/P,i,N)*	*(P/A,i,N)*	*(A/G,i,N)*
1	1.0050	0.99502	1.0000	1.0000	1.0050	0.99502	0.00000
2	1.0100	0.99007	0.49875	2.0050	0.50375	1.9851	0.49875
3	1.0151	0.98515	0.33167	3.0150	0.33667	2.9702	0.99667
4	1.0202	0.98025	0.24813	4.0301	0.25313	3.9505	1.4938
5	1.0253	0.97537	0.19801	5.0503	0.20301	4.9259	1.9900
6	1.0304	0.97052	0.16460	6.0755	0.16960	5.8964	2.4855
7	1.0355	0.96569	0.14073	7.1059	0.14573	6.8621	2.9801
8	1.0407	0.96089	0.12283	8.1414	0.12783	7.8230	3.4738
9	1.0459	0.95610	0.10891	9.1821	0.11391	8.7791	3.9668
10	1.0511	0.95135	0.09777	10.228	0.10277	9.7304	4.4589
11	1.0564	0.94661	0.08866	11.279	0.09366	10.677	4.9501
12	1.0617	0.94191	0.08107	12.336	0.08607	11.619	5.4406
13	1.0670	0.93722	0.07464	13.397	0.07964	12.556	5.9302
14	1.0723	0.93256	0.06914	14.464	0.07414	13.489	6.4190
15	1.0777	0.92792	0.06436	15.537	0.06936	14.417	6.9069
16	1.0831	0.92330	0.06019	16.614	0.06519	15.340	7.3940
17	1.0885	0.91871	0.05651	17.697	0.06151	16.259	7.8803
18	1.0939	0.91414	0.05323	18.786	0.05823	17.173	8.3658
19	1.0994	0.90959	0.05030	19.880	0.05530	18.082	8.8504
20	1.1049	0.90506	0.04767	20.979	0.05267	18.987	9.3342
21	1.1104	0.90056	0.04528	22.084	0.05028	19.888	9.8172
22	1.1160	0.89608	0.04311	23.194	0.04811	20.784	10.299
23	1.1216	0.89162	0.04113	24.310	0.04613	21.676	10.781
24	1.1272	0.88719	0.03932	25.432	0.04432	22.563	11.261
25	1.1328	0.88277	0.03765	26.559	0.04265	23.446	11.741
26	1.1385	0.87838	0.03611	27.692	0.04111	24.324	12.220
27	1.1442	0.87401	0.03469	28.830	0.03969	25.198	12.698
28	1.1499	0.86966	0.03336	29.975	0.03836	26.068	13.175
29	1.1556	0.86533	0.03213	31.124	0.03713	26.933	13.651
30	1.1614	0.86103	0.03098	32.280	0.03598	27.794	14.126
31	1.1672	0.85675	0.02990	33.441	0.03490	28.651	14.601
32	1.1730	0.85248	0.02889	34.609	0.03389	29.503	15.075
33	1.1789	0.84824	0.02795	35.782	0.03295	30.352	15.548
34	1.1848	0.84402	0.02706	36.961	0.03206	31.196	16.020
35	1.1907	0.83982	0.02622	38.145	0.03122	32.035	16.492
40	1.2208	0.81914	0.02265	44.159	0.02765	36.172	18.836
45	1.2516	0.79896	0.01987	50.324	0.02487	40.207	21.159
50	1.2832	0.77929	0.01765	56.645	0.02265	44.143	23.462
55	1.3156	0.76009	0.01584	63.126	0.02084	47.981	25.745
60	1.3489	0.74137	0.01433	69.770	0.01933	51.726	28.006
65	1.3829	0.72311	0.01306	76.582	0.01806	55.377	30.247
70	1.4178	0.70530	0.01197	83.566	0.01697	58.939	32.468
75	1.4536	0.68793	0.01102	90.727	0.01602	62.414	34.668
80	1.4903	0.67099	0.01020	98.068	0.01520	65.802	36.847
85	1.5280	0.65446	0.00947	105.59	0.01447	69.108	39.006
90	1.5666	0.63834	0.00883	113.31	0.01383	72.331	41.145
95	1.6061	0.62262	0.00825	121.22	0.01325	75.476	43.263
100	1.6467	0.60729	0.00773	129.33	0.01273	78.543	45.361

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i = 1% Discrete Compounding, Discrete Cash Flows

	SINGLE PAYMENT		UNIFORM SERIES				Arithmetic Gradient Series Factor
	Compound Amount Factor	Present Worth Factor	Sinking Fund Factor	Uniform Series Factor	Capital Recovery Factor	Series Present Worth Factor	
N	(F/P,i,N)	(P/F,i,N)	(A/F,i,N)	(F/A,i,N)	(A/P,i,N)	(P/A,i,N)	(A/G,i,N)
1	1.0100	0.99010	1.0000	1.0000	1.0100	0.99010	0.00000
2	1.0201	0.98030	0.49751	2.0100	0.50751	1.9704	0.49751
3	1.0303	0.97059	0.33002	3.0301	0.34002	2.9410	0.99337
4	1.0406	0.96098	0.24628	4.0604	0.25628	3.9020	1.4876
5	1.0510	0.95147	0.19604	5.1010	0.20604	4.8534	1.9801
6	1.0615	0.94205	0.16255	6.1520	0.17255	5.7955	2.4710
7	1.0721	0.93272	0.13863	7.2135	0.14863	6.7282	2.9602
8	1.0829	0.92348	0.12069	8.2857	0.13069	7.6517	3.4478
9	1.0937	0.91434	0.10674	9.3685	0.11674	8.5660	3.9337
10	1.1046	0.90529	0.09558	10.462	0.10558	9.4713	4.4179
11	1.1157	0.89632	0.08645	11.567	0.09645	10.368	4.9005
12	1.1268	0.88745	0.07885	12.683	0.08885	11.255	5.3815
13	1.1381	0.87866	0.07241	13.809	0.08241	12.134	5.8607
14	1.1495	0.86996	0.06690	14.947	0.07690	13.004	6.3384
15	1.1610	0.86135	0.06212	16.097	0.07212	13.865	6.8143
16	1.1726	0.85282	0.05794	17.258	0.06794	14.718	7.2886
17	1.1843	0.84438	0.05426	18.430	0.06426	15.562	7.7613
18	1.1961	0.83602	0.05098	19.615	0.06098	16.398	8.2323
19	1.2081	0.82774	0.04805	20.811	0.05805	17.226	8.7017
20	1.2202	0.81954	0.04542	22.019	0.05542	18.046	9.1694
21	1.2324	0.81143	0.04303	23.239	0.05303	18.857	9.6354
22	1.2447	0.80340	0.04086	24.472	0.05086	19.660	10.100
23	1.2572	0.79544	0.03889	25.716	0.04889	20.456	10.563
24	1.2697	0.78757	0.03707	26.973	0.04707	21.243	11.024
25	1.2824	0.77977	0.03541	28.243	0.04541	22.023	11.483
26	1.2953	0.77205	0.03387	29.526	0.04387	22.795	11.941
27	1.3082	0.76440	0.03245	30.821	0.04245	23.560	12.397
28	1.3213	0.75684	0.03112	32.129	0.04112	24.316	12.852
29	1.3345	0.74934	0.02990	33.450	0.03990	25.066	13.304
30	1.3478	0.74192	0.02875	34.785	0.03875	25.808	13.756
31	1.3613	0.73458	0.02768	36.133	0.03768	26.542	14.205
32	1.3749	0.72730	0.02667	37.494	0.03667	27.270	14.653
33	1.3887	0.72010	0.02573	38.869	0.03573	27.990	15.099
34	1.4026	0.71297	0.02484	40.258	0.03484	28.703	15.544
35	1.4166	0.70591	0.02400	41.660	0.03400	29.409	15.987
40	1.4889	0.67165	0.02046	48.886	0.03046	32.835	18.178
45	1.5648	0.63905	0.01771	56.481	0.02771	36.095	20.327
50	1.6446	0.60804	0.01551	64.463	0.02551	39.196	22.436
55	1.7285	0.57853	0.01373	72.852	0.02373	42.147	24.505
60	1.8167	0.55045	0.01224	81.670	0.02224	44.955	26.533
65	1.9094	0.52373	0.01100	90.937	0.02100	47.627	28.522
70	2.0068	0.49831	0.00993	100.68	0.01993	50.169	30.470
75	2.1091	0.47413	0.00902	110.91	0.01902	52.587	32.379
80	2.2167	0.45112	0.00822	121.67	0.01822	54.888	34.249
85	2.3298	0.42922	0.00752	132.98	0.01752	57.078	36.080
90	2.4486	0.40839	0.00690	144.86	0.01690	59.161	37.872
95	2.5735	0.38857	0.00636	157.35	0.01636	61.143	39.626
100	2.7048	0.36971	0.00587	170.48	0.01587	63.029	41.343

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i = 1.5% — Discrete Compounding, Discrete Cash Flows

	SINGLE PAYMENT		UNIFORM SERIES				Arithmetic Gradient Series Factor
	Compound Amount Factor	Present Worth Factor	Sinking Fund Factor	Uniform Series Factor	Capital Recovery Factor	Series Present Worth Factor	
N	*(F/P,i,N)*	*(P/F,i,N)*	*(A/F,i,N)*	*(F/A,i,N)*	*(A/P,i,N)*	*(P/A,i,N)*	*(A/G,i,N)*
1	1.0150	0.98522	1.0000	1.0000	1.0150	0.98522	0.00000
2	1.0302	0.97066	0.49628	2.0150	0.51128	1.9559	0.49628
3	1.0457	0.95632	0.32838	3.0452	0.34338	2.9122	0.99007
4	1.0614	0.94218	0.24444	4.0909	0.25944	3.8544	1.4814
5	1.0773	0.92826	0.19409	5.1523	0.20909	4.7826	1.9702
6	1.0934	0.91454	0.16053	6.2296	0.17553	5.6972	2.4566
7	1.1098	0.90103	0.13656	7.3230	0.15156	6.5982	2.9405
8	1.1265	0.88771	0.11858	8.4328	0.13358	7.4859	3.4219
9	1.1434	0.87459	0.10461	9.5593	0.11961	8.3605	3.9008
10	1.1605	0.86167	0.09343	10.703	0.10843	9.2222	4.3772
11	1.1779	0.84893	0.08429	11.863	0.09929	10.071	4.8512
12	1.1956	0.83639	0.07668	13.041	0.09168	10.908	5.3227
13	1.2136	0.82403	0.07024	14.237	0.08524	11.732	5.7917
14	1.2318	0.81185	0.06472	15.450	0.07972	12.543	6.2582
15	1.2502	0.79985	0.05994	16.682	0.07494	13.343	6.7223
16	1.2690	0.78803	0.05577	17.932	0.07077	14.131	7.1839
17	1.2880	0.77639	0.05208	19.201	0.06708	14.908	7.6431
18	1.3073	0.76491	0.04881	20.489	0.06381	15.673	8.0997
19	1.3270	0.75361	0.04588	21.797	0.06088	16.426	8.5539
20	1.3469	0.74247	0.04325	23.124	0.05825	17.169	9.0057
21	1.3671	0.73150	0.04087	24.471	0.05587	17.900	9.4550
22	1.3876	0.72069	0.03870	25.838	0.05370	18.621	9.9018
23	1.4084	0.71004	0.03673	27.225	0.05173	19.331	10.346
24	1.4295	0.69954	0.03492	28.634	0.04992	20.030	10.788
25	1.4509	0.68921	0.03326	30.063	0.04826	20.720	11.228
26	1.4727	0.67902	0.03173	31.514	0.04673	21.399	11.665
27	1.4948	0.66899	0.03032	32.987	0.04532	22.068	12.099
28	1.5172	0.65910	0.02900	34.481	0.04400	22.727	12.531
29	1.5400	0.64936	0.02778	35.999	0.04278	23.376	12.961
30	1.5631	0.63976	0.02664	37.539	0.04164	24.016	13.388
31	1.5865	0.63031	0.02557	39.102	0.04057	24.646	13.813
32	1.6103	0.62099	0.02458	40.688	0.03958	25.267	14.236
33	1.6345	0.61182	0.02364	42.299	0.03864	25.879	14.656
34	1.6590	0.60277	0.02276	43.933	0.03776	26.482	15.073
35	1.6839	0.59387	0.02193	45.592	0.03693	27.076	15.488
40	1.8140	0.55126	0.01843	54.268	0.03343	29.916	17.528
45	1.9542	0.51171	0.01572	63.614	0.03072	32.552	19.507
50	2.1052	0.47500	0.01357	73.683	0.02857	35.000	21.428
55	2.2679	0.44093	0.01183	84.530	0.02683	37.271	23.289
60	2.4432	0.40930	0.01039	96.215	0.02539	39.380	25.093
65	2.6320	0.37993	0.00919	108.80	0.02419	41.338	26.839
70	2.8355	0.35268	0.00817	122.36	0.02317	43.155	28.529
75	3.0546	0.32738	0.00730	136.97	0.02230	44.842	30.163
80	3.2907	0.30389	0.00655	152.71	0.02155	46.407	31.742
85	3.5450	0.28209	0.00589	169.67	0.02089	47.861	33.268
90	3.8189	0.26185	0.00532	187.93	0.02032	49.210	34.740
95	4.1141	0.24307	0.00482	207.61	0.01982	50.462	36.160
100	4.4320	0.22563	0.00437	228.80	0.01937	51.625	37.530

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i = 2% **Discrete Compounding, Discrete Cash Flows**

	SINGLE PAYMENT		UNIFORM SERIES				Arithmetic Gradient Series Factor
	Compound Amount Factor	Present Worth Factor	Sinking Fund Factor	Uniform Series Factor	Capital Recovery Factor	Series Present Worth Factor	
N	(*F/P,i,N*)	(*P/F,i,N*)	(*A/F,i,N*)	(*F/A,i,N*)	(*A/P,i,N*)	(*P/A,i,N*)	(*A/G,i,N*)
1	1.0200	0.98039	1.0000	1.0000	1.0200	0.98039	0.00000
2	1.0404	0.96117	0.49505	2.0200	0.51505	1.9416	0.49505
3	1.0612	0.94232	0.32675	3.0604	0.34675	2.8839	0.98680
4	1.0824	0.92385	0.24262	4.1216	0.26262	3.8077	1.4752
5	1.1041	0.90573	0.19216	5.2040	0.21216	4.7135	1.9604
6	1.1262	0.88797	0.15853	6.3081	0.17853	5.6014	2.4423
7	1.1487	0.87056	0.13451	7.4343	0.15451	6.4720	2.9208
8	1.1717	0.85349	0.11651	8.5830	0.13651	7.3255	3.3961
9	1.1951	0.83676	0.10252	9.7546	0.12252	8.1622	3.8681
10	1.2190	0.82035	0.09133	10.950	0.11133	8.9826	4.3367
11	1.2434	0.80426	0.08218	12.169	0.10218	9.787	4.8021
12	1.2682	0.78849	0.07456	13.412	0.09456	10.575	5.2642
13	1.2936	0.77303	0.06812	14.680	0.08812	11.348	5.7231
14	1.3195	0.75788	0.06260	15.974	0.08260	12.106	6.1786
15	1.3459	0.74301	0.05783	17.293	0.07783	12.849	6.6309
16	1.3728	0.72845	0.05365	18.639	0.07365	13.578	7.0799
17	1.4002	0.71416	0.04997	20.012	0.06997	14.292	7.5256
18	1.4282	0.70016	0.04670	21.412	0.06670	14.992	7.9681
19	1.4568	0.68643	0.04378	22.841	0.06378	15.678	8.4073
20	1.4859	0.67297	0.04116	24.297	0.06116	16.351	8.8433
21	1.5157	0.65978	0.03878	25.783	0.05878	17.011	9.2760
22	1.5460	0.64684	0.03663	27.299	0.05663	17.658	9.7050
23	1.5769	0.63416	0.03467	28.845	0.05467	18.292	10.1320
24	1.6084	0.62172	0.03287	30.422	0.05287	18.914	10.5550
25	1.6406	0.60953	0.03122	32.030	0.05122	19.523	10.9740
26	1.6734	0.59758	0.02970	33.671	0.04970	20.121	11.391
27	1.7069	0.58586	0.02829	35.344	0.04829	20.707	11.804
28	1.7410	0.57437	0.02699	37.051	0.04699	21.281	12.214
29	1.7758	0.56311	0.02578	38.792	0.04578	21.844	12.621
30	1.8114	0.55207	0.02465	40.568	0.04465	22.396	13.025
31	1.8476	0.54125	0.02360	42.379	0.04360	22.938	13.426
32	1.8845	0.53063	0.02261	44.227	0.04261	23.468	13.823
33	1.9222	0.52023	0.02169	46.112	0.04169	23.989	14.217
34	1.9607	0.51003	0.02082	48.034	0.04082	24.499	14.608
35	1.9999	0.50003	0.02000	49.994	0.04000	24.999	14.996
40	2.2080	0.45289	0.01656	60.402	0.03656	27.355	16.889
45	2.4379	0.41020	0.01391	71.893	0.03391	29.490	18.703
50	2.6916	0.37153	0.01182	84.579	0.03182	31.424	20.442
55	2.9717	0.33650	0.01014	98.587	0.03014	33.175	22.106
60	3.2810	0.30478	0.00877	114.05	0.02877	34.761	23.696
65	3.6225	0.27605	0.00763	131.13	0.02763	36.197	25.215
70	3.9996	0.25003	0.00667	149.98	0.02667	37.499	26.663
75	4.4158	0.22646	0.00586	170.79	0.02586	38.677	28.043
80	4.8754	0.20511	0.00516	193.77	0.02516	39.745	29.357
85	5.3829	0.18577	0.00456	219.14	0.02456	40.711	30.606
90	5.9431	0.16826	0.00405	247.16	0.02405	41.587	31.793
95	6.5617	0.15240	0.00360	278.08	0.02360	42.380	32.919
100	7.2446	0.13803	0.00320	312.23	0.02320	43.098	33.986

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$i = 3\%$ Discrete Compounding, Discrete Cash Flows

	SINGLE PAYMENT		UNIFORM SERIES				Arithmetic Gradient Series Factor
	Compound Amount Factor	Present Worth Factor	Sinking Fund Factor	Uniform Series Factor	Capital Recovery Factor	Series Present Worth Factor	
N	*(F/P,i,N)*	*(P/F,i,N)*	*(A/F,i,N)*	*(F/A,i,N)*	*(A/P,i,N)*	*(P/A,i,N)*	*(A/G,i,N)*
1	1.0300	0.97087	1.0000	1.0000	1.0300	0.97087	0.00000
2	1.0609	0.94260	0.49261	2.0300	0.52261	1.9135	0.49261
3	1.0927	0.91514	0.32353	3.0909	0.35353	2.8286	0.98030
4	1.1255	0.88849	0.23903	4.1836	0.26903	3.7171	1.4631
5	1.1593	0.86261	0.18835	5.3091	0.21835	4.5797	1.9409
6	1.1941	0.83748	0.15460	6.4684	0.18460	5.4172	2.4138
7	1.2299	0.81309	0.13051	7.6625	0.16051	6.2303	2.8819
8	1.2668	0.78941	0.11246	8.8923	0.14246	7.0197	3.3450
9	1.3048	0.76642	0.09843	10.159	0.12843	7.7861	3.8032
10	1.3439	0.74409	0.08723	11.464	0.11723	8.5302	4.2565
11	1.3842	0.72242	0.07808	12.808	0.10808	9.2526	4.7049
12	1.4258	0.70138	0.07046	14.192	0.10046	9.9540	5.1485
13	1.4685	0.68095	0.06403	15.618	0.09403	10.635	5.5872
14	1.5126	0.66112	0.05853	17.086	0.08853	11.296	6.0210
15	1.5580	0.64186	0.05377	18.599	0.08377	11.938	6.4500
16	1.6047	0.62317	0.04961	20.157	0.07961	12.561	6.8742
17	1.6528	0.60502	0.04595	21.762	0.07595	13.166	7.2936
18	1.7024	0.58739	0.04271	23.414	0.07271	13.754	7.7081
19	1.7535	0.57029	0.03981	25.117	0.06981	14.324	8.1179
20	1.8061	0.55368	0.03722	26.870	0.06722	14.877	8.5229
21	1.8603	0.53755	0.03487	28.676	0.06487	15.415	8.9231
22	1.9161	0.52189	0.03275	30.537	0.06275	15.937	9.3186
23	1.9736	0.50669	0.03081	32.453	0.06081	16.444	9.7093
24	2.0328	0.49193	0.02905	34.426	0.05905	16.936	10.095
25	2.0938	0.47761	0.02743	36.459	0.05743	17.413	10.477
26	2.1566	0.46369	0.02594	38.553	0.05594	17.877	10.853
27	2.2213	0.45019	0.02456	40.710	0.05456	18.327	11.226
28	2.2879	0.43708	0.02329	42.931	0.05329	18.764	11.593
29	2.3566	0.42435	0.02211	45.219	0.05211	19.188	11.956
30	2.4273	0.41199	0.02102	47.575	0.05102	19.600	12.314
31	2.5001	0.39999	0.02000	50.003	0.05000	20.000	12.668
32	2.5751	0.38834	0.01905	52.503	0.04905	20.389	13.017
33	2.6523	0.37703	0.01816	55.078	0.04816	20.766	13.362
34	2.7319	0.36604	0.01732	57.730	0.04732	21.132	13.702
35	2.8139	0.35538	0.01654	60.462	0.04654	21.487	14.037
40	3.2620	0.30656	0.01326	75.401	0.04326	23.115	15.650
45	3.7816	0.26444	0.01079	92.720	0.04079	24.519	17.156
50	4.3839	0.22811	0.00887	112.80	0.03887	25.730	18.558
55	5.0821	0.19677	0.00735	136.07	0.03735	26.774	19.860
60	5.8916	0.16973	0.00613	163.05	0.03613	27.676	21.067
65	6.8300	0.14641	0.00515	194.33	0.03515	28.453	22.184
70	7.9178	0.12630	0.00434	230.59	0.03434	29.123	23.215
75	9.1789	0.10895	0.00367	272.63	0.03367	29.702	24.163
80	10.641	0.09398	0.00311	321.36	0.03311	30.201	25.035
85	12.336	0.08107	0.00265	377.86	0.03265	30.631	25.835
90	14.300	0.06993	0.00226	443.35	0.03226	31.002	26.567
95	16.578	0.06032	0.00193	519.27	0.03193	31.323	27.235
100	19.219	0.05203	0.00165	607.29	0.03165	31.599	27.844

PDF compression, OCR, web optimization using a watermarked evaluation copy of CVISION PDFCompressor

$i = 4\%$ **Discrete Compounding, Discrete Cash Flows**

	SINGLE PAYMENT		UNIFORM SERIES				
	Compound Amount Factor	Present Worth Factor	Sinking Fund Factor	Uniform Series Factor	Capital Recovery Factor	Series Present Worth Factor	Arithmetic Gradient Series Factor
N	*(F/P,i,N)*	*(P/F,i,N)*	*(A/F,i,N)*	*(F/A,i,N)*	*(A/P,i,N)*	*(P/A,i,N)*	*(A/G,i,N)*
1	1.0400	0.96154	1.0000	1.0000	1.0400	0.96154	0.00000
2	1.0816	0.92456	0.49020	2.0400	0.53020	1.8861	0.49020
3	1.1249	0.88900	0.32035	3.1216	0.36035	2.7751	0.97386
4	1.1699	0.85480	0.23549	4.2465	0.27549	3.6299	1.4510
5	1.2167	0.82193	0.18463	5.4163	0.22463	4.4518	1.9216
6	1.2653	0.79031	0.15076	6.6330	0.19076	5.2421	2.3857
7	1.3159	0.75992	0.12661	7.8983	0.16661	6.0021	2.8433
8	1.3686	0.73069	0.10853	9.2142	0.14853	6.7327	3.2944
9	1.4233	0.70259	0.09449	10.583	0.13449	7.4353	3.7391
10	1.4802	0.67556	0.08329	12.006	0.12329	8.1109	4.1773
11	1.5395	0.64958	0.07415	13.486	0.11415	8.7605	4.6090
12	1.6010	0.62460	0.06655	15.026	0.10655	9.3851	5.0343
13	1.6651	0.60057	0.06014	16.627	0.10014	9.9856	5.4533
14	1.7317	0.57748	0.05467	18.292	0.09467	10.563	5.8659
15	1.8009	0.55526	0.04994	20.024	0.08994	11.118	6.2721
16	1.8730	0.53391	0.04582	21.825	0.08582	11.652	6.6720
17	1.9479	0.51337	0.04220	23.698	0.08220	12.166	7.0656
18	2.0258	0.49363	0.03899	25.645	0.07899	12.659	7.4530
19	2.1068	0.47464	0.03614	27.671	0.07614	13.134	7.8342
20	2.1911	0.45639	0.03358	29.778	0.07358	13.590	8.2091
21	2.2788	0.43883	0.03128	31.969	0.07128	14.029	8.5779
22	2.3699	0.42196	0.02920	34.248	0.06920	14.451	8.9407
23	2.4647	0.40573	0.02731	36.618	0.06731	14.857	9.2973
24	2.5633	0.39012	0.02559	39.083	0.06559	15.247	9.6479
25	2.6658	0.37512	0.02401	41.646	0.06401	15.622	9.9925
26	2.7725	0.36069	0.02257	44.312	0.06257	15.983	10.331
27	2.8834	0.34682	0.02124	47.084	0.06124	16.330	10.664
28	2.9987	0.33348	0.02001	49.968	0.06001	16.663	10.991
29	3.1187	0.32065	0.01888	52.966	0.05888	16.984	11.312
30	3.2434	0.30832	0.01783	56.085	0.05783	17.292	11.627
31	3.3731	0.29646	0.01686	59.328	0.05686	17.588	11.937
32	3.5081	0.28506	0.01595	62.701	0.05595	17.874	12.241
33	3.6484	0.27409	0.01510	66.210	0.05510	18.148	12.540
34	3.7943	0.26355	0.01431	69.858	0.05431	18.411	12.832
35	3.9461	0.25342	0.01358	73.652	0.05358	18.665	13.120
40	4.8010	0.20829	0.01052	95.026	0.05052	19.793	14.477
45	5.8412	0.17120	0.00826	121.03	0.04826	20.720	15.705
50	7.1067	0.14071	0.00655	152.67	0.04655	21.482	16.812
55	8.6464	0.11566	0.00523	191.16	0.04523	22.109	17.807
60	10.520	0.09506	0.00420	237.99	0.04420	22.623	18.697
65	12.799	0.07813	0.00339	294.97	0.04339	23.047	19.491
70	15.572	0.06422	0.00275	364.29	0.04275	23.395	20.196
75	18.945	0.05278	0.00223	448.63	0.04223	23.680	20.821
80	23.050	0.04338	0.00181	551.24	0.04181	23.915	21.372
85	28.044	0.03566	0.00148	676.09	0.04148	24.109	21.857
90	34.119	0.02931	0.00121	827.98	0.04121	24.267	22.283
95	41.511	0.02409	0.00099	1012.8	0.04099	24.398	22.655
100	50.505	0.01980	0.00081	1237.6	0.04081	24.505	22.980

PDF compression, OCR, web optimization using a watermarked evaluation copy of CVISION PDFCompressor

i = 5% Discrete Compounding, Discrete Cash Flows

	SINGLE PAYMENT		UNIFORM SERIES				Arithmetic Gradient Series Factor
	Compound Amount Factor	Present Worth Factor	Sinking Fund Factor	Uniform Series Factor	Capital Recovery Factor	Series Present Worth Factor	
N	*(F/P,i,N)*	*(P/F,i,N)*	*(A/F,i,N)*	*(F/A,i,N)*	*(A/P,i,N)*	*(P/A,i,N)*	*(A/G,i,N)*
1	1.0500	0.95238	1.0000	1.0000	1.0500	0.95238	0.00000
2	1.1025	0.90703	0.48780	2.0500	0.53780	1.8594	0.48780
3	1.1576	0.86384	0.31721	3.1525	0.36721	2.7232	0.96749
4	1.2155	0.82270	0.23201	4.3101	0.28201	3.5460	1.4391
5	1.2763	0.78353	0.18097	5.5256	0.23097	4.3295	1.9025
6	1.3401	0.74622	0.14702	6.8019	0.19702	5.0757	2.3579
7	1.4071	0.71068	0.12282	8.1420	0.17282	5.7864	2.8052
8	1.4775	0.67684	0.10472	9.5491	0.15472	6.4632	3.2445
9	1.5513	0.64461	0.09069	11.027	0.14069	7.1078	3.6758
10	1.6289	0.61391	0.07950	12.578	0.12950	7.7217	4.0991
11	1.7103	0.58468	0.07039	14.207	0.12039	8.3064	4.5144
12	1.7959	0.55684	0.06283	15.917	0.11283	8.8633	4.9219
13	1.8856	0.53032	0.05646	17.713	0.10646	9.3936	5.3215
14	1.9799	0.50507	0.05102	19.599	0.10102	9.8986	5.7133
15	2.0789	0.48102	0.04634	21.579	0.09634	10.380	6.0973
16	2.1829	0.45811	0.04227	23.657	0.09227	10.838	6.4736
17	2.2920	0.43630	0.03870	25.840	0.08870	11.274	6.8423
18	2.4066	0.41552	0.03555	28.132	0.08555	11.690	7.2034
19	2.5270	0.39573	0.03275	30.539	0.08275	12.085	7.5569
20	2.6533	0.37689	0.03024	33.066	0.08024	12.462	7.9030
21	2.7860	0.35894	0.02800	35.719	0.07800	12.821	8.2416
22	2.9253	0.34185	0.02597	38.505	0.07597	13.163	8.5730
23	3.0715	0.32557	0.02414	41.430	0.07414	13.489	8.8971
24	3.2251	0.31007	0.02247	44.502	0.07247	13.799	9.2140
25	3.3864	0.29530	0.02095	47.727	0.07095	14.094	9.5238
26	3.5557	0.28124	0.01956	51.113	0.06956	14.375	9.8266
27	3.7335	0.26785	0.01829	54.669	0.06829	14.643	10.122
28	3.9201	0.25509	0.01712	58.403	0.06712	14.898	10.411
29	4.1161	0.24295	0.01605	62.323	0.06605	15.141	10.694
30	4.3219	0.23138	0.01505	66.439	0.06505	15.372	10.969
31	4.5380	0.22036	0.01413	70.761	0.06413	15.593	11.238
32	4.7649	0.20987	0.01328	75.299	0.06328	15.803	11.501
33	5.0032	0.19987	0.01249	80.064	0.06249	16.003	11.757
34	5.2533	0.19035	0.01176	85.067	0.06176	16.193	12.006
35	5.5160	0.18129	0.01107	90.320	0.06107	16.374	12.250
40	7.0400	0.14205	0.00828	120.80	0.05828	17.159	13.377
45	8.9850	0.11130	0.00626	159.70	0.05626	17.774	14.364
50	11.467	0.08720	0.00478	209.35	0.05478	18.256	15.223
55	14.636	0.06833	0.00367	272.71	0.05367	18.633	15.966
60	18.679	0.05354	0.00283	353.58	0.05283	18.929	16.606
65	23.840	0.04195	0.00219	456.80	0.05219	19.161	17.154
70	30.426	0.03287	0.00170	588.53	0.05170	19.343	17.621
75	38.833	0.02575	0.00132	756.65	0.05132	19.485	18.018
80	49.561	0.02018	0.00103	971.23	0.05103	19.596	18.353
85	63.254	0.01581	0.00080	1245.1	0.05080	19.684	18.635
90	80.730	0.01239	0.00063	1594.6	0.05063	19.752	18.871
95	103.03	0.00971	0.00049	2040.7	0.05049	19.806	19.069
100	131.50	0.00760	0.00038	2610.0	0.05038	19.848	19.234

PDF compression, OCR, web optimization using a watermarked evaluation copy of CVISION PDFCompressor

i = 6% Discrete Compounding, Discrete Cash Flows

	SINGLE PAYMENT		UNIFORM SERIES				
	Compound Amount Factor	Present Worth Factor	Sinking Fund Factor	Uniform Series Factor	Capital Recovery Factor	Series Present Worth Factor	Arithmetic Gradient Series Factor
N	*(F/P,i,N)*	*(P/F,i,N)*	*(A/F,i,N)*	*(F/A,i,N)*	*(A/P,i,N)*	*(P/A,i,N)*	*(A/G,i,N)*
1	1.0600	0.94340	1.0000	1.0000	1.0600	0.94340	0.00000
2	1.1236	0.89000	0.48544	2.0600	0.54544	1.8334	0.48544
3	1.1910	0.83962	0.31411	3.1836	0.37411	2.6730	0.96118
4	1.2625	0.79209	0.22859	4.3746	0.28859	3.4651	1.4272
5	1.3382	0.74726	0.17740	5.6371	0.23740	4.2124	1.8836
6	1.4185	0.70496	0.14336	6.9753	0.20336	4.9173	2.3304
7	1.5036	0.66506	0.11914	8.3938	0.17914	5.5824	2.7676
8	1.5938	0.62741	0.10104	9.8975	0.16104	6.2098	3.1952
9	1.6895	0.59190	0.08702	11.491	0.14702	6.8017	3.6133
10	1.7908	0.55839	0.07587	13.181	0.13587	7.3601	4.0220
11	1.8983	0.52679	0.06679	14.972	0.12679	7.8869	4.4213
12	2.0122	0.49697	0.05928	16.870	0.11928	8.3838	4.8113
13	2.1329	0.46884	0.05296	18.882	0.11296	8.8527	5.1920
14	2.2609	0.44230	0.04758	21.015	0.10758	9.2950	5.5635
15	2.3966	0.41727	0.04296	23.276	0.10296	9.7122	5.9260
16	2.5404	0.39365	0.03895	25.673	0.09895	10.106	6.2794
17	2.6928	0.37136	0.03544	28.213	0.09544	10.477	6.6240
18	2.8543	0.35034	0.03236	30.906	0.09236	10.828	6.9597
19	3.0256	0.33051	0.02962	33.760	0.08962	11.158	7.2867
20	3.2071	0.31180	0.02718	36.786	0.08718	11.470	7.6051
21	3.3996	0.29416	0.02500	39.993	0.08500	11.764	7.9151
22	3.6035	0.27751	0.02305	43.392	0.08305	12.042	8.2166
23	3.8197	0.26180	0.02128	46.996	0.08128	12.303	8.5099
24	4.0489	0.24698	0.01968	50.816	0.07968	12.550	8.7951
25	4.2919	0.23300	0.01823	54.865	0.07823	12.783	9.0722
26	4.5494	0.21981	0.01690	59.156	0.07690	13.003	9.3414
27	4.8223	0.20737	0.01570	63.706	0.07570	13.211	9.6029
28	5.1117	0.19563	0.01459	68.528	0.07459	13.406	9.8568
29	5.4184	0.18456	0.01358	73.640	0.07358	13.591	10.103
30	5.7435	0.17411	0.01265	79.058	0.07265	13.765	10.342
31	6.0881	0.16425	0.01179	84.802	0.07179	13.929	10.574
32	6.4534	0.15496	0.01100	90.890	0.07100	14.084	10.799
33	6.8406	0.14619	0.01027	97.343	0.07027	14.230	11.017
34	7.2510	0.13791	0.00960	104.18	0.06960	14.368	11.228
35	7.6861	0.13011	0.00897	111.43	0.06897	14.498	11.432
40	10.286	0.09722	0.00646	154.76	0.06646	15.046	12.359
45	13.765	0.07265	0.00470	212.74	0.06470	15.456	13.141
50	18.420	0.05429	0.00344	290.34	0.06344	15.762	13.796
55	24.650	0.04057	0.00254	394.17	0.06254	15.991	14.341
60	32.988	0.03031	0.00188	533.13	0.06188	16.161	14.791
65	44.145	0.02265	0.00139	719.08	0.06139	16.289	15.160
70	59.076	0.01693	0.00103	967.93	0.06103	16.385	15.461
75	79.057	0.01265	0.00077	1300.9	0.06077	16.456	15.706
80	105.80	0.00945	0.00057	1746.6	0.06057	16.509	15.903
85	141.58	0.00706	0.00043	2343.0	0.06043	16.549	16.062
90	189.46	0.00528	0.00032	3141.1	0.06032	16.579	16.189
95	253.55	0.00394	0.00024	4209.1	0.06024	16.601	16.290
100	339.30	0.00295	0.00018	5638.4	0.06018	16.618	16.371

PDF compression, OCR, web optimization using a watermarked evaluation copy of CVISION PDFCompressor

$i = 7\%$ Discrete Compounding, Discrete Cash Flows

	SINGLE PAYMENT		UNIFORM SERIES				Arithmetic Gradient Series Factor
	Compound Amount Factor	Present Worth Factor	Sinking Fund Factor	Uniform Series Factor	Capital Recovery Factor	Series Present Worth Factor	
N	*(F/P,i,N)*	*(P/F,i,N)*	*(A/F,i,N)*	*(F/A,i,N)*	*(A/P,i,N)*	*(P/A,i,N)*	*(A/G,i,N)*
1	1.0700	0.93458	1.0000	1.0000	1.0700	0.93458	0.00000
2	1.1449	0.87344	0.48309	2.0700	0.55309	1.8080	0.48309
3	1.2250	0.81630	0.31105	3.2149	0.38105	2.6243	0.95493
4	1.3108	0.76290	0.22523	4.4399	0.29523	3.3872	1.4155
5	1.4026	0.71299	0.17389	5.7507	0.24389	4.1002	1.8650
6	1.5007	0.66634	0.13980	7.1533	0.20980	4.7665	2.3032
7	1.6058	0.62275	0.11555	8.6540	0.18555	5.3893	2.7304
8	1.7182	0.58201	0.09747	10.260	0.16747	5.9713	3.1465
9	1.8385	0.54393	0.08349	11.978	0.15349	6.5152	3.5517
10	1.9672	0.50835	0.07238	13.816	0.14238	7.0236	3.9461
11	2.1049	0.47509	0.06336	15.784	0.13336	7.4987	4.3296
12	2.2522	0.44401	0.05590	17.888	0.12590	7.9427	4.7025
13	2.4098	0.41496	0.04965	20.141	0.11965	8.3577	5.0648
14	2.5785	0.38782	0.04434	22.550	0.11434	8.7455	5.4167
15	2.7590	0.36245	0.03979	25.129	0.10979	9.1079	5.7583
16	2.9522	0.33873	0.03586	27.888	0.10586	9.4466	6.0897
17	3.1588	0.31657	0.03243	30.840	0.10243	9.7632	6.4110
18	3.3799	0.29586	0.02941	33.999	0.09941	10.059	6.7225
19	3.6165	0.27651	0.02675	37.379	0.09675	10.336	7.0242
20	3.8697	0.25842	0.02439	40.995	0.09439	10.594	7.3163
21	4.1406	0.24151	0.02229	44.865	0.09229	10.836	7.5990
22	4.4304	0.22571	0.02041	49.006	0.09041	11.061	7.8725
23	4.7405	0.21095	0.01871	53.436	0.08871	11.272	8.1369
24	5.0724	0.19715	0.01719	58.177	0.08719	11.469	8.3923
25	5.4274	0.18425	0.01581	63.249	0.08581	11.654	8.6391
26	5.8074	0.17220	0.01456	68.676	0.08456	11.826	8.8773
27	6.2139	0.16093	0.01343	74.484	0.08343	11.987	9.1072
28	6.6488	0.15040	0.01239	80.698	0.08239	12.137	9.3289
29	7.1143	0.14056	0.01145	87.347	0.08145	12.278	9.5427
30	7.6123	0.13137	0.01059	94.461	0.08059	12.409	9.7487
31	8.1451	0.12277	0.00980	102.07	0.07980	12.532	9.9471
32	8.7153	0.11474	0.00907	110.22	0.07907	12.647	10.138
33	9.3253	0.10723	0.00841	118.93	0.07841	12.754	10.322
34	9.9781	0.10022	0.00780	128.26	0.07780	12.854	10.499
35	10.677	0.09366	0.00723	138.24	0.07723	12.948	10.669
40	14.974	0.06678	0.00501	199.64	0.07501	13.332	11.423
45	21.002	0.04761	0.00350	285.75	0.07350	13.606	12.036
50	29.457	0.03395	0.00246	406.53	0.07246	13.801	12.529
55	41.315	0.02420	0.00174	575.93	0.07174	13.940	12.921
60	57.946	0.01726	0.00123	813.52	0.07123	14.039	13.232
65	81.273	0.01230	0.00087	1146.8	0.07087	14.110	13.476
70	113.99	0.00877	0.00062	1614.1	0.07062	14.160	13.666
75	159.88	0.00625	0.00044	2269.7	0.07044	14.196	13.814
80	224.23	0.00446	0.00031	3189.1	0.07031	14.222	13.927
85	314.50	0.00318	0.00022	4478.6	0.07022	14.240	14.015
90	441.10	0.00227	0.00016	6287.2	0.07016	14.253	14.081
95	618.67	0.00162	0.00011	8823.9	0.07011	14.263	14.132
100	867.72	0.00115	0.00008	12 382.0	0.07008	14.269	14.170

PDF compression, OCR, web optimization using a watermarked evaluation copy of CVISION PDFCompressor

$i = 8\%$

Discrete Compounding, Discrete Cash Flows

	SINGLE PAYMENT		UNIFORM SERIES				
	Compound Amount Factor	Present Worth Factor	Sinking Fund Factor	Uniform Series Factor	Capital Recovery Factor	Series Present Worth Factor	Arithmetic Gradient Series Factor
N	(F/P,i,N)	(P/F,i,N)	(A/F,i,N)	(F/A,i,N)	(A/P,i,N)	(P/A,i,N)	(A/G,i,N)
1	1.0800	0.92593	1.0000	1.0000	1.0800	0.92593	0.00000
2	1.1664	0.85734	0.48077	2.0800	0.56077	1.7833	0.48077
3	1.2597	0.79383	0.30803	3.2464	0.38803	2.5771	0.94874
4	1.3605	0.73503	0.22192	4.5061	0.30192	3.3121	1.4040
5	1.4693	0.68058	0.17046	5.8666	0.25046	3.9927	1.8465
6	1.5869	0.63017	0.13632	7.3359	0.21632	4.6229	2.2763
7	1.7138	0.58349	0.11207	8.9228	0.19207	5.2064	2.6937
8	1.8509	0.54027	0.09401	10.637	0.17401	5.7466	3.0985
9	1.9990	0.50025	0.08008	12.488	0.16008	6.2469	3.4910
10	2.1589	0.46319	0.06903	14.487	0.14903	6.7101	3.8713
11	2.3316	0.42888	0.06008	16.645	0.14008	7.1390	4.2395
12	2.5182	0.39711	0.05270	18.977	0.13270	7.5361	4.5957
13	2.7196	0.36770	0.04652	21.495	0.12652	7.9038	4.9402
14	2.9372	0.34046	0.04130	24.215	0.12130	8.2442	5.2731
15	3.1722	0.31524	0.03683	27.152	0.11683	8.5595	5.5945
16	3.4259	0.29189	0.03298	30.324	0.11298	8.8514	5.9046
17	3.7000	0.27027	0.02963	33.750	0.10963	9.1216	6.2037
18	3.9960	0.25025	0.02670	37.450	0.10670	9.3719	6.4920
19	4.3157	0.23171	0.02413	41.446	0.10413	9.6036	6.7697
20	4.6610	0.21455	0.02185	45.762	0.10185	9.8181	7.0369
21	5.0338	0.19866	0.01983	50.423	0.09983	10.017	7.2940
22	5.4365	0.18394	0.01803	55.457	0.09803	10.201	7.5412
23	5.8715	0.17032	0.01642	60.893	0.09642	10.371	7.7786
24	6.3412	0.15770	0.01498	66.765	0.09498	10.529	8.0066
25	6.8485	0.14602	0.01368	73.106	0.09368	10.675	8.2254
26	7.3964	0.13520	0.01251	79.954	0.09251	10.810	8.4352
27	7.9881	0.12519	0.01145	87.351	0.09145	10.935	8.6363
28	8.6271	0.11591	0.01049	95.339	0.09049	11.051	8.8289
29	9.3173	0.10733	0.00962	103.97	0.08962	11.158	9.0133
30	10.063	0.09938	0.00883	113.28	0.08883	11.258	9.1897
31	10.868	0.09202	0.00811	123.35	0.08811	11.350	9.3584
32	11.737	0.08520	0.00745	134.21	0.08745	11.435	9.5197
33	12.676	0.07889	0.00685	145.95	0.08685	11.514	9.6737
34	13.690	0.07305	0.00630	158.63	0.08630	11.587	9.8208
35	14.785	0.06763	0.00580	172.32	0.08580	11.655	9.9611
40	21.725	0.04603	0.00386	259.06	0.08386	11.925	10.570
45	31.920	0.03133	0.00259	386.51	0.08259	12.108	11.045
50	46.902	0.02132	0.00174	573.77	0.08174	12.233	11.411
55	68.914	0.01451	0.00118	848.92	0.08118	12.319	11.690
60	101.26	0.00988	0.00080	1253.2	0.08080	12.377	11.902
65	148.78	0.00672	0.00054	1847.2	0.08054	12.416	12.060
70	218.61	0.00457	0.00037	2720.1	0.08037	12.443	12.178
75	321.20	0.00311	0.00025	4002.6	0.08025	12.461	12.266
80	471.95	0.00212	0.00017	5886.9	0.08017	12.474	12.330
85	693.46	0.00144	0.00012	8655.7	0.08012	12.482	12.377
90	1018.9	0.00098	0.00008	12 724.0	0.08008	12.488	12.412
95	1497.1	0.00067	0.00005	18 702.0	0.08005	12.492	12.437
100	2199.8	0.00045	0.00004	27 485.0	0.08004	12.494	12.455

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$i = 9\%$ Discrete Compounding, Discrete Cash Flows

	SINGLE PAYMENT		UNIFORM SERIES				Arithmetic Gradient Series Factor
	Compound Amount Factor	Present Worth Factor	Sinking Fund Factor	Uniform Series Factor	Capital Recovery Factor	Series Present Worth Factor	
N	*(F/P,i,N)*	*(P/F,i,N)*	*(A/F,i,N)*	*(F/A,i,N)*	*(A/P,i,N)*	*(P/A,i,N)*	*(A/G,i,N)*
1	1.0900	0.91743	1.0000	1.0000	1.0900	0.91743	0.00000
2	1.1881	0.84168	0.47847	2.0900	0.56847	1.7591	0.47847
3	1.2950	0.77218	0.30505	3.2781	0.39505	2.5313	0.94262
4	1.4116	0.70843	0.21867	4.5731	0.30867	3.2397	1.3925
5	1.5386	0.64993	0.16709	5.9847	0.25709	3.8897	1.8282
6	1.6771	0.59627	0.13292	7.5233	0.22292	4.4859	2.2498
7	1.8280	0.54703	0.10869	9.2004	0.19869	5.0330	2.6574
8	1.9926	0.50187	0.09067	11.028	0.18067	5.5348	3.0512
9	2.1719	0.46043	0.07680	13.021	0.16680	5.9952	3.4312
10	2.3674	0.42241	0.06582	15.193	0.15582	6.4177	3.7978
11	2.5804	0.38753	0.05695	17.560	0.14695	6.8052	4.1510
12	2.8127	0.35553	0.04965	20.141	0.13965	7.1607	4.4910
13	3.0658	0.32618	0.04357	22.953	0.13357	7.4869	4.8182
14	3.3417	0.29925	0.03843	26.019	0.12843	7.7862	5.1326
15	3.6425	0.27454	0.03406	29.361	0.12406	8.0607	5.4346
16	3.9703	0.25187	0.03030	33.003	0.12030	8.3126	5.7245
17	4.3276	0.23107	0.02705	36.974	0.11705	8.5436	6.0024
18	4.7171	0.21199	0.02421	41.301	0.11421	8.7556	6.2687
19	5.1417	0.19449	0.02173	46.018	0.11173	8.9501	6.5236
20	5.6044	0.17843	0.01955	51.160	0.10955	9.1285	6.7674
21	6.1088	0.16370	0.01762	56.765	0.10762	9.2922	7.0006
22	6.6586	0.15018	0.01590	62.873	0.10590	9.4424	7.2232
23	7.2579	0.13778	0.01438	69.532	0.10438	9.5802	7.4357
24	7.9111	0.12640	0.01302	76.790	0.10302	9.7066	7.6384
25	8.6231	0.11597	0.01181	84.701	0.10181	9.8226	7.8316
26	9.3992	0.10639	0.01072	93.324	0.10072	9.9290	8.0156
27	10.245	0.09761	0.00973	102.72	0.09973	10.027	8.1906
28	11.167	0.08955	0.00885	112.97	0.09885	10.116	8.3571
29	12.172	0.08215	0.00806	124.14	0.09806	10.198	8.5154
30	13.268	0.07537	0.00734	136.31	0.09734	10.274	8.6657
31	14.462	0.06915	0.00669	149.58	0.09669	10.343	8.8083
32	15.763	0.06344	0.00610	164.04	0.09610	10.406	8.9436
33	17.182	0.05820	0.00556	179.80	0.09556	10.464	9.0718
34	18.728	0.05339	0.00508	196.98	0.09508	10.518	9.1933
35	20.414	0.04899	0.00464	215.71	0.09464	10.567	9.3083
40	31.409	0.03184	0.00296	337.88	0.09296	10.757	9.7957
45	48.327	0.02069	0.00190	525.86	0.09190	10.881	10.160
50	74.358	0.01345	0.00123	815.08	0.09123	10.962	10.430
55	114.41	0.00874	0.00079	1260.1	0.09079	11.014	10.626
60	176.03	0.00568	0.00051	1944.8	0.09051	11.048	10.768
65	270.85	0.00369	0.00033	2998.3	0.09033	11.070	10.870
70	416.73	0.00240	0.00022	4619.2	0.09022	11.084	10.943
75	641.19	0.00156	0.00014	7113.2	0.09014	11.094	10.994
80	986.55	0.00101	0.00009	10 951.0	0.09009	11.100	11.030
85	1517.9	0.00066	0.00006	16 855.0	0.09006	11.104	11.055
90	2335.5	0.00043	0.00004	25 939.0	0.09004	11.106	11.073
95	3593.5	0.00028	0.00003	39 917.0	0.09003	11.108	11.085
100	5529.0	0.00018	0.00002	61 423.0	0.09002	11.109	11.093

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i = 10% **Discrete Compounding, Discrete Cash Flows**

	SINGLE PAYMENT		UNIFORM SERIES				Arithmetic Gradient Series Factor
	Compound Amount Factor	Present Worth Factor	Sinking Fund Factor	Uniform Series Factor	Capital Recovery Factor	Series Present Worth Factor	
N	(F/P,i,N)	(P/F,i,N)	(A/F,i,N)	(F/A,i,N)	(A/P,i,N)	(P/A,i,N)	(A/G,i,N)
1	1.1000	0.90909	1.0000	1.0000	1.1000	0.90909	0.00000
2	1.2100	0.82645	0.47619	2.1000	0.57619	1.7355	0.47619
3	1.3310	0.75131	0.30211	3.3100	0.40211	2.4869	0.93656
4	1.4641	0.68301	0.21547	4.6410	0.31547	3.1699	1.3812
5	1.6105	0.62092	0.16380	6.1051	0.26380	3.7908	1.8101
6	1.7716	0.56447	0.12961	7.7156	0.22961	4.3553	2.2236
7	1.9487	0.51316	0.10541	9.4872	0.20541	4.8684	2.6216
8	2.1436	0.46651	0.08744	11.436	0.18744	5.3349	3.0045
9	2.3579	0.42410	0.07364	13.579	0.17364	5.7590	3.3724
10	2.5937	0.38554	0.06275	15.937	0.16275	6.1446	3.7255
11	2.8531	0.35049	0.05396	18.531	0.15396	6.4951	4.0641
12	3.1384	0.31863	0.04676	21.384	0.14676	6.8137	4.3884
13	3.4523	0.28966	0.04078	24.523	0.14078	7.1034	4.6988
14	3.7975	0.26333	0.03575	27.975	0.13575	7.3667	4.9955
15	4.1772	0.23939	0.03147	31.772	0.13147	7.6061	5.2789
16	4.5950	0.21763	0.02782	35.950	0.12782	7.8237	5.5493
17	5.0545	0.19784	0.02466	40.545	0.12466	8.0216	5.8071
18	5.5599	0.17986	0.02193	45.599	0.12193	8.2014	6.0526
19	6.1159	0.16351	0.01955	51.159	0.11955	8.3649	6.2861
20	6.7275	0.14864	0.01746	57.275	0.11746	8.5136	6.5081
21	7.4002	0.13513	0.01562	64.002	0.11562	8.6487	6.7189
22	8.1403	0.12285	0.01401	71.403	0.11401	8.7715	6.9189
23	8.9543	0.11168	0.01257	79.543	0.11257	8.8832	7.1085
24	9.8497	0.10153	0.01130	88.497	0.11130	8.9847	7.2881
25	10.835	0.09230	0.01017	98.347	0.11017	9.0770	7.4580
26	11.918	0.08391	0.00916	109.18	0.10916	9.1609	7.6186
27	13.110	0.07628	0.00826	121.10	0.10826	9.2372	7.7704
28	14.421	0.06934	0.00745	134.21	0.10745	9.3066	7.9137
29	15.863	0.06304	0.00673	148.63	0.10673	9.3696	8.0489
30	17.449	0.05731	0.00608	164.49	0.10608	9.4269	8.1762
31	19.194	0.05210	0.00550	181.94	0.10550	9.4790	8.2962
32	21.114	0.04736	0.00497	201.14	0.10497	9.5264	8.4091
33	23.225	0.04306	0.00450	222.25	0.10450	9.5694	8.5152
34	25.548	0.03914	0.00407	245.48	0.10407	9.6086	8.6149
35	28.102	0.03558	0.00369	271.02	0.10369	9.6442	8.7086
40	45.259	0.02209	0.00226	442.59	0.10226	9.7791	9.0962
45	72.890	0.01372	0.00139	718.90	0.10139	9.8628	9.3740
50	117.39	0.00852	0.00086	1163.9	0.10086	9.9148	9.5704
55	189.06	0.00529	0.00053	1880.6	0.10053	9.9471	9.7075
60	304.48	0.00328	0.00033	3034.8	0.10033	9.9672	9.8023
65	490.37	0.00204	0.00020	4893.7	0.10020	9.9796	9.8672
70	789.75	0.00127	0.00013	7887.5	0.10013	9.9873	9.9113
75	1271.9	0.00079	0.00008	12 709.0	0.10008	9.9921	9.9410

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$i = 11\%$ Discrete Compounding, Discrete Cash Flows

	SINGLE PAYMENT		UNIFORM SERIES				Arithmetic Gradient Series Factor
	Compound Amount Factor	Present Worth Factor	Sinking Fund Factor	Uniform Series Factor	Capital Recovery Factor	Series Present Worth Factor	
N	(F/P,i,N)	(P/F,i,N)	(A/F,i,N)	(F/A,i,N)	(A/P,i,N)	(P/A,i,N)	(A/G,i,N)
1	1.1100	0.90090	1.0000	1.0000	1.1100	0.90090	0.00000
2	1.2321	0.81162	0.47393	2.1100	0.58393	1.7125	0.47393
3	1.3676	0.73119	0.29921	3.3421	0.40921	2.4437	0.93055
4	1.5181	0.65873	0.21233	4.7097	0.32233	3.1024	1.3700
5	1.6851	0.59345	0.16057	6.2278	0.27057	3.6959	1.7923
6	1.8704	0.53464	0.12638	7.9129	0.23638	4.2305	2.1976
7	2.0762	0.48166	0.10222	9.783	0.21222	4.7122	2.5863
8	2.3045	0.43393	0.08432	11.859	0.19432	5.1461	2.9585
9	2.5580	0.39092	0.07060	14.164	0.18060	5.5370	3.3144
10	2.8394	0.35218	0.05980	16.722	0.16980	5.8892	3.6544
11	3.1518	0.31728	0.05112	19.561	0.16112	6.2065	3.9788
12	3.4985	0.28584	0.04403	22.713	0.15403	6.4924	4.2879
13	3.8833	0.25751	0.03815	26.212	0.14815	6.7499	4.5822
14	4.3104	0.23199	0.03323	30.095	0.14323	6.9819	4.8619
15	4.7846	0.20900	0.02907	34.405	0.13907	7.1909	5.1275
16	5.3109	0.18829	0.02552	39.190	0.13552	7.3792	5.3794
17	5.8951	0.16963	0.02247	44.501	0.13247	7.5488	5.6180
18	6.5436	0.15282	0.01984	50.396	0.12984	7.7016	5.8439
19	7.2633	0.13768	0.01756	56.939	0.12756	7.8393	6.0574
20	8.0623	0.12403	0.01558	64.203	0.12558	7.9633	6.2590
21	8.949	0.11174	0.01384	72.265	0.12384	8.0751	6.4491
22	9.934	0.10067	0.01231	81.214	0.12231	8.1757	6.6283
23	11.026	0.09069	0.01097	91.15	0.12097	8.2664	6.7969
24	12.239	0.08170	0.00979	102.17	0.11979	8.3481	6.9555
25	13.585	0.07361	0.00874	114.41	0.11874	8.4217	7.1045
26	15.080	0.06631	0.00781	128.00	0.11781	8.4881	7.2443
27	16.739	0.05974	0.00699	143.08	0.11699	8.5478	7.3754
28	18.580	0.05382	0.00626	159.82	0.11626	8.6016	7.4982
29	20.624	0.04849	0.00561	178.40	0.11561	8.6501	7.6131
30	22.892	0.04368	0.00502	199.02	0.11502	8.6938	7.7206
31	25.410	0.03935	0.00451	221.91	0.11451	8.7331	7.8210
32	28.206	0.03545	0.00404	247.32	0.11404	8.7686	7.9147
33	31.308	0.03194	0.00363	275.53	0.11363	8.8005	8.0021
34	34.752	0.02878	0.00326	306.84	0.11326	8.8293	8.0836
35	38.575	0.02592	0.00293	341.59	0.11293	8.8552	8.1594
40	65.001	0.01538	0.00172	581.83	0.11172	8.9511	8.4659
45	109.53	0.00913	0.00101	986.6	0.11101	9.0079	8.6763
50	184.56	0.00542	0.00060	1668.8	0.11060	9.0417	8.8185
55	311.00	0.00322	0.00035	2818.2	0.11035	9.0617	8.9135

PDF compression, OCR, web optimization using a watermarked evaluation copy of CVISION PDFCompressor

i = 12% Discrete Compounding, Discrete Cash Flows

	SINGLE PAYMENT		UNIFORM SERIES				Arithmetic Gradient Series Factor
	Compound Amount Factor	Present Worth Factor	Sinking Fund Factor	Uniform Series Factor	Capital Recovery Factor	Series Present Worth Factor	
N	(F/P,i,N)	(P/F,i,N)	(A/F,i,N)	(F/A,i,N)	(A/P,i,N)	(P/A,i,N)	(A/G,i,N)
1	1.1200	0.89286	1.0000	1.0000	1.1200	0.89286	0.00000
2	1.2544	0.79719	0.47170	2.1200	0.59170	1.6901	0.47170
3	1.4049	0.71178	0.29635	3.3744	0.41635	2.4018	0.92461
4	1.5735	0.63552	0.20923	4.7793	0.32923	3.0373	1.3589
5	1.7623	0.56743	0.15741	6.3528	0.27741	3.6048	1.7746
6	1.9738	0.50663	0.12323	8.1152	0.24323	4.1114	2.1720
7	2.2107	0.45235	0.09912	10.089	0.21912	4.5638	2.5515
8	2.4760	0.40388	0.08130	12.300	0.20130	4.9676	2.9131
9	2.7731	0.36061	0.06768	14.776	0.18768	5.3282	3.2574
10	3.1058	0.32197	0.05698	17.549	0.17698	5.6502	3.5847
11	3.4785	0.28748	0.04842	20.655	0.16842	5.9377	3.8953
12	3.8960	0.25668	0.04144	24.133	0.16144	6.1944	4.1897
13	4.3635	0.22917	0.03568	28.029	0.15568	6.4235	4.4683
14	4.8871	0.20462	0.03087	32.393	0.15087	6.6282	4.7317
15	5.4736	0.18270	0.02682	37.280	0.14682	6.8109	4.9803
16	6.1304	0.16312	0.02339	42.753	0.14339	6.9740	5.2147
17	6.8660	0.14564	0.02046	48.884	0.14046	7.1196	5.4353
18	7.6900	0.13004	0.01794	55.750	0.13794	7.2497	5.6427
19	8.6128	0.11611	0.01576	63.440	0.13576	7.3658	5.8375
20	9.6463	0.10367	0.01388	72.052	0.13388	7.4694	6.0202
21	10.804	0.09256	0.01224	81.699	0.13224	7.5620	6.1913
22	12.100	0.08264	0.01081	92.503	0.13081	7.6446	6.3514
23	13.552	0.07379	0.00956	104.60	0.12956	7.7184	6.5010
24	15.179	0.06588	0.00846	118.16	0.12846	7.7843	6.6406
25	17.000	0.05882	0.00750	133.33	0.12750	7.8431	6.7708
26	19.040	0.05252	0.00665	150.33	0.12665	7.8957	6.8921
27	21.325	0.04689	0.00590	169.37	0.12590	7.9426	7.0049
28	23.884	0.04187	0.00524	190.70	0.12524	7.9844	7.1098
29	26.750	0.03738	0.00466	214.58	0.12466	8.0218	7.2071
30	29.960	0.03338	0.00414	241.33	0.12414	8.0552	7.2974
31	33.555	0.02980	0.00369	271.29	0.12369	8.0850	7.3811
32	37.582	0.02661	0.00328	304.85	0.12328	8.1116	7.4586
33	42.092	0.02376	0.00292	342.43	0.12292	8.1354	7.5302
34	47.143	0.02121	0.00260	384.52	0.12260	8.1566	7.5965
35	52.800	0.01894	0.00232	431.66	0.12232	8.1755	7.6577
40	93.051	0.01075	0.00130	767.09	0.12130	8.2438	7.8988
45	163.99	0.00610	0.00074	1358.2	0.12074	8.2825	8.0572
50	289.00	0.00346	0.00042	2400.0	0.12042	8.3045	8.1597
55	509.32	0.00196	0.00024	4236.0	0.12024	8.3170	8.2251

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$i = 13\%$ Discrete Compounding, Discrete Cash Flows

	SINGLE PAYMENT		UNIFORM SERIES				Arithmetic Gradient Series Factor
	Compound Amount Factor	Present Worth Factor	Sinking Fund Factor	Uniform Series Factor	Capital Recovery Factor	Series Present Worth Factor	
N	*(F/P,i,N)*	*(P/F,i,N)*	*(A/F,i,N)*	*(F/A,i,N)*	*(A/P,i,N)*	*(P/A,i,N)*	*(A/G,i,N)*
1	1.1300	0.88496	1.0000	1.0000	1.1300	0.88496	0.00000
2	1.2769	0.78315	0.46948	2.1300	0.59948	1.6681	0.46948
3	1.4429	0.69305	0.29352	3.4069	0.42352	2.3612	0.91872
4	1.6305	0.61332	0.20619	4.8498	0.33619	2.9745	1.3479
5	1.8424	0.54276	0.15431	6.4803	0.28431	3.5172	1.7571
6	2.0820	0.48032	0.12015	8.3227	0.25015	3.9975	2.1468
7	2.3526	0.42506	0.09611	10.405	0.22611	4.4226	2.5171
8	2.6584	0.37616	0.07839	12.757	0.20839	4.7988	2.8685
9	3.0040	0.33288	0.06487	15.416	0.19487	5.1317	3.2014
10	3.3946	0.29459	0.05429	18.420	0.18429	5.4262	3.5162
11	3.8359	0.26070	0.04584	21.814	0.17584	5.6869	3.8134
12	4.3345	0.23071	0.03899	25.650	0.16899	5.9176	4.0936
13	4.8980	0.20416	0.03335	29.985	0.16335	6.1218	4.3573
14	5.5348	0.18068	0.02867	34.883	0.15867	6.3025	4.6050
15	6.2543	0.15989	0.02474	40.417	0.15474	6.4624	4.8375
16	7.0673	0.14150	0.02143	46.672	0.15143	6.6039	5.0552
17	7.9861	0.12522	0.01861	53.739	0.14861	6.7291	5.2589
18	9.0243	0.11081	0.01620	61.725	0.14620	6.8399	5.4491
19	10.197	0.09806	0.01413	70.749	0.14413	6.9380	5.6265
20	11.523	0.08678	0.01235	80.947	0.14235	7.0248	5.7917
21	13.021	0.07680	0.01081	92.470	0.14081	7.1016	5.9454
22	14.714	0.06796	0.00948	105.49	0.13948	7.1695	6.0881
23	16.627	0.06014	0.00832	120.20	0.13832	7.2297	6.2205
24	18.788	0.05323	0.00731	136.83	0.13731	7.2829	6.3431
25	21.231	0.04710	0.00643	155.62	0.13643	7.3300	6.4566
26	23.991	0.04168	0.00565	176.85	0.13565	7.3717	6.5614
27	27.109	0.03689	0.00498	200.84	0.13498	7.4086	6.6582
28	30.633	0.03264	0.00439	227.95	0.13439	7.4412	6.7474
29	34.616	0.02889	0.00387	258.58	0.13387	7.4701	6.8296
30	39.116	0.02557	0.00341	293.20	0.13341	7.4957	6.9052
31	44.201	0.02262	0.00301	332.32	0.13301	7.5183	6.9747
32	49.947	0.02002	0.00266	376.52	0.13266	7.5383	7.0385
33	56.440	0.01772	0.00234	426.46	0.13234	7.5560	7.0971
34	63.777	0.01568	0.00207	482.90	0.13207	7.5717	7.1507
35	72.069	0.01388	0.00183	546.68	0.13183	7.5856	7.1998
40	132.78	0.00753	0.00099	1013.7	0.13099	7.6344	7.3888
45	244.64	0.00409	0.00053	1874.2	0.13053	7.6609	7.5076
50	450.74	0.00222	0.00029	3459.5	0.13029	7.6752	7.5811
55	830.45	0.00120	0.00016	6380.4	0.13016	7.6830	7.6260

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i = 14% Discrete Compounding, Discrete Cash Flows

	SINGLE PAYMENT		UNIFORM SERIES				Arithmetic Gradient Series Factor
	Compound Amount Factor	Present Worth Factor	Sinking Fund Factor	Uniform Series Factor	Capital Recovery Factor	Series Present Worth Factor	
N	(F/P,i,N)	(P/F,i,N)	(A/F,i,N)	(F/A,i,N)	(A/P,i,N)	(P/A,i,N)	(A/G,i,N)
1	1.1400	0.87719	1.0000	1.0000	1.1400	0.87719	0.00000
2	1.2996	0.76947	0.46729	2.1400	0.60729	1.6467	0.46729
3	1.4815	0.67497	0.29073	3.4396	0.43073	2.3216	0.91290
4	1.6890	0.59208	0.20320	4.9211	0.34320	2.9137	1.3370
5	1.9254	0.51937	0.15128	6.6101	0.29128	3.4331	1.7399
6	2.1950	0.45559	0.11716	8.5355	0.25716	3.8887	2.1218
7	2.5023	0.39964	0.09319	10.730	0.23319	4.2883	2.4832
8	2.8526	0.35056	0.07557	13.233	0.21557	4.6389	2.8246
9	3.2519	0.30751	0.06217	16.085	0.20217	4.9464	3.1463
10	3.7072	0.26974	0.05171	19.337	0.19171	5.2161	3.4490
11	4.2262	0.23662	0.04339	23.045	0.18339	5.4527	3.7333
12	4.8179	0.20756	0.03667	27.271	0.17667	5.6603	3.9998
13	5.4924	0.18207	0.03116	32.089	0.17116	5.8424	4.2491
14	6.2613	0.15971	0.02661	37.581	0.16661	6.0021	4.4819
15	7.1379	0.14010	0.02281	43.842	0.16281	6.1422	4.6990
16	8.1372	0.12289	0.01962	50.980	0.15962	6.2651	4.9011
17	9.2765	0.10780	0.01692	59.118	0.15692	6.3729	5.0888
18	10.575	0.09456	0.01462	68.394	0.15462	6.4674	5.2630
19	12.056	0.08295	0.01266	78.969	0.15266	6.5504	5.4243
20	13.743	0.07276	0.01099	91.025	0.15099	6.6231	5.5734
21	15.668	0.06383	0.00954	104.77	0.14954	6.6870	5.7111
22	17.861	0.05599	0.00830	120.44	0.14830	6.7429	5.8381
23	20.362	0.04911	0.00723	138.30	0.14723	6.7921	5.9549
24	23.212	0.04308	0.00630	158.66	0.14630	6.8351	6.0624
25	26.462	0.03779	0.00550	181.87	0.14550	6.8729	6.1610
26	30.167	0.03315	0.00480	208.33	0.14480	6.9061	6.2514
27	34.390	0.02908	0.00419	238.50	0.14419	6.9352	6.3342
28	39.204	0.02551	0.00366	272.89	0.14366	6.9607	6.4100
29	44.693	0.02237	0.00320	312.09	0.14320	6.9830	6.4791
30	50.950	0.01963	0.00280	356.79	0.14280	7.0027	6.5423
31	58.083	0.01722	0.00245	407.74	0.14245	7.0199	6.5998
32	66.215	0.01510	0.00215	465.82	0.14215	7.0350	6.6522
33	75.485	0.01325	0.00188	532.04	0.14188	7.0482	6.6998
34	86.053	0.01162	0.00165	607.52	0.14165	7.0599	6.7431
35	98.100	0.01019	0.00144	693.57	0.14144	7.0700	6.7824
40	188.88	0.00529	0.00075	1342.0	0.14075	7.1050	6.9300
45	363.68	0.00275	0.00039	2590.6	0.14039	7.1232	7.0188
50	700.23	0.00143	0.00020	4994.5	0.14020	7.1327	7.0714
55	1348.2	0.00074	0.00010	9623.1	0.14010	7.1376	7.1020

PDF compression, OCR, web optimization using a watermarked evaluation copy of CVISION PDFCompressor

i = 15% Discrete Compounding, Discrete Cash Flows

	SINGLE PAYMENT		UNIFORM SERIES				Arithmetic Gradient Series Factor
	Compound Amount Factor	Present Worth Factor	Sinking Fund Factor	Uniform Series Factor	Capital Recovery Factor	Series Present Worth Factor	
N	*(F/P,i,N)*	*(P/F,i,N)*	*(A/F,i,N)*	*(F/A,i,N)*	*(A/P,i,N)*	*(P/A,i,N)*	*(A/G,i,N)*
1	1.1500	0.86957	1.0000	1.0000	1.1500	0.86957	0.00000
2	1.3225	0.75614	0.46512	2.1500	0.61512	1.6257	0.46512
3	1.5209	0.65752	0.28798	3.4725	0.43798	2.2832	0.90713
4	1.7490	0.57175	0.20027	4.9934	0.35027	2.8550	1.3263
5	2.0114	0.49718	0.14832	6.7424	0.29832	3.3522	1.7228
6	2.3131	0.43233	0.11424	8.7537	0.26424	3.7845	2.0972
7	2.6600	0.37594	0.09036	11.067	0.24036	4.1604	2.4498
8	3.0590	0.32690	0.07285	13.727	0.22285	4.4873	2.7813
9	3.5179	0.28426	0.05957	16.786	0.20957	4.7716	3.0922
10	4.0456	0.24718	0.04925	20.304	0.19925	5.0188	3.3832
11	4.6524	0.21494	0.04107	24.349	0.19107	5.2337	3.6549
12	5.3503	0.18691	0.03448	29.002	0.18448	5.4206	3.9082
13	6.1528	0.16253	0.02911	34.352	0.17911	5.5831	4.1438
14	7.0757	0.14133	0.02469	40.505	0.17469	5.7245	4.3624
15	8.1371	0.12289	0.02102	47.580	0.17102	5.8474	4.5650
16	9.3576	0.10686	0.01795	55.717	0.16795	5.9542	4.7522
17	10.761	0.09293	0.01537	65.075	0.16537	6.0472	4.9251
18	12.375	0.08081	0.01319	75.836	0.16319	6.1280	5.0843
19	14.232	0.07027	0.01134	88.212	0.16134	6.1982	5.2307
20	16.367	0.06110	0.00976	102.44	0.15976	6.2593	5.3651
21	18.822	0.05313	0.00842	118.81	0.15842	6.3125	5.4883
22	21.645	0.04620	0.00727	137.63	0.15727	6.3587	5.6010
23	24.891	0.04017	0.00628	159.28	0.15628	6.3988	5.7040
24	28.625	0.03493	0.00543	184.17	0.15543	6.4338	5.7979
25	32.919	0.03038	0.00470	212.79	0.15470	6.4641	5.8834
26	37.857	0.02642	0.00407	245.71	0.15407	6.4906	5.9612
27	43.535	0.02297	0.00353	283.57	0.15353	6.5135	6.0319
28	50.066	0.01997	0.00306	327.10	0.15306	6.5335	6.0960
29	57.575	0.01737	0.00265	377.17	0.15265	6.5509	6.1541
30	66.212	0.01510	0.00230	434.75	0.15230	6.5660	6.2066
31	76.144	0.01313	0.00200	500.96	0.15200	6.5791	6.2541
32	87.565	0.01142	0.00173	577.10	0.15173	6.5905	6.2970
33	100.70	0.00993	0.00150	664.67	0.15150	6.6005	6.3357
34	115.80	0.00864	0.00131	765.37	0.15131	6.6091	6.3705
35	133.18	0.00751	0.00113	881.17	0.15113	6.6166	6.4019
40	267.86	0.00373	0.00056	1779.1	0.15056	6.6418	6.5168
45	538.77	0.00186	0.00028	3585.1	0.15028	6.6543	6.5830
50	1083.7	0.00092	0.00014	7217.7	0.15014	6.6605	6.6205
55	2179.6	0.00046	0.00007	14 524.0	0.15007	6.6636	6.6414

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$i = 20\%$ Discrete Compounding, Discrete Cash Flows

	SINGLE PAYMENT		UNIFORM SERIES				Arithmetic Gradient Series Factor
	Compound Amount Factor	Present Worth Factor	Sinking Fund Factor	Uniform Series Factor	Capital Recovery Factor	Series Present Worth Factor	
N	(F/P,i,N)	(P/F,i,N)	(A/F,i,N)	(F/A,i,N)	(A/P,i,N)	(P/A,i,N)	(A/G,i,N)
1	1.2000	0.83333	1.0000	1.0000	1.2000	0.83333	0.00000
2	1.4400	0.69444	0.45455	2.2000	0.65455	1.5278	0.45455
3	1.7280	0.57870	0.27473	3.6400	0.47473	2.1065	0.87912
4	2.0736	0.48225	0.18629	5.3680	0.38629	2.5887	1.2742
5	2.4883	0.40188	0.13438	7.4416	0.33438	2.9906	1.6405
6	2.9860	0.33490	0.10071	9.9299	0.30071	3.3255	1.9788
7	3.5832	0.27908	0.07742	12.916	0.27742	3.6046	2.2902
8	4.2998	0.23257	0.06061	16.499	0.26061	3.8372	2.5756
9	5.1598	0.19381	0.04808	20.799	0.24808	4.0310	2.8364
10	6.1917	0.16151	0.03852	25.959	0.23852	4.1925	3.0739
11	7.4301	0.13459	0.03110	32.150	0.23110	4.3271	3.2893
12	8.9161	0.11216	0.02526	39.581	0.22526	4.4392	3.4841
13	10.699	0.09346	0.02062	48.497	0.22062	4.5327	3.6597
14	12.839	0.07789	0.01689	59.196	0.21689	4.6106	3.8175
15	15.407	0.06491	0.01388	72.035	0.21388	4.6755	3.9588
16	18.488	0.05409	0.01144	87.442	0.21144	4.7296	4.0851
17	22.186	0.04507	0.00944	105.93	0.20944	4.7746	4.1976
18	26.623	0.03756	0.00781	128.12	0.20781	4.8122	4.2975
19	31.948	0.03130	0.00646	154.74	0.20646	4.8435	4.3861
20	38.338	0.02608	0.00536	186.69	0.20536	4.8696	4.4643
21	46.005	0.02174	0.00444	225.03	0.20444	4.8913	4.5334
22	55.206	0.01811	0.00369	271.03	0.20369	4.9094	4.5941
23	66.247	0.01509	0.00307	326.24	0.20307	4.9245	4.6475
24	79.497	0.01258	0.00255	392.48	0.20255	4.9371	4.6943
25	95.396	0.01048	0.00212	471.98	0.20212	4.9476	4.7352
26	114.48	0.00874	0.00176	567.38	0.20176	4.9563	4.7709
27	137.37	0.00728	0.00147	681.85	0.20147	4.9636	4.8020
28	164.84	0.00607	0.00122	819.22	0.20122	4.9697	4.8291
29	197.81	0.00506	0.00102	984.07	0.20102	4.9747	4.8527
30	237.38	0.00421	0.00085	1181.9	0.20085	4.9789	4.8731
31	284.85	0.00351	0.00070	1419.3	0.20070	4.9824	4.8908
32	341.82	0.00293	0.00059	1704.1	0.20059	4.9854	4.9061
33	410.19	0.00244	0.00049	2045.9	0.20049	4.9878	4.9194
34	492.22	0.00203	0.00041	2456.1	0.20041	4.9898	4.9308
35	590.67	0.00169	0.00034	2948.3	0.20034	4.9915	4.9406

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i = 25% Discrete Compounding, Discrete Cash Flows

	SINGLE PAYMENT		UNIFORM SERIES				Arithmetic Gradient Series Factor
	Compound Amount Factor	Present Worth Factor	Sinking Fund Factor	Uniform Series Factor	Capital Recovery Factor	Series Present Worth Factor	
N	(*F/P,i,N*)	(*P/F,i,N*)	(*A/F,i,N*)	(*F/A,i,N*)	(*A/P,i,N*)	(*P/A,i,N*)	(*A/G,i,N*)
1	1.2500	0.80000	1.0000	1.0000	1.2500	0.80000	0.00000
2	1.5625	0.64000	0.44444	2.2500	0.69444	1.4400	0.44444
3	1.9531	0.51200	0.26230	3.8125	0.51230	1.9520	0.85246
4	2.4414	0.40960	0.17344	5.7656	0.42344	2.3616	1.2249
5	3.0518	0.32768	0.12185	8.2070	0.37185	2.6893	1.5631
6	3.8147	0.26214	0.08882	11.259	0.33882	2.9514	1.8683
7	4.7684	0.20972	0.06634	15.073	0.31634	3.1611	2.1424
8	5.9605	0.16777	0.05040	19.842	0.30040	3.3289	2.3872
9	7.4506	0.13422	0.03876	25.802	0.28876	3.4631	2.6048
10	9.3132	0.10737	0.03007	33.253	0.28007	3.5705	2.7971
11	11.642	0.08590	0.02349	42.566	0.27349	3.6564	2.9663
12	14.552	0.06872	0.01845	54.208	0.26845	3.7251	3.1145
13	18.190	0.05498	0.01454	68.760	0.26454	3.7801	3.2437
14	22.737	0.04398	0.01150	86.949	0.26150	3.8241	3.3559
15	28.422	0.03518	0.00912	109.69	0.25912	3.8593	3.4530
16	35.527	0.02815	0.00724	138.11	0.25724	3.8874	3.5366
17	44.409	0.02252	0.00576	173.64	0.25576	3.9099	3.6084
18	55.511	0.01801	0.00459	218.04	0.25459	3.9279	3.6698
19	69.389	0.01441	0.00366	273.56	0.25366	3.9424	3.7222
20	86.736	0.01153	0.00292	342.94	0.25292	3.9539	3.7667
21	108.42	0.00922	0.00233	429.68	0.25233	3.9631	3.8045
22	135.53	0.00738	0.00186	538.10	0.25186	3.9705	3.8365
23	169.41	0.00590	0.00148	673.63	0.25148	3.9764	3.8634
24	211.76	0.00472	0.00119	843.03	0.25119	3.9811	3.8861
25	264.70	0.00378	0.00095	1054.8	0.25095	3.9849	3.9052
26	330.87	0.00302	0.00076	1319.5	0.25076	3.9879	3.9212
27	413.59	0.00242	0.00061	1650.4	0.25061	3.9903	3.9346
28	516.99	0.00193	0.00048	2064.0	0.25048	3.9923	3.9457
29	646.23	0.00155	0.00039	2580.9	0.25039	3.9938	3.9551
30	807.79	0.00124	0.00031	3227.2	0.25031	3.9950	3.9628
31	1009.7	0.00099	0.00025	4035.0	0.25025	3.9960	3.9693
32	1262.2	0.00079	0.00020	5044.7	0.25020	3.9968	3.9746
33	1577.7	0.00063	0.00016	6306.9	0.25016	3.9975	3.9791
34	1972.2	0.00051	0.00013	7884.6	0.25013	3.9980	3.9828
35	2465.2	0.00041	0.00010	9856.8	0.25010	3.9984	3.9858

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$i = 30\%$ Discrete Compounding, Discrete Cash Flows

	SINGLE PAYMENT		UNIFORM SERIES				Arithmetic Gradient Series Factor
	Compound Amount Factor	Present Worth Factor	Sinking Fund Factor	Uniform Series Factor	Capital Recovery Factor	Series Present Worth Factor	
N	(F/P,i,N)	(P/F,i,N)	(A/F,i,N)	(F/A,i,N)	(A/P,i,N)	(P/A,i,N)	(A/G,i,N)
1	1.3000	0.76923	1.0000	1.0000	1.3000	0.76923	0.00000
2	1.6900	0.59172	0.43478	2.3000	0.73478	1.3609	0.43478
3	2.1970	0.45517	0.25063	3.9900	0.55063	1.8161	0.82707
4	2.8561	0.35013	0.16163	6.1870	0.46163	2.1662	1.1783
5	3.7129	0.26933	0.11058	9.0431	0.41058	2.4356	1.4903
6	4.8268	0.20718	0.07839	12.756	0.37839	2.6427	1.7654
7	6.2749	0.15937	0.05687	17.583	0.35687	2.8021	2.0063
8	8.1573	0.12259	0.04192	23.858	0.34192	2.9247	2.2156
9	10.604	0.09430	0.03124	32.015	0.33124	3.0190	2.3963
10	13.786	0.07254	0.02346	42.619	0.32346	3.0915	2.5512
11	17.922	0.05580	0.01773	56.405	0.31773	3.1473	2.6833
12	23.298	0.04292	0.01345	74.327	0.31345	3.1903	2.7952
13	30.288	0.03302	0.01024	97.625	0.31024	3.2233	2.8895
14	39.374	0.02540	0.00782	127.91	0.30782	3.2487	2.9685
15	51.186	0.01954	0.00598	167.29	0.30598	3.2682	3.0344
16	66.542	0.01503	0.00458	218.47	0.30458	3.2832	3.0892
17	86.504	0.01156	0.00351	285.01	0.30351	3.2948	3.1345
18	112.46	0.00889	0.00269	371.52	0.30269	3.3037	3.1718
19	146.19	0.00684	0.00207	483.97	0.30207	3.3105	3.2025
20	190.05	0.00526	0.00159	630.17	0.30159	3.3158	3.2275
21	247.06	0.00405	0.00122	820.22	0.30122	3.3198	3.2480
22	321.18	0.00311	0.00094	1067.3	0.30094	3.3230	3.2646
23	417.54	0.00239	0.00072	1388.5	0.30072	3.3254	3.2781
24	542.80	0.00184	0.00055	1806.0	0.30055	3.3272	3.2890
25	705.64	0.00142	0.00043	2348.8	0.30043	3.3286	3.2979
26	917.33	0.00109	0.00033	3054.4	0.30033	3.3297	3.3050
27	1192.5	0.00084	0.00025	3971.8	0.30025	3.3305	3.3107
28	1550.3	0.00065	0.00019	5164.3	0.30019	3.3312	3.3153
29	2015.4	0.00050	0.00015	6714.6	0.30015	3.3317	3.3189
30	2620.0	0.00038	0.00011	8730.0	0.30011	3.3321	3.3219
31	3406.0	0.00029	0.00009	11 350.0	0.30009	3.3324	3.3242
32	4427.8	0.00023	0.00007	14 756.0	0.30007	3.3326	3.3261
33	5756.1	0.00017	0.00005	19 184.0	0.30005	3.3328	3.3276
34	7483.0	0.00013	0.00004	24 940.0	0.30004	3.3329	3.3288
35	9727.9	0.00010	0.00003	32 423.0	0.30003	3.3330	3.3297

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i = 40% Discrete Compounding, Discrete Cash Flows

	SINGLE PAYMENT		UNIFORM SERIES				Arithmetic Gradient Series Factor
	Compound Amount Factor	Present Worth Factor	Sinking Fund Factor	Uniform Series Factor	Capital Recovery Factor	Series Present Worth Factor	
N	(*F*/*P*,*i*,*N*)	(*P*/*F*,*i*,*N*)	(*A*/*F*,*i*,*N*)	(*F*/*A*,*i*,*N*)	(*A*/*P*,*i*,*N*)	(*P*/*A*,*i*,*N*)	(*A*/*G*,*i*,*N*)
1	1.4000	0.71429	1.0000	1.0000	1.4000	0.71429	0.00000
2	1.9600	0.51020	0.41667	2.4000	0.81667	1.2245	0.41667
3	2.7440	0.36443	0.22936	4.3600	0.62936	1.5889	0.77982
4	3.8416	0.26031	0.14077	7.1040	0.54077	1.8492	1.0923
5	5.3782	0.18593	0.09136	10.946	0.49136	2.0352	1.3580
6	7.5295	0.13281	0.06126	16.324	0.46126	2.1680	1.5811
7	10.541	0.09486	0.04192	23.853	0.44192	2.2628	1.7664
8	14.758	0.06776	0.02907	34.395	0.42907	2.3306	1.9185
9	20.661	0.04840	0.02034	49.153	0.42034	2.3790	2.0422
10	28.925	0.03457	0.01432	69.814	0.41432	2.4136	2.1419
11	40.496	0.02469	0.01013	98.739	0.41013	2.4383	2.2215
12	56.694	0.01764	0.00718	139.23	0.40718	2.4559	2.2845
13	79.371	0.01260	0.00510	195.93	0.40510	2.4685	2.3341
14	111.12	0.00900	0.00363	275.30	0.40363	2.4775	2.3729
15	155.57	0.00643	0.00259	386.42	0.40259	2.4839	2.4030
16	217.80	0.00459	0.00185	541.99	0.40185	2.4885	2.4262
17	304.91	0.00328	0.00132	759.78	0.40132	2.4918	2.4441
18	426.88	0.00234	0.00094	1064.70	0.40094	2.4941	2.4577
19	597.63	0.00167	0.00067	1491.58	0.40067	2.4958	2.4682
20	836.68	0.00120	0.00048	2089.21	0.40048	2.4970	2.4761
21	1171.36	0.00085	0.00034	2925.89	0.40034	2.4979	2.4821
22	1639.90	0.00061	0.00024	4097.24	0.40024	2.4985	2.4866
23	2295.86	0.00044	0.00017	5737.14	0.40017	2.4989	2.4900
24	3214.20	0.00031	0.00012	8033.00	0.40012	2.4992	2.4925
25	4499.88	0.00022	0.00009	11 247.0	0.40009	2.4994	2.4944
26	6299.83	0.00016	0.00006	15 747.0	0.40006	2.4996	2.4959
27	8819.76	0.00011	0.00005	22 047.0	0.40005	2.4997	2.4969
28	12 348.0	0.00008	0.00003	30 867.0	0.40003	2.4998	2.4977
29	17 287.0	0.00006	0.00002	43 214.0	0.40002	2.4999	2.4983
30	24 201.0	0.00004	0.00002	60 501.0	0.40002	2.4999	2.4988
31	33 882.0	0.00003	0.00001	84 703.0	0.40001	2.4999	2.4991
32	47 435.0	0.00002	0.00001	118 585.0	0.40001	2.4999	2.4993
33	66 409.0	0.00002	0.00001	166 019.0	0.40001	2.5000	2.4995
34	92 972.0	0.00001	0.00000	232 428.0	0.40000	2.5000	2.4996
35	130 161.0	0.00001	0.00000	325 400.0	0.40000	2.5000	2.4997

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i = 50% Discrete Compounding, Discrete Cash Flows

	SINGLE PAYMENT		UNIFORM SERIES				Arithmetic Gradient Series Factor
	Compound Amount Factor	Present Worth Factor	Sinking Fund Factor	Uniform Series Factor	Capital Recovery Factor	Series Present Worth Factor	
N	$(F/P,i,N)$	$(P/F,i,N)$	$(A/F,i,N)$	$(F/A,i,N)$	$(A/P,i,N)$	$(P/A,i,N)$	$(A/G,i,N)$
1	1.5000	0.66667	1.0000	1.0000	1.5000	0.66667	0.00000
2	2.2500	0.44444	0.40000	2.5000	0.90000	1.1111	0.40000
3	3.3750	0.29630	0.21053	4.7500	0.71053	1.4074	0.73684
4	5.0625	0.19753	0.12308	8.1250	0.62308	1.6049	1.0154
5	7.5938	0.13169	0.07583	13.1875	0.57583	1.7366	1.2417
6	11.3906	0.08779	0.04812	20.781	0.54812	1.8244	1.4226
7	17.0859	0.05853	0.03108	32.172	0.53108	1.8829	1.5648
8	25.6289	0.03902	0.02030	49.258	0.52030	1.9220	1.6752
9	38.443	0.02601	0.01335	74.887	0.51335	1.9480	1.7596
10	57.665	0.01734	0.00882	113.330	0.50882	1.9653	1.8235
11	86.498	0.01156	0.00585	170.995	0.50585	1.9769	1.8713
12	129.746	0.00771	0.00388	257.493	0.50388	1.9846	1.9068
13	194.620	0.00514	0.00258	387.239	0.50258	1.9897	1.9329
14	291.929	0.00343	0.00172	581.86	0.50172	1.9931	1.9519
15	437.894	0.00228	0.00114	873.79	0.50114	1.9954	1.9657
16	656.841	0.00152	0.00076	1311.68	0.50076	1.9970	1.9756
17	985.261	0.00101	0.00051	1968.52	0.50051	1.9980	1.9827
18	1477.89	0.00068	0.00034	2953.78	0.50034	1.9986	1.9878
19	2216.84	0.00045	0.00023	4431.68	0.50023	1.9991	1.9914
20	3325.26	0.00030	0.00015	6648.51	0.50015	1.9994	1.9940
21	4987.89	0.00020	0.00010	9973.77	0.50010	1.9996	1.9958
22	7481.83	0.00013	0.00007	14 962.0	0.50007	1.9997	1.9971
23	11 223.0	0.00009	0.00004	22 443.0	0.50004	1.9998	1.9980
24	16 834.0	0.00006	0.00003	33 666.0	0.50003	1.9999	1.9986
25	25 251.0	0.00004	0.00002	50 500.0	0.50002	1.9999	1.9990
26	37 877.0	0.00003	0.00001	75 752.0	0.50001	1.9999	1.9993
27	56 815.0	0.00002	0.00001	113 628.0	0.50001	2.0000	1.9995
28	85 223.0	0.00001	0.00001	170 443.0	0.50001	2.0000	1.9997
29	127 834.0	0.00001	0.00000	255 666.0	0.50000	2.0000	1.9998
30	191 751.0	0.00001	0.00000	383 500.0	0.50000	2.0000	1.9998
31	287 627.0	0.00000	0.00000	575 251.0	0.50000	2.0000	1.9999
32	431 440.0	0.00000	0.00000	862 878.0	0.50000	2.0000	1.9999
33	647 160.0	0.00000	0.00000	1 294 318.0	0.50000	2.0000	1.9999
34	970 740.0	0.00000	0.00000	1 941 477.0	0.50000	2.0000	2.0000
35	1 456 110.0	0.00000	0.00000	2 912 217.0	0.50000	2.0000	2.0000

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APPENDIX B

Answers to Selected Problems

Taken from *Engineering Economics: Financial Decision Making for Engineers*, Fifth Edition by Niall M. Fraser and Elizabeth M. Jewkes and *Engineering Economy*, Fifteenth Edition, by William G. Sullivan, Elin M. Wicks, and C. Patrick Koelling.

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CHAPTER 3

3.1	$120
3.3	$5000
3.6 (a)	$1210
3.8	18.75 percent
3.13	8 percent
3.15	$29 719
3.17 (a)	Five years
3.19 (a)	$6728
3.21 (a)	26.6 percent
3.23	5 percent
3.26	$i_{e,\text{continuous}}$ = 8.318 percent
3.27	$i_{e,\text{weekly}}$ = 5.65 percent
3.29	0.5 percent
3.30	$2140
3.34 (a)	105 months
3.36	$665 270
3.38	Brand 2 about $51 less
3.41	Decisional equivalence holds
3.43 (b)	Lost $60 by locking in

CHAPTER 4

4.3	$317.22
4.6	£74 790
4.7	$18 466 per year
4.10	£3.98
4.11	$35 981.09
4.14	$94.13
4.16	$3 086 287
4.17	$257 143
4.20	162.5 MW
4.21	11.7 percent
4.22	5.8 years
4.23	20.3 percent
4.26 (b)	$26.44 per week
4.30	$34 616
4.32	$6678
4.33	$74 514
4.35	No, P = $3 670 261
4.37	$85.9 million
4.38	€122 316
4.40	$211 000
4.41	No more than $504
4.42	Up to $4587
4.46	$8 013 275
4.49	27 months

CHAPTER 5

5.3	A, AB, BC, ABC, BCD
5.7	Second offer, PW = $137 000
5.8	Earthen dam, PW = $396 038
5.11	Hydraulic press, AW = $24 716
5.12	No, AC(car) = $10 126
5.13	$1344
5.19	3.71 years
5.21	BC, CD
5.24 (a)	18.1 percent
5.27	Plastic liner, PW = $1 100 000
5.28	XJ3, PW = –$6565
5.30	About 20 percent
5.32 (a)	T, PW = $96 664
5.34	T, AW = $26 154
5.36 (a)	Only B, AW = $15 746
5.38	Curtains, payback period = 1.67 years
5.41	No, PW = –$16
5.45	Landfill site, AW = $125 351

CHAPTER 6

6.2	Payback period
6.4	IRR or present worth
6.6	Payback period
6.8	Annual worth

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6.10 (a) 9.2 percent

6.12 12.4 percent

6.13 B and D

6.16 E

6.18 (b) 2.46 percent

6.19 (b) 7.58 percent

6.21 New machine

6.22 Approximate ERR > 25 percent

6.27 A and C

6.29 B

6.31 21.7 percent

6.33 3.19 percent

6.35 (c) Clip Job

6.36 Used refrigerator

6.38 (b) 2

6.41 $119

CHAPTER 7

7.1 (b) The approximate after-tax MARR is 7 percent.

7.4 $i^* = 6.226$ percent

7.6 (a) CSF = 0.6552
CTF = 0.6694

7.8 Taxes paid = $14 850

7.12 PW = $1 540 133. ICC should make this investment.

7.14 The after-tax present worth of the chip placer is –$1683.

7.16 $i^* = 10.1087$ percent. Canadian Widgets should not invest.

7.18 $51 929

7.20 $12 962

7.22 PW = $5656. The project should not be done.

7.24 $MARR_{after\text{-}tax} = 6.0$ percent. The purchase should not be made.

7.26 $10 737 for A and $12 080 for B.

7.28 $IRR_{after\text{-}tax} \cong 8.44$ percent; $IRR_{before\text{-}tax} = 18.77$ percent. The backhoe should not be purchased.

7.30 (a) About $132 000

7.32 Alternative 1 AW = $274 113; alternative 2 AW = $204 562. Select alternative 2.

7.34 $P_T = 9974$; $P_A = 7084$; $P_X = 340$. Model T has the highest present worth.

7.36 $IRR_{T\text{-}after\text{-}tax} \cong 20.69$ percent, $IRR_{A\text{-}after\text{-}tax} \cong 15.07$, $IRR_{X\text{-}after\text{-}tax} \cong 11.67$ percent

7.38 $IRR_{T\text{-}after\text{-}tax} = 20.69\%$; $IRR_{A\text{-}T\text{ }after\text{-}tax} = 2.58\%$, $IRR_{X\text{-}T\text{ }after\text{-}tax} = 5.98\%$. Model T should be chosen.

7.40 ERR = a) 4.88 percent

CHAPTER 8

8.2 No

8.4 $10 920

8.6 (c) Six years

8.8 (a) Replace old pump after four years

8.14 Every three years

8.17 Move robot immediately

8.19 Yes

8.20 (a) Yes

8.22 (c) $12 879

8.26 No

8.28 Challenger EAC is $39 452 with an economic life of five years

8.29 Overhaul old cutter and replace after four years

8.31 4.7 years

8.33 Replace immediately

8.34 (b) Defender two years, followed by Challenger 2

8.36 Replace the computer now, and keep the replacement for three years

8.38 (a) A1 = 4 years, B1 = 7 years

8.40 (a) A3 = 12 years, B3 = 4 years

CHAPTER 9

9.1 (a) Current

9.3 (a) $292

9.5 (a) 14.5 percent

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9.7 (b) −2.9 percent

9.9 67 years

9.11 14.3 percent

9.13 $14 683

9.15 11 216 million rubles

9.17 (a) 7.75 percent

9.19 (b) –$125 532

9.20 (b) $243 547

9.26 (a) About 16 percent

9.29 (c) 2.13 percent

9.30 (b) $998 for f = 2 percent

CHAPTER 10

10.3 (a) Break-even analysis for multiple projects

10.5 (a) $4146

10.5 (b) Break-even operating hours = 671

10.7 Break-even interest rate 11.2 percent

10.9 $855

10.13 (c) E(send stock) = 4000

10.15 E(combined rate) = 15.9 percent

10.16 PW(base) = $34 617

10.18 PW(base) = $6 636 000, most sensitive to the first cost

10.20 (a) AW(base) = $176 620, most sensitive to the first cost

10.21 (a) 179 deliveries per month

10.25 $17 535

10.27 Break-even maintenance cost $61.50

10.29 $23 367 000

10.31 €6384

10.33 E(buy ticket) = 150

10.36 E(partnership) = $113 750

10.38 (a) $141 045, outside of the likely values

10.40 (b) 47 375 boards per year

10.41 Lease if tax rate is below 27 percent

10.44 (a) AW(optimistic, public accept) = $925 000

10.44 (b) E(new product) = $107 975

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Glossary

Taken from *Engineering Economics: Financial Decision Making for Engineers*, Fifth Edition, by Niall M. Fraser and Elizabeth M. Jewkes

Taken from *Entrepreneurship: Successfully Launching New Ventures*, Fifth Edition, by Bruce R. Barringer and R. Duane Ireland.

10-K: A report that is similar to the annual report, except that it contains more detailed information about the company's business. *585*

accounts receivable: The money owed to a firm by its customers. *582*

actual dollars: See **current dollars.** *330*

amortization period: The duration over which a loan is repaid. It is used to compute periodic loan payment amounts. *130*

annual worth method: Comparing alternatives by converting all cash flows to a uniform series—i.e., an annuity. *161*

annuity: A series of uniform-sized receipts or disbursements that start at the end of the first period and continue over a number, *N*, of regularly spaced time intervals. *121*

annuity due: An annuity whose first of *N* receipts or disbursements is immediate, at time zero, rather than at the end of the first period. *128*

arithmetic gradient series: A series of receipts or disbursements that start at the end of the first period and then increase by a constant amount from period to period. *121*

arithmetic gradient to annuity conversion factor: Denoted by $(A/G,i,N)$, gives the value of an annuity, A, that is equivalent to an arithmetic gradient series where the constant increase in receipts or disbursements is G per period, the interest rate is i, and the number of periods is N. *134*

assumptions sheet: An explanation in a new firm's business plan of the sources of the numbers for its financial forecast and the assumptions used to generate them.

backward induction: See **rollback procedure.** *385*

balance sheet: A snapshot of a company's assets, liabilities, and owner's equity at a specific point in time. *588*

base year: The year on which real dollars are based. *330*

board of advisors: A panel of experts asked by a firm's management to provide counsel and advice on an ongoing basis. *640*

board of directors: A panel of individuals who are elected by a corporation's shareholders to oversee the management of the firm. *640*

brainstorming: A technique used to quickly generate a large number of ideas and solutions to problems; conducted to generate ideas that might represent product or business opportunities. *515*

break-even analysis: The process of varying a parameter of a problem and determining what parameter value causes the performance measure to reach some threshold or "break-even" value. *369*

break-even point: The point where total revenue received equals total costs associated with the output. *597*

budgets: Itemized forecasts of a company's income, expenses, and capital needs that are also important tools for financial planning and control. *583*

bug report: A popular technique that is used in classrooms to teach brainstorming. *516*

business-level (competitive) strategy: Identifies the ways a business will compete in its chosen line of products or services. *684*

business plan: A document that

proposed business venture, explains why it is an opportunity, and outlines its marketing plan, its operational and financial details, and its managers' skills and abilities. *621*

capacity: The ability to produce, often measured in units of production per time period. *284*

capital cost: The depreciation expense incurred by the difference between what is paid for the assets required for a particular capacity and what the assets could be resold for some time after purchase. *284*

capital cost allowance (CCA): The maximum depreciation expense allowed for tax purposes on all assets belonging to an asset class. *251*

capital cost allowance (CCA) asset class: A categorization of assets for which a specified CCA rate is used to compute CCA. Numerous CCA asset classes exist in the CCA system. *253*

capital cost allowance (CCA) rate: The maximum depreciation rate allowed for assets in a designated asset class within the CCA system. *253*

capital cost allowance (CCA) system: The system established by the Canadian government whereby the amount and timing of depreciation expenses on capital assets is controlled. *253*

capital expense: The expenditure associated with the purchase of a long-term depreciable asset. *239*

capitalized value: The present worth of an infinitely long series of uniform cash flows. *141*

capital recovery factor: Denoted by $(A/P,i,N)$, gives the value, A, of the periodic payments or receipts that is equivalent to a present amount, P, when the interest rate is i and the

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capital recovery formula: A formula that can be used to calculate the savings necessary to justify a capital purchase based on first cost and salvage value. *126, 127*

capital salvage factor (CSF): A factor that summarizes the effect of the loss of future tax savings when an asset is scrapped or sold. *258*

capital tax factor (CTF): A factor that summarizes the effect of the future benefit of tax savings due to the CCA. *257*

cash flow diagram: A chart that summarizes the timing and magnitude of cash flows as they occur over time. The X axis represents time, measured in periods, and the Y axis represents the size and direction of the cash flows. Individual cash flows are indicated by arrows pointing up (positive cash flows, or receipts) or down (negative cash flows, or disbursements). *105*

challenger: A potential replacement for an existing asset. See **defender**. *282*

comparison methods: Methods of evaluating and comparing projects, such as present worth, annual worth, payback, and IRR. *161*

competitor analysis: A detailed evaluation of a firm's direct, indirect, and future competitors. *634*

compound amount factor: Denoted by $(F/P,i,N)$, gives the future amount, F, that is equivalent to a present amount, P, when the interest rate is i and the number of periods is N. *122*

compound interest: The standard method of computing interest where interest accumulated in one interest period is added to the principal amount used to calculate interest in the next period. *97*

compound interest factors: Functions that define the mathematical equivalence of certain common cash flow patterns. *121*

compounding period: The interest period used with the compound interest method of computing interest. *97*

concentration strategy: Focussing the company on one product or product line. *684*

concept statement: A preliminary description of a business that includes descriptions of the product or service being offered, the intended target market, the benefits of the product or service, the product's position in the market, and how the product or service will be sold and distributed. *540*

concept test: A representation of the product or service to prospective users to gauge customer interest, desirability, and purchase intent. *540*

conceptual skills: A person's ability to think in the abstract, to diagnose and analyze different situations, and to see beyond the present situation. *676*

contingency planning: Identifying aspects of a business or its environment that might entail changes in strategy. *688*

constant dollars: See **real dollars**. *330*

constant ratio method of forecasting: A forecasting approach using the percent of sales method in which expense items on a firm's income statement are expected to grow at the same rate as sales. *597*

consumer price index (CPI): The CPI relates the average price of a standard set of goods and services in some base period to the average price of the same set of goods and services in another period. Currently, Statistics Canada uses a base year of 2002 for the CPI. *328*

continuous compounding: Compounding of interest that occurs continuously over time; i.e., as the length of the compounding period tends toward zero. *102*

continuous models: Models that assume that all cash flows and all compounding of cash flows occur

contribution margin: The amount per unit of sale that is left over and is available to "contribute" to covering the firm's fixed costs and producing a profit. *637*

controlling: The process of monitoring a firm's performance to make sure that it is meeting its goals. *669*

corporate culture: The shared experiences, stories, beliefs, norms, and ethical stance that characterize an organization. *689*

corporate-level strategy: Identifies the various businesses that a company will be in and how these businesses will relate to each other. *684*

cost leadership: Becoming the low-cost leader in an industry. *686*

cost of capital: The minimum rate of return required to induce investors to invest in a business. *165*

cost of goods sold: The materials and direct labor needed to produce firm's revenue. *637*

cost of sales: All of the direct costs associated with producing or delivering a product or service, including the material costs and direct labor costs (also cost of goods sold). *587*

creativity: The process of generating a novel or useful idea. *515*

crisis management: An organization's plan for dealing with emergencies that require an immediate response. *688*

current assets: Cash plus items that are readily convertible to cash, such as accounts receivable, inventories, and marketable securities. *588*

current dollars: Monetary units at the time of payment. Also called **actual dollars**. *330*

current interest rate: The stated, or observed, interest rate based on current dollars. If the real interest rate is i' and the inflation rate is f, the current interest rate i is found by: $i = i' + f + i'f$. *334*

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current internal rate of return (IRR_C): The internal rate of return on a project based on current dollar cash flows associated with the project; also the real internal rate of return that has been adjusted upward to include the effect of inflation. *336*

current liabilities: Obligations that are payable within a year, including accounts payable, accrued expenses, and the current portion of long-term debt. *590*

current MARR: The minimum acceptable rate of return for *current dollar* cash flows. It is the real MARR adjusted upward for inflation. *334*

current ratio: A ratio that equals the firm's current assets divided by its current liabilities. *590*

customer advisory boards: A panel of individuals set up by some companies to meet regularly to discuss needs, wants, and problems that may lead to new product, service, or customer service ideas. *518*

day-in-the-life research: A form of anthropological research used by companies to make sure customers are satisfied and to probe for new product ideas by sending researchers to the customers' homes or business. *518*

debt-to-equity ratio: A ratio calculated by dividing the firm's long-term debt by its shareholders' equity. *585*

decisional equivalence: Decisional equivalence is a consequence of indifference on the part of a decision maker among available choices. *106*

decision making: Choosing one alternative from among several options. *676*

decision-making skills: Skills in defining problems and selecting the best courses of action. *676*

decision tree: A graphical representation of the logical structure of a decision problem in terms of a sequence of decisions and chance events. *383*

defender: An existing asset being assessed for possible replacement. See **challenger**. *282*

deflation: The decrease, over time, in average prices. It can also be described as the increase in the purchasing power of money over time. *327*

differentiation strategy: A firm seeks to be unique in its industry along some dimension that is valued by buyers. *686*

discrete models: Models that assume all cash flows and all compounding of cash flows occur at the ends of conventionally defined periods like months or years. *121*

discrete probability distribution function: A **probability distribution function** in which the random variable is discrete. *377*

diversification: Expanding into related or unrelated products or market segments. *685*

economic life: The service life of an asset that minimizes its total cost of use. *286*

effective interest rate: The actual but not usually stated interest rate, found by converting a given interest rate (with an arbitrary compounding period, normally less than a year) to an equivalent interest rate, with a one-year compounding period. *100*

effectiveness: Achieving the organizational goals that have been set. *666*

efficiency: Achieving the greatest level of output with a given amount of input. *585, 666*

entrepreneurial alertness: The ability to notice things without engaging in deliberate search. *512*

environmental analysis: The process of scanning the environment for threats and opportunities. *685*

escalation of commitment: When a manager makes a decision and then remains committed to its implementation in spite of clear evidence that it was a bad decision. *680*

equivalence: A condition that exists when the value of a cost at one time is equivalent to the value of the related benefit at a different time. *106*

equivalent annual cost (EAC): An annuity that is mathematically equivalent to a more complex set of cash flows. *281*

executive summary: A quick overview of the entire business plan that provides a busy reader everything that he or she needs to know about the distinctive nature of the new venture. *631*

expected value: A summary statistic of a random variable that gives its mean or average value. Also known as the **mean**. *379*

expenses: Either real costs associated with performing a corporation's business or a portion of the capital expense for an asset. *259*

external rate of return (ERR): The rate of return on a project where any cash flows that are not invested in the project are assumed to earn interest at a predetermined rate (such as the MARR). *214*

feasibility analysis: A preliminary evaluation of a business idea to determine if it is worth pursuing. *538*

financial feasibility analysis: A preliminary financial assessment of a new venture that considers the total start-up cash needed, financial performance of similar businesses, and the overall financial attractiveness of the proposed venture. *556*

financial management: The process of raising money and managing a company's finances in a way that achieves the highest rate of return. *581*

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financial ratios: Ratios showing the relationships between items on a firm's financial statements that are used to discern whether a firm is meeting its financial objectives and how it stacks up against industry peers. *583*

financial statement: Written reports that quantitatively describe a firm's financial health. *583*

financing activities: Activities that raise cash during a certain period by borrowing money or selling stock, and/or use cash during a certain period by paying dividends, buying back outstanding stock, or buying back outstanding bonds. *592*

first-line managers: Those managers responsible for supervising the work of employees. *672*

fixed assets: Assets used over a longer time frame, such as real estate, buildings, equipment, and furniture. *588*

fixed costs: Costs that remain the same, regardless of actual units of production. *284, 637*

focus group: A gathering of five to ten people who have been selected based on their common characteristics relative to the issue being discussed; conducted to generate ideas that might represent product or business opportunities. *517*

focus strategy: Selecting a market segment and serving the customers in that market niche better than competitors. *686*

forecasts: Estimates of a firm's future income and expenses, based on its past performance, its current circumstances, and its future plans. *583, 594*

full business plan: A document that spells out a company's operations and plans in much more detail than a summary business plan; the format that is usually used to prepare a business plan for an investor. *627*

functional strategies: Identify the basic courses of action that each department in the firm will pursue so that it contributes to the attainment of the business's overall goals. *684*

future worth: See the definition of **interest rate**. *95*

future worth method: Comparing alternatives by taking all cash flows to future worth. *169*

geographic expansion: Expanding operations in new geographic areas or countries. *685*

geometric gradient series: A set of disbursements or receipts that change by a constant *proportion* from one period to the next in a sequence of periods. *121*

geometric gradient to present worth conversion factor: Denoted by $(P/A,g,i,N)$, gives the present worth, P, that is equivalent to a geometric gradient series where the base receipt or disbursement is A, and where the rate of growth is g, the interest rate is i, and the number of periods is N. *135*

growth-adjusted interest rate, i^o: $i^o = (1 + i)/(1 + g)$ so that $1/(1 + i^o) = (1 + i)/(1 + g)$, where i is the interest rate and g is the growth rate. The growth-adjusted interest rate is used in computing the geometric gradient to present worth conversion factor. *137*

historical financial statements: Reflect past performance and are usually prepared on a quarterly and annual basis. *585*

horizontal integration: Acquiring control of competitors in the same or similar markets with the same or similar products. *685*

human relations skills: Skills that enable managers to understand and get along with other people. *675*

idea: A thought, impression, or notion. *498*

idea bank: A physical or digital repository for storing ideas. *520*

income statement: A financial statement that reflects the results of the operations of a firm over a specified period of time; prepared on a monthly, quarterly, or annual basis. *587*

independent projects: Two projects are independent if the expected costs and the expected benefits of each of the projects do not depend on whether the other one is chosen. *162*

industry: A group of firms producing a similar product or service, such as airlines, fitness drinks, or electronic games. *548*

industry/target market feasibility: An assessment of the overall appeal of the industry and target market for the product or service being proposed. *548*

inflation: The increase, over time, in average prices of goods and services. It can also be described as the decrease in the purchasing power of money over time. *327*

inflation rate: The rate of increase in average prices of goods and services over a specified time period, usually a year; also, the rate of decrease in purchasing power of money over a specified time period, usually a year. *328*

installation costs: Costs of acquiring capacity (excluding the purchase cost) that may include disruption of production, training of workers, and perhaps a reorganization of other production. *284*

interest: The compensation for giving up the use of money. *94*

interest period: The base unit of time over which an interest rate is quoted. The interest period is referred to as the compounding period when compound interest is used. *95*

interest rate: If the right to P at the beginning of a time period exchanges for the right to F at the end of the period, where $F = P(1 + i)$, i is the interest rate per time period. In this definition, P is called the *present*

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worth of F, and F is called the *future worth* of P. *95*

intermediate goals: Goals set for a period of one to five years. *681*

internal rate of return (IRR): The interest rate, i^*, such that, when all cash flows associated with a project are discounted at i^*, the present worth of the cash inflows equals the present worth of the cash outflows. *201*

intranet: A privately maintained Internet site that can be accessed only by authorized users. *520*

intuition: An "inner sense" or "hunch" usually based on years of experience and practice in making decisions in similar situations. *679*

inventory: A company's merchandise, raw materials, and products waiting to be sold. *582*

investing activities: Activities that include the purchase, sale, or investment in fixed assets, such as real estate and buildings. *592*

investment reduction: Reducing the company's investment in one or more of its lines of business. *685*

landing page: A single Web page that typically provides direct sales copy, like "click here to buy a Hawaiian vacation." *546*

leading (or directing): Involves the interactions between managers and their subordinates as they both work to meet the firm's objectives. *669*

liquidity: The ability to sell a business or other asset quickly at a price that is close to its market value; also, a company's ability to meet its short-term financial obligations. *582*

long-term goals: Goals set for extended periods of time, typically five years or more into the future. *681*

long-term liabilities: Notes or loans that are repayable beyond one year, including liabilities associated with purchasing real estate, buildings, and equipment. *590*

management: The process of planning, organizing, leading, and controlling an enterprise's financial, physical, human, and information resources to achieve the organization's goals of supplying various products and services. *666*

managers: People who plan, organize, lead, and control the operations of an organization. *665*

market analysis: An analysis that breaks the industry into segments and zeros in on the specific segment (or target market) to which the firm will try to appeal. *634*

market equivalence: The ability to exchange one cash flow for another at zero cost. *106*

market penetration: Boosting sales of present products by more aggressive selling in the firm's current markets. *684*

market segmentation: The process of studying the industry in which a firm intends to compete to determine the different potential target markets in that industry. *634*

marketing strategy: A firm's overall approach for marketing its products and services. *638*

mathematical equivalence: An equivalence of cash flows due to the mathematical relationship between time and money. *106*

mean: See **expected value**. *579*

mentor: Someone who is more experienced than you and is willing to by your counselor, confidant, and go-to person for advice. *519*

middle managers: Those managers responsible for implementing the decisions made by top managers. *672*

milestone: In a business plan context, a noteworthy event in the past or future development of a business. *654*

minimum acceptable rate of return (MARR): An interest rate that must be earned for any project to be accepted. *164*

mission statement: An organization's statement of how it will achieve its purpose in the environment in which it conducts its business. *633, 681*

mutually exclusive projects: Projects are mutually exclusive if, in the process of choosing one, all the other alternatives are excluded. *162*

net cash flow: The difference between cash inflows and outflows for the period. The net cash flow, A_t, is given by $A_t = R_t - D_t$, where R_t is cash inflow in period t, and D_t is cash disbursed in period t. *212*

net sales: Total sales minus allowances for returned goods and discounts. *587*

network entrepreneurs: Entrepreneurs who identified their idea through social contacts. *515*

new-venture team: The group of founders, key employees, and advisors that move a new venture from an idea to a fully functioning firm. *552*

nominal dollars: See **current dollars.** *530*

nominal interest rate: The conventional method of stating the annual interest rate. It is calculated by multiplying the interest rate per compounding period by the number of compounding periods per year. *100*

one year principle: This principle states that if the EAC(capital costs) for the defender are small compared to the EAC(operating costs), and the yearly operating costs are monotonically increasing, the economic life of a defender is one year and its total EAC is the cost of using the defender for one more year. *290*

operating activities: Activities that affect net income (or loss), depreciation, and changes in current assets and current liabilities other than cash and short-term debt. *592*

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operating and maintenance costs: Ongoing costs to operate and maintain an asset over its useful life. Includes costs such as electricity, gasoline, parts, repair, and insurance. *284*

operating expenses: Marketing, administrative costs, and other expenses not directly related to producing a product or service. *588*

operating leverage: An analysis of the firm's fixed costs versus its variable costs. *637*

operational business plan: A blueprint for a company's operations; primarily meant for an internal audience. *627*

operational plans: Plans developed by middle and lower-level managers that set short-term targets for daily, weekly, or monthly performance. *667*

opportunity: A favorable set of circumstances that creates a need for a new product, service, or business. *497*

opportunity decision: Taking new initiatives or doing a current activity more effectively even if no problem exists. *677*

opportunity gap: An entrepreneur recognizes a problem and creates a business to fill it. *497*

opportunity recognition: The process of perceiving the possibility of a profitable new business or a new product or service. *510*

organizational analysis: The process of analyzing a firm's strengths and weaknesses. *682*

organizational chart: A graphic representation of how authority and responsibility are distributed within a company. *641*

organizational feasibility analysis: A study conducted to determine whether a proposed business has sufficient management expertise, organizational competence, and resources to be successful. *552*

organizational politics: The actions that people take as they try to get what they want. *679*

organizing: Mobilizing the resources that are required to complete a particular task. *668*

other assets: Miscellaneous assets including accumulated goodwill. *588*

owner's equity: The equity invested in the business by its owner(s) plus the accumulated earnings retained by the business after paying dividends. *590*

payback period: The period of time it takes for an investment to be recouped when the interest rate is assumed to be zero. *175*

payback period method: A method used for comparing alternatives by comparing the periods of time required for the investments to pay for themselves. *161*

percent-of-sales method: A method for expressing each expense item as a percent of sales. *596*

planning: The process of determining the firm's goals and developing a strategy for achieving them. *666*

position: How the entire company is situated relative to its competitors. *633*

prediction markets: Creating a market where people can buy "shares" in various answers to important questions that need to be answered. *668*

present worth: See **interest rate**. *95*

present worth factor: Denoted by $(P/F,i,N)$, gives the present amount, P, that is equivalent to a future amount, F, when the interest rate is i and the number of periods is N. *125*

present worth method: Comparing alternatives by taking all cash flows to present worth. *161*

price/earnings (P/E) ratio: A simple ratio that measures the price of a company's stock against its earnings. *588*

primary research: Research that is original and is collected firsthand by the entrepreneur by, for example, talking to potential customers and key industry participants. *539*

probability: The limit of a long-run proportion or relative frequency; see Close-Up 12.1 for other views of probability. *376*

probability distribution function: A set of numerical measures (probabilities) associated with outcomes of a random variable. Also known as a **risk profile**. *376*

problem decision: A decision that is necessary when actual results do not conform to those expected. *677*

product development: Developing improved products for current markets. *685*

product prototype: The first physical manifestation of a new product, often in a crude or preliminary form. *647*

product/service feasibility analysis: An assessment of the overall appeal of the product or service being proposed. *540*

pro forma balance sheet: Financial statements that show a projected snapshot of a company's assets, liabilities, and owner's equity at a specific point in time. *602*

pro forma financial statements: Projections for future periods, based on a firm's forecasts, and typically completed for two to three years in the future. *586*

pro forma income statement: A financial statement that shows the projected results of the operations of a firm over a specific period. *601*

pro form (or projected) financial statements: Statements that are at the heart of the financial section of a business plan. *642*

pro forma statement of cash flows: A financial statement that

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shows the projected flow of cash into and out of a company for a specific period. *602*

profit margin: A measure of a firm's return on sales that is computed by dividing net income by average net sales. *588*

profitability: The ability to earn a profit. *582*

progressive tax rate: A taxation rate that increases as the income level increases. *239*

project: 1) An investment opportunity. 2) A temporary activity that is carried out to deliver a specific product or service. *161*

project balance: If a project has a sequence of net cash flows A_0, A_1, A_2, . . ., A_T, and the interest rate is i', there are $T + 1$ project balances, B_0, B_1, . . ., B_T, one at the end of each period t, $t = 0, 1, \ldots, T$. A project balance, B_t, is the cumulative future value of all cash flows up to the end of period t, compounded at the rate i'. *212*

random variable: A random variable is a parameter or variable that can take on a number of possible outcomes. The probability of each outcome is given by its probability distribution. *376*

ratio analysis: Ratios showing the relationships between items on a firm's financial statements that are used to discern whether a firm is meeting its financial objectives and how it stacks up against industry peers. *642*

real dollars: Monetary units of constant purchasing power. *330*

real interest rate: The interest rate, i', is the interest rate that would yield the same number of real dollars in the absence of inflation as the current interest rate yields in the presence of inflation at the rate f. It is given by $i' = (1 + i)/(1 + f) - 1$. *334*

real internal rate of return: The internal rate of return on a project based on real dollar cash flows associated with the project. *336*

real MARR: The minimum acceptable rate of return when cash flows are expressed in real, or constant, dollars. *334*

regression analysis: A statistical technique used to find relationships between variables for the purpose of predicting future values. *596*

related but not mutually exclusive projects: For pairs of projects in this category, the expected costs and benefits of one project depend on whether the other one is chosen. *162*

repeated lives: Used for comparing alternatives with different service lives, based on the assumption that alternatives can be repeated in the future, with the same costs and benefits, as often as necessary. The life of each alternative is repeated until a common total time period is reached for all alternatives. *171*

replacement: An asset may be replaced if there is a cheaper way to get the service the asset provides or if the service provided by the asset is no longer adequate. *283*

retire: To remove an asset from use without replacement. *283*

risk propensity: How much a manager is willing to gamble when making decisions. *680*

rollback procedure: A procedure in decision tree analysis that computes an expected value at each chance node and selects a preferred alternative at each decision node; also known as **backward induction**. *385*

sales forecast: A projection of a firm's sales for a specified period (such as a year); most firms though forecast their sales for two to five years into the future. *595*

secondary research: Data collected previously by someone else for a different purpose. *540*

sensitivity analysis: Methods that assess the sensitivity of an economic measure to uncertainties in estimates in the various parameters of

sensitivity graph: A graph of the changes in a performance measure, holding all other variables fixed. *366*

series present worth factor: Denoted by $(P/A,i,N)$, gives the present amount, P, that is equivalent to an annuity, A, when the interest rate is i and the number of periods is N. *126*

short-term goals: Goals set for the very near future, typically less than one year. *681*

simple interest: A method of computing interest where interest earned during an interest period is not added to the principal amount used to calculate interest in the next period. Simple interest is rarely used, except as a method of calculating approximate interest. *97*

simple investment: A project that consists of one or more cash outflows at the beginning, followed only by one or more cash inflows. *216*

sinking fund: Interest-bearing account into which regular deposits are made in order to accumulate some amount. *125*

sinking fund factor: Denoted by $(A/F,i,N)$, gives the size, A, of a repeated receipt or disbursement that is equivalent to a future amount, F, when the interest rate is i and the number of periods is N. *125*

small business deduction: A tax deduction that reduces the effective tax rate for a small Canadian company to less than 20 percent. *241*

SMART goals: Goals that are specific, measurable, achievable, relevant, and time-framed. *681*

solo entrepreneurs: Entrepreneurs who identified their business idea on their own. *515*

sources and uses of funds statement: A document, usually included in the financial section of a business plan, that lays out specifically how much money a firm needs, where the money will come

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from, and what the money will be used for. *641*

specialist company: A firm that concentrates on manufacturing a limited range of very specialized products. *283*

stability: The strength and vigor of the firm's overall financial posture. *585*

strategic goals: The overall objectives that a business wants to achieve. *682*

strategic management: The process of aligning the organization with its external environment. *680*

strategic plans: Set by top management; reflect decisions about resource allocations, company priorities, and the steps needed to meet strategic goals. *667*

strategy: The broad set of organizational plans for implementing the decisions made for achieving organizational goals. *680*

strategy formulation: Creation of a broad program for defining and meeting an organization's goals. *682*

statement of cash flows: A financial statement summarizing the changes in a firm's cash position for a specified period of time and detailing why the changes occurred. Similar to a month end bank statement, it reveals how much cash is on hand at the end of the month as well as how the cash was acquired and spent during the month. *592*

strong-tie relationships: Relationships characterized by frequent interaction that form between like-minded individuals such as coworkers, friends, and spouses; these relationships tend to reinforce insights and ideas the individuals already have and, therefore, are not likely to introduce new ideas. *513*

study period: A period of time over which alternative projects are compared. *171*

summary business plan: A business plan 10 to 15 pages long that works best for companies very early in their development that are not prepared to write a full plan. *627*

sunk costs: Costs that were incurred in the past and are no longer relevant in replacement decisions. *293*

SWOT analysis: Identification and analysis of organizational strengths and weaknesses and environmental opportunities and threats as part of strategy formulation. *682*

tactical plans: Shorter-range plans concerned with implementing specific aspects of the company's strategic plans. They typically involve upper and middle management. *667*

tagline: A phrase that is used consistently in a company's literature, advertisements, promotions, stationery, and even invoices to develop and to reinforce the position the company has staked out in its market. *635*

target market: The limited group of individuals or businesses that a firm goes after or tries to appeal to at a certain point in time. *548*

tax credits: Real or nominal costs that are not taxed or are taxed at a reduced rate. *259*

technical skills: Skills associated with performing specialized tasks within a company. *674*

time management skills: The productive use that managers make of their time. *676*

top managers: Those managers responsible for a firm's overall performance and effectiveness and for developing long-range plans for the company. *671*

undepreciated capital cost (UCC): The remaining book value of assets subject to depreciation for taxation purposes. For any given year, the UCC balance can be calculated as follows: $UCC_{opening}$ + additions − disposals − CCA = UCC_{ending}. *254*

uniform series compound amount factor: Denoted by $(F/A,i,N)$, gives the future value, F, that is equivalent to a series of equal-sized receipts or disbursements, A, when the interest rate is i and the number of periods is N. *126*

variable costs: Costs that change depending on the number of units produced. *285, 637*

vertical integration: Owning or controlling the inputs to the firm's processes and/or the channels through which the products or services are distributed. *685*

virtual prototype: A computer generated 3-D image of an idea. *659*

weak-tie relationships: Relationships characterized by infrequent interaction that form between casual acquaintances who do not have a lot in common and, therefore, may be the source of completely new ideas. *513*

window of opportunity: The time period in which a firm or an entrepreneur can realistically enter a new market. *497*

Work breakdown structure (WBS): A hierarchical description of a project into more and more detailed components. *55*

working capital: A firm's current assets minus its current liabilities. *590*

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List of Formulas

After-tax IRR:

$$\text{IRR}_{\text{after-tax}} \cong \text{IRR}_{\text{before-tax}} \times (1 - t)$$

After-tax MARR:

$$\text{MARR}_{\text{after-tax}} \doteq \text{MARR}_{\text{before-tax}} \times (1 - t)$$

Benefit–Cost Ratio:

$$\text{BCR} = \frac{\text{PW(benefits)}}{\text{PW(costs)}}$$

Book Value, Declining-Balance:

$$BV_{db}(n) = P(1 - d)^n$$

Book Value, Straight-Line:

$$BV_{sl}(n) = P - n\left(\frac{P - S}{N}\right)$$

Capital Tax Factor:

$$\text{CTF} = 1 - \frac{td(1 + i/2)}{(i + d)(1 + i)}$$

Capital Salvage Factor:

$$\text{CSF} = 1 - \frac{td}{(i + d)}$$

Capitalized Value:

$$P = \frac{A}{i}$$

Capital Recovery Formula:

$$A = (P - S)(A/P,i,N) + Si$$

Compound Interest:

$$F = P(1 + i)^N$$

Compound Interest Factors:

- **Compound Amount Factor**

$$(F/P,i,N) = (1 + i)^N$$

- **Present Worth Factor**

$$(P/F,i,N) = \frac{1}{(1 + i)^N}$$

- **Sinking Fund Factor**

$$(A/F,i,N) = \frac{i}{(1 + i)^N - 1}$$

- **Uniform Series Compound Amount Factor**

$$(F/A,i,N) = \frac{(1 + i)^N - 1}{i}$$

- **Capital Recovery Factor**

$$(A/P,i,N) = \frac{i(1 + i)^N}{(1 + i)^N - 1}$$

- **Series Present Worth Factor**

$$(P/A,i,N) = \frac{(1 + i)^N - 1}{i(1 + i)^N}$$

- **Arithmetic Gradient to Annuity Conversion Factor**

$$(A/G,i,N) = \frac{1}{i} - \frac{N}{(1 + i)^N - 1}$$

- **Geometric Gradient Series to Present Worth Conversion Factor**

$$(P/A,g,i,N) = \frac{(P/A,i^\circ,N)}{1 + g}$$

$$(P/A,g,i,N) = \left(\frac{(1 + i^\circ)^N - 1}{i^\circ(1 + i^\circ)^N}\right)\frac{1}{1 + g}$$

$$i^\circ = \frac{1 + i}{1 + g} - 1$$

Depreciation Amount, Straight Line:

$$D_{sl}(n) = \frac{P - S}{N}$$

Depreciation Amount, Declining Balance:

$$D_{db}(n) = BV_{db}(n - 1) \times d$$

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Depreciation Rate:

$$d = 1 - \sqrt[n]{\frac{S}{P}}$$

Effective Interest Rate:

$$i_e = \left(1 + \frac{r}{m}\right)^m - 1 \text{ or}$$

$$i_e = (1 + i_s)^m - 1$$

Effective Interest Rate for Continuous Compounding:

$$i_e = e^r - 1$$

Expected Value of the Discrete Random Variable:

$$\mathrm{E}(X) = \sum x_i\, p(x_i)$$

Financial Ratios:

- **Acid test ratio** $= \dfrac{\text{Quick assets}}{\text{Current liabilities}}$
- **Current ratio** $= \dfrac{\text{Current assets}}{\text{Current liabilities}}$
- **Equity ratio** $= \dfrac{\text{Total equity}}{\text{Total assets}}$
- **Inventory turnover** $= \dfrac{\text{Sales}}{\text{Inventories}}$
- **Return on total assets** $= \dfrac{\text{Profits after taxes}}{\text{Total assets}}$

Growth-Adjusted Interest Rate:

$$i^\circ = \frac{1 + i}{1 + g} - 1$$

Internal Rate of Return:

$$\sum_{t=0}^{T} \frac{(R_t - D_t)}{(1 + i^*)^t} = 0 \text{ or}$$

$$\sum_{t=0}^{T} \frac{R_t}{(1 + i^*)^t} = \sum_{t=0}^{T} \frac{D_t}{(1 + i^*)^t}$$

Linear Interpolation:

$$x^* = x_1 + (x_2 - x_1)\left[\frac{y^* - y_1}{y_2 - y_1}\right]$$

Modified Benefit–Cost Ratio:

$$\text{BCRM} = \frac{\text{PW(benefits)} - \text{PW(operating costs)}}{\text{PW(capital costs)}}$$

Payback Period:

$$\text{Payback period} = \frac{\text{First cost}}{\text{Annual savings}}$$

Real Dollars:

$$R_{0,N} = \frac{A_N}{I_{0,N}/100}$$

$$R_N = \frac{A_N}{(1 + f)^N}$$

$$R_N = A_N\,(P/F,f,N)$$

Real MARR:

$$\text{MARR}_R = \frac{1 + \text{MARR}_C}{1 + f} - 1$$

Real Interest Rate:

$$i' = \frac{1 + i}{1 + f} - 1$$

Real IRR:

$$\text{IRR}_R = \frac{1 + \text{IRR}_C}{1 + f} - 1$$

Simple Interest Amount:

$$I_s = PiN$$

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