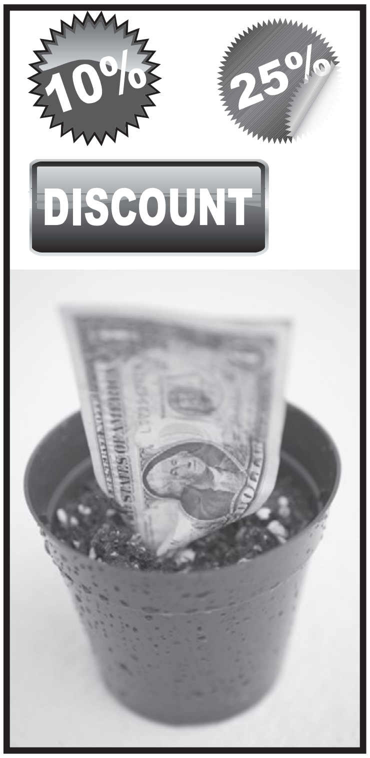
4

Chapter

Present Worth Analysis



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A future amount of money converted to its equivalent value now has a present worth (PW) that is less than that of the actual cash flow, because for any interest rate greater than zero, all P/F factors have a value less than 1.0. For this reason, present worth values are often referred to as *discounted cash flows* (*DCF*). Similarly, the interest rate may be referred to as the *discount rate*. Besides PW, equivalent terms frequently used are present value (PV) and net present value (NPV). Up to this point, present worth computations have been made for one project. In this chapter, techniques for comparing two or more mutually exclusive alternatives by the present worth method are treated. Additionally, techniques that evaluate capitalized costs, life cycle costs, and independent projects are discussed.

Purpose: Compare alternatives on a present worth basis.

LEARNING OUTCOMES

Formulating alternatives	1. Identify mutually exclusive and independent projects, and define a revenue and a cost alternative.
PW of equal-life alternatives	2. Evaluate a single alternative and select the best of equal-life alternatives using present worth analysis.
PW of different-life alternatives	3. Select the best of different-life alternatives using present worth analysis.
Capitalized cost (CC)	4. Select the best alternative using capitalized cost calculations.
Independent projects	5. Select the best independent projects with and without a budget limit.
Spreadsheets	6. Use a spreadsheet to select an alternative by PW analysis.

4.1 FORMULATING ALTERNATIVES

Alternatives are developed from project proposals to accomplish a stated purpose. The logic of alternative formulation and evaluation is depicted in Figure 4.1. Some projects are economically and technologically viable, and others are not. Once the viable projects are defined, it is possible to formulate the alternatives.

Alternatives are one of two types: mutually exclusive or independent. Each type is evaluated differently.

- **Mutually exclusive (ME).** *Only one of the viable projects can be selected.* Each viable project *is* an alternative. If no alternative is economically justifiable, do nothing (DN) is the default selection.
- **Independent.** *More than one viable project may be selected* for investment. (There may be dependent projects requiring a particular project to be selected before another, and/or contingent projects where one project may be substituted for another.)

An alternative or project is comprised of estimates for the first cost, expected life, salvage value, and annual costs. Salvage value is the best estimate of an anticipated future market or trade-in value at the end of the expected life. Salvage may be estimated as a percentage of the first cost or an actual monetary amount; salvage is often estimated as nil or zero. Annual costs are commonly termed annual operating costs (AOC) or maintenance and operating (M&O) costs. They may be uniform over the entire life, increase or decrease each year as a percentage or arithmetic gradient series, or vary over time according to some other expected pattern.

A mutually exclusive alternative selection is the most common type in engineering practice. It takes place, for example, when an engineer must select the one best diesel-powered engine from several competing models. Mutually exclusive alternatives are, therefore, the same as the viable projects; each one is evaluated, and the one best alternative is chosen. Mutually exclusive alternatives *compete with one another* in the evaluation. All the analysis techniques compare mutually exclusive alternatives. Present worth is discussed in the remainder of this chapter.

The *do-nothing (DN)* option is usually understood to be an alternative when the evaluation is performed. If it is absolutely required that one of the defined alternatives be selected, do nothing is not considered an option. (This may occur when a mandated function must be installed for safety, legal, or other purposes.) Selection of the DN alternative means that the current approach is maintained; no new costs, revenues, or savings are generated.

Independent projects are usually designed to accomplish different purposes, thus the possibility of selecting any number of the projects. These projects (or bundles of projects) do not compete with one another; each project is evaluated separately, and the *comparison is* with the MARR. Independent project selection is treated in Section 4.5.

Finally, it is important to classify an *alternative's* cash flows as revenue-based or cost-based. All alternatives evaluated in one study must be of the same type.

- **Revenue.** *Each alternative generates cost and revenue cash flow estimates, and possibly savings,* which are treated like revenues. Revenues may be different

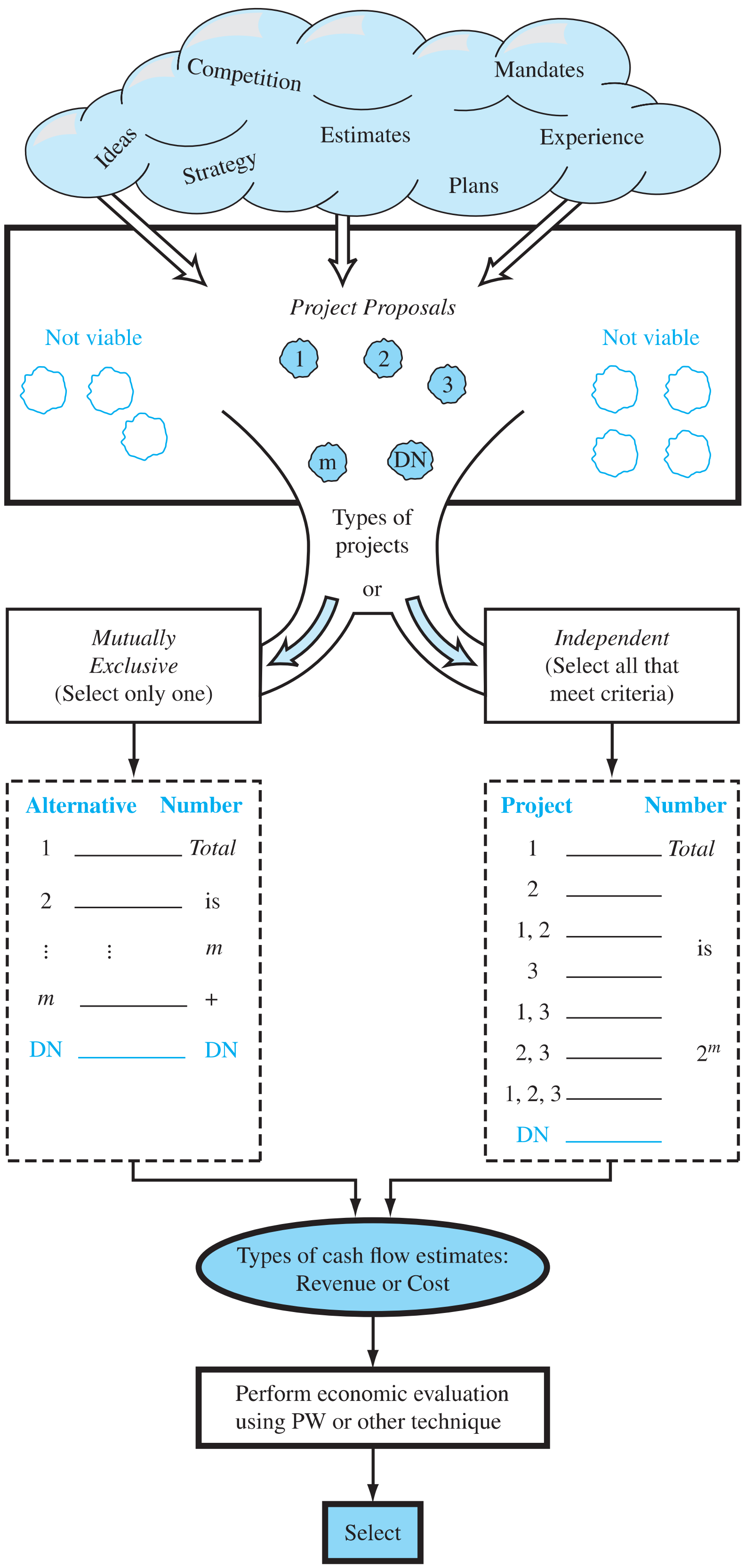

FIGURE 4.1 Logical progression from proposals to alternatives to selection.

for each alternative. These alternatives usually involve new systems, products, and services that require capital investment to generate revenues and/or savings. Purchasing new equipment to increase productivity and sales is a revenue alternative.

- **Cost.** *Each alternative has only cost cash flow estimates.* Revenues are assumed to be equal for all alternatives. These may be public sector (government) initiatives, or legally mandated or safety improvements. Cost alternatives are compared to each other; do-nothing is not an option when selecting from mutually exclusive cost alternatives.

4.2 PRESENT WORTH ANALYSIS OF EQUAL-LIFE ALTERNATIVES

4.2.1 Mutually Exclusive Alternatives

In present worth analysis, the *P* value, now called *PW*, is calculated at the MARR for each alternative. This converts all future cash flows into present dollar equivalents. This makes it easy to determine the economic advantage of one alternative over another.

The PW comparison of alternatives with equal lives is straightforward. If both alternatives are used in identical capacities for the same time period, they are termed *equal-service* alternatives.

For mutually exclusive alternatives the following guidelines are applied:

One alternative: Calculate PW at the MARR. If PW ≥ 0, the alternative is financially viable.

Two or more alternatives: Calculate the PW of each alternative at the MARR. *Select the alternative with the PW value that is numerically largest,* that is, less negative or more positive.

The second guideline uses the criterion of *numerically largest* to indicate a lower PW of costs only or larger PW of net cash flows. Numerically largest is *not the absolute value* because the sign matters here. The selections below correctly apply this guideline.

PW_1	PW_2	Selected Alternative
\$−1500	\$−500	2
−500	+1000	2
+2500	−500	1
+2500	+1500	1

EXAMPLE 4.1 Perform a present worth analysis of equal-service machines that have the costs shown on the next page, if the MARR is 10% per year. Revenues for all three alternatives are expected to be the same.

	Electric-Powered	Gas-Powered	Solar-Powered
First cost, $	−2500	−3500	−6000
Annual operating cost (AOC), $/year	−900	−700	−50
Salvage value, $	200	350	100
Life, years	5	5	5

Solution

These are cost alternatives. The salvage values are considered a "negative" cost, so a + sign precedes them. The PW of each machine is calculated at $i = 10\%$ for $n = 5$ years. Use subscripts E, G, and S.

$$\mathrm{PW}_E = -2500 - 900(P/A,10\%,5) + 200(P/F,10\%,5) = \$-5788$$
$$\mathrm{PW}_G = -3500 - 700(P/A,10\%,5) + 350(P/F,10\%,5) = \$-5936$$
$$\mathrm{PW}_S = -6000 - 50(P/A,10\%,5) + 100(P/F,10\%,5) = \$-6127$$

The electric-powered machine is selected since the PW of its costs is the lowest; it has the numerically largest PW value.

4.2.2 Evaluation of a Bond Purchase

Often a corporation or government obtains investment capital for projects by selling *bonds.* A good application of the PW method is the evaluation of a bond purchase alternative. If PW < 0 at the MARR, the do-nothing alternative is selected. A bond is like an IOU for time periods such as 5, 10, 20, or more years. Each bond has a *face value V* of $100, $1000, $5000 or more that is fully returned to the purchaser when the bond maturity is reached. Additionally, bonds provide the purchaser with periodic *interest payments I* (also called bond dividends) using the *bond coupon* (or interest) *rate b*, and *c*, the number of payment periods per year.

$$I = \frac{(\text{bond face value})(\text{bond coupon rate})}{\text{number of payments per year}} = \frac{Vb}{c} \qquad [4.1]$$

At the time of purchase, the bond may sell for more or less than the face value, depending upon the financial reputation of the issuer. A purchase discount is more attractive financially to the purchaser; a premium is better for the issuer. For example, suppose a person is offered a 2% discount for an 8% $10,000 20-year bond that pays the dividend quarterly. He will pay $9800 now, and, according to Equation [4.1], he will receive quarterly dividends of $I = \$200$, plus the $10,000 face value after 20 years.

To evaluate a proposed bond purchase, determine the PW at the MARR of all cash flows—initial payment and receipts of periodic dividends and the bond's face value at the maturity date. Then apply the guideline for one alternative, that is, if PW ≥ 0, the bond is financially viable. It is important to use the effective MARR rate in the PW relation that matches the time period of the payments. The simplest method is the procedure in Section 3.4 for PP = CP, as illustrated in the next example.

EXAMPLE 4.2 Marcie has some extra money that she wants to place into a relatively safe investment. Her employer is offering to employees a generous 5% discount for 10-year \$5,000 bonds that carry a coupon rate of 6% paid semiannually. The expectation is to match her return on other safe investments, which have averaged 6.7% per year compounded semiannually. (This is an effective rate of 6.81% per year.) Should she buy the bond?

Solution

Equation [4.1] results in a dividend of $I = (5000)(0.06)/2 = \$150$ every 6 months for a total of $n = 20$ dividend payments. The semiannual MARR is $6.7/2 = 3.35\%$, and the purchase price now is $-5000(0.95) = \$-4750$. Using PW evaluation,

$$\begin{aligned} \text{PW} &= -4750 + 150(P/A,3.35\%,20) + 5000(P/F,3.35\%,20) \\ &= \$-2.13 \end{aligned}$$

To be correct, she should not buy the bond, because the effective rate is slightly less than 6.81% per year since PW < 0. However, if Marcie had to pay just \$2.13 less for the bond, she would meet her MARR goal. She should probably purchase the bond since the return is so close to her goal.

In order to speed up a PW analysis with a spreadsheet, the PV function is utilized. If all annual amounts for AOC are the same, the PW value for year 1 to n cash flows is found by entering the function $= P - \text{PV}(i\%, n, A, F)$. In Example 4.1, $\text{PW}_\text{E} = \$-5788$ is determined by entering = −2500 − PV(10%,5,−900,200) into any cell. Spreadsheet solutions are demonstrated in detail in Section 4.6.

4.3 PRESENT WORTH ANALYSIS OF DIFFERENT-LIFE ALTERNATIVES

Present worth analysis requires an *equal service* comparison of alternatives, that is, the number of years considered must be the same for all alternatives. *If equal service is not present, shorter-lived alternatives will be favored based on lower PW of total costs,* even though they may not be economically favorable. Fundamentally, there are two ways to use PW analysis to compare alternatives with unequal life estimates; evaluate over a specific study period (planning horizon), or use the least common multiple of lives for each pair of alternatives. In both cases, the PW is calculated at the MARR, and the selection guidelines of the previous section are applied.

4.3.1 Study Period

This is a commonly used approach. Once a study period is selected, only cash flows during this time frame are considered. If an expected life is *longer* than this period, the estimated market value of the alternative is used as a "salvage value" in the last year of the study period. If the expected life is *shorter* than the study period, cash flow estimates to continue equivalent service must be made for the time period between the end of the alternative's life and the end of the study period.

In both cases, the result is an equal-service evaluation of the alternatives. As one example, assume a construction company wins a highway maintenance contract for 5 years, but plans to purchase specialized equipment expected to be operational for 10 years. For analysis purposes, the anticipated market value after 5 years is a salvage value in the PW equation, and any cash flows after year 5 are ignored. Example 4.3 illustrates a study period analysis.

4.3.2 Least Common Multiple (LCM)

The LCM approach can result in unrealistic assumptions since equal service comparison is achieved by assuming:

- The same service is needed for the LCM number of years. For example, the LCM of 5- and 9-year lives presumes the same need for 45 years!
- Cash flow estimates are initially expected to remain the same over each life cycle, which is correct *only* when changes in future cash flows exactly match the inflation or deflation rate.
- Each alternative is available for multiple life cycles, something that is usually not true.

EXAMPLE 4.3

A project engineer with EnvironCare is assigned to start up a new office in a city where a 6-year contract has been finalized to collect and analyze ozone-level readings. Two lease options are available, each with a first cost, annual lease cost, and deposit-return estimates shown below. The MARR is 15% per year.

	Location A	Location B
First cost, $	−15,000	−18,000
Annual lease cost, $ per year	−3,500	−3,100
Deposit return, $	1,000	2,000
Lease term, years	6	9

a. EnvironCare has a practice of evaluating all projects over a 5-year period. If the deposit returns are not expected to change, which location should be selected?
b. Perform the analysis using an 8-year planning horizon.
c. Determine which lease option should be selected on the basis of a present worth comparison using the LCM.

Solution

a. For a 5-year study period, use the estimated deposit returns as positive cash flows in year 5.

$$\begin{aligned} PW_A &= -15{,}000 - 3500(P/A,15\%,5) + 1000(P/F,15\%,5) \\ &= \$-26{,}236 \\ PW_B &= -18{,}000 - 3100(P/A,15\%,5) + 2000(P/F,15\%,5) \\ &= \$-27{,}397 \end{aligned}$$

Location A is the better economic choice.

b. For an 8-year study period, the deposit return for B remains at $2000 in year 8. For A, an estimate for equivalent service for the additional 2 years is needed. Assume this is expected to be relatively expensive at $6000 per year.

$$\begin{aligned}PW_A &= -15{,}000 - 3500(P/A,15\%,6) + 1000(P/F,15\%,6)\\ &\quad - 6000(P/A,15\%,2)(P/F,15\%,6)\\ &= \$-32{,}030\\ PW_B &= -18{,}000 - 3100(P/A,15\%,8) + 2000(P/F,15\%,8)\\ &= \$-31{,}257\end{aligned}$$

Location B has an economic advantage for this longer study period.

c. Since the leases have different terms, compare them over the LCM of 18 years. For life cycles after the first, the first cost is repeated at the beginning (year 0) of each new cycle, which is the last year of the previous cycle. These are years 6 and 12 for location A and year 9 for B. The cash flow diagram is in Figure 4.2.

$$\begin{aligned}PW_A &= -15{,}000 - 15{,}000(P/F,15\%,6) + 1000(P/F,15\%,6)\\ &\quad - 15{,}000(P/F,15\%,12) + 1000(P/F,15\%,12)\\ &\quad + 1000(P/F,15\%,18) - 3500(P/A,15\%,18)\\ &= \$-45{,}036\\ PW_B &= -18{,}000 - 18{,}000(P/F,15\%,9) + 2000(P/F,15\%,9)\\ &\quad + 2000(P/F,15\%,18) - 3100(P/A,15\%,18)\\ &= \$-41{,}384\end{aligned}$$

Location B is selected.

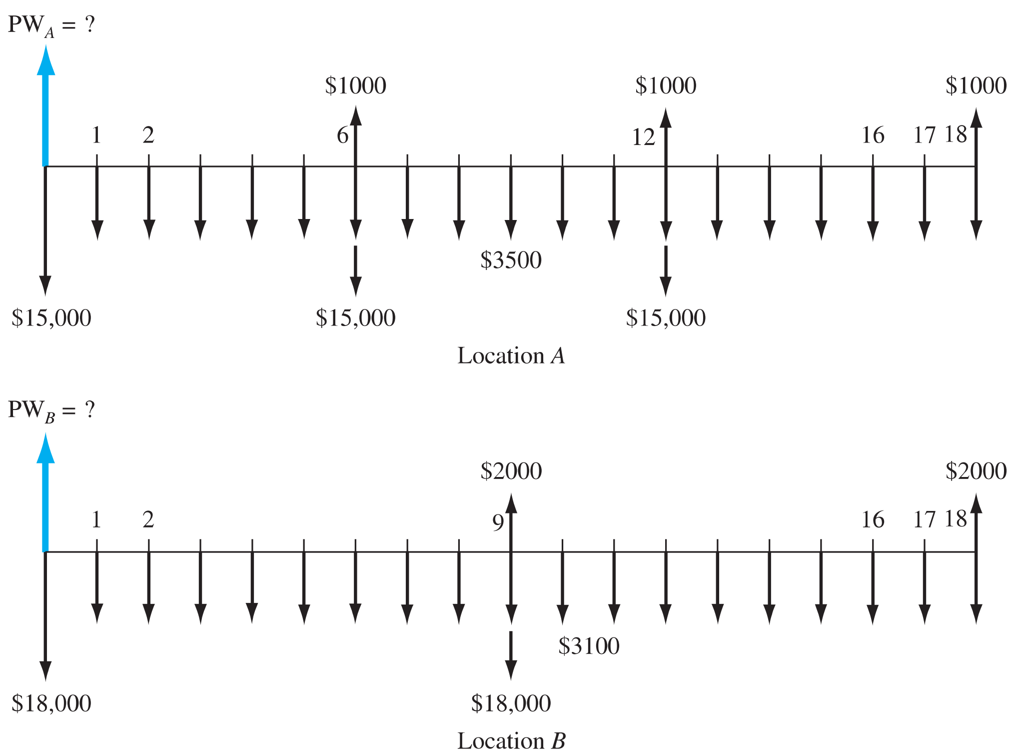

FIGURE 4.2
Cash flow diagram for different-life alternatives, Example 4.3c.

Present worth analysis illustrated in Example 4.3 using the LCM method is correct, but it is not recommended as the primary method of analysis. The same correct conclusion is easier to reach using each alternative's life and an annual worth (AW) analysis, as discussed in Chapter 5.

4.3.3 Future Worth

The future worth (FW) of an alternative may also be used to select an alternative. The FW is determined directly from the cash flows or by multiplying the PW value by the F/P factor at the established MARR. The n value in the F/P factor depends upon which time period has been used to determine PW—the LCM or a study period. Using FW values is especially applicable to large capital investment decisions when a prime goal is to maximize the *future wealth* of a corporation's stockholders. Alternatives such as electric generation facilities, toll roads, hotels, and the like can be analyzed using the FW value of investment commitments made during construction. Selection guidelines are the same as those for PW analysis.

4.3.4 Life-Cycle Cost

Life-cycle cost (LCC) is another extension of present worth analysis. The LCC method, as its name implies, is commonly applied to alternatives with cost estimates over the entire *system life span.* This means that costs from the early stage of the project (needs assessment and design), through marketing, warranty, and operation phases and through the final stage (phaseout and disposal) are estimated. Typical applications for LCC are buildings (new construction or purchases), new product lines, manufacturing plants, commercial aircraft, new automobile models, defense systems, and the like.

A PW analysis with all definable costs (and possibly incomes) estimatable are considered in a LCC analysis. However, the broad definition of the term *system life span* requires cost estimates not usually made for a regular PW analysis, such as design and development costs. *LCC is most effectively applied when a substantial percentage of the total costs over the system life span, relative to the initial investment, will be operating and maintenance costs* (postpurchase costs such as warranty, personnel, energy, upkeep, and materials). If Exxon-Mobil is evaluating the purchase of equipment for a large chemical processing plant for \$150,000 with a 5-year life and annual costs of \$15,000, LCC analysis is probably not justified. On the other hand, suppose Toyota is considering the design, construction, marketing, and after-delivery costs for a new automobile model. If the total start-up cost is estimated at \$125 million (over 3 years) and total annual costs are expected to be 25 to 30% of this figure to build, market, and service the cars for the next 15 years (estimated life span of the model), then the logic of LCC analysis will help the decision makers understand the profile of costs and their economic consequences using PW, FW, or AW analysis. LCC is required for most defense and aerospace industries, where the approach may be called Design to Cost (see Section 11.1). LCC is usually not applied to public sector projects, because the benefits and costs are difficult to estimate with much accuracy. Benefit/cost analysis is better applied here, as discussed in Chapter 7.

4.4 CAPITALIZED COST ANALYSIS

Capitalized cost (CC) is the present worth of an alternative that will last "forever." Public sector projects such as bridges, dams, irrigation systems, and railroads fall into this category, since they have useful lives of 30, 40, and more years. In addition, permanent and charitable organization endowments are evaluated using capitalized cost.

The formula to calculate CC is derived from the relation $PW = A(P/A,i,n)$, where $n = \infty$. The equation can be written

$$PW = A\left[\frac{1 - \dfrac{1}{(1+i)^n}}{i}\right]$$

As n approaches ∞, the bracketed term becomes $1/i$. The symbol CC replaces PW, and AW (annual worth) replaces A to yield

$$\mathbf{CC} = \frac{A}{i} = \frac{\mathbf{AW}}{i} \qquad [4.2]$$

Equation [4.2] is illustrated by considering the time value of money. If \$10,000 earns 10% per year, the interest earned at the end of every year for *eternity* is \$1000. This leaves the original \$10,000 intact to earn more next year. In general, the equivalent A value from Equation [4.2] for an infinite number of periods is

$$A = \mathbf{CC}(i) \qquad [4.3]$$

The cash flows (costs or receipts) in a capitalized cost calculation are usually of two types: *recurring,* also called periodic, and *nonrecurring,* also called one-time. An annual operating cost of \$50,000 and a rework cost estimated at \$40,000 every 12 years are examples of recurring cash flows. Examples of nonrecurring cash flows are the initial investment amount in year 0 and one-time cash flow estimates, for example, \$500,000 in royalty fees 2 years hence. The following procedure assists in calculating the CC for an infinite sequence of cash flows.

1. Draw a cash flow diagram showing all nonrecurring and at least two cycles of all recurring cash flows. (Drawing the cash flow diagram is more important in CC calculations than elsewhere.)
2. Find the present worth of all nonrecurring amounts. This is their CC value.
3. Find the equivalent uniform annual worth (A value) through *one life cycle* of all recurring amounts. This is the same value in all succeeding life cycles. Add this to all other uniform amounts occurring in years 1 through infinity and the result is the total equivalent uniform annual worth (AW).
4. Divide the AW obtained in step 3 by the interest rate i to obtain a CC value. This is an application of Equation [4.2].
5. Add the CC values obtained in steps 2 and 4.

EXAMPLE 4.4 The property appraisal district for Marin County has just installed new software to track residential market values for property tax computations. The manager wants to know the total equivalent cost of all future costs incurred when the three county judges agreed to purchase the software system. If the new system will be used for the indefinite future, find the equivalent value (*a*) now and (*b*) for each year hereafter.

The system has an installed cost of \$150,000 and an additional cost of \$50,000 after 10 years. The annual software maintenance contract cost is \$5000 for the first 4 years and \$8000 thereafter. In addition, there is expected to be a recurring major upgrade cost of \$15,000 every 13 years. Assume that $i = 5\%$ per year for county funds.

Solution

a. The detailed procedure is applied.

1. Draw a cash flow diagram for two cycles (Figure 4.3).
2. Find the present worth of the nonrecurring costs of \$150,000 now and \$50,000 in year 10 at $i = 5\%$. Label this CC_1.

$$CC_1 = -150{,}000 - 50{,}000(P/F,5\%,10) = \$-180{,}695$$

3. Convert the recurring cost of \$15,000 every 13 years into an annual worth A_1 for the first 13 years.

$$A_1 = -15{,}000(A/F,5\%,13) = \$-847$$

The same value, $A_1 = \$-847$, applies to all the other 13-year periods as well.

4. The capitalized cost for the two annual maintenance cost series may be determined in either of two ways: (1) consider a series of \$−5000 from now to infinity plus a series of \$−3000 from year 5 on; or (2) a series of \$−5000 for 4 years followed by a series of \$−8000 from year 5 to infinity. Using the first method, the annual cost (A_2) is \$−5000 forever.

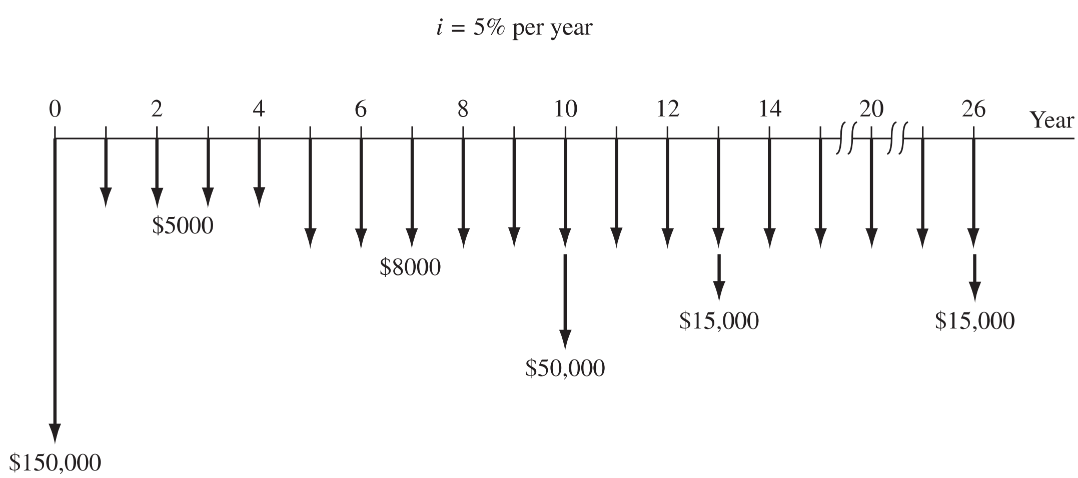

FIGURE 4.3 Cash flows for two cycles of recurring costs and all nonrecurring amounts, Example 4.4.

The capitalized cost CC_2 of \$$-3000$ from year 5 to infinity is found using Equation [4.2] times the P/F factor.

$$CC_2 = \frac{-3000}{0.05}(P/F,5\%,4) = \$-49{,}362$$

The CC_2 value is calculated using $n = 4$ because the present worth of the annual \$3000 cost is located in year 4, one period ahead of the first A. The two annual cost series are converted into a capitalized cost CC_3.

$$CC_3 = \frac{A_1 + A_2}{i} = \frac{-847 + (-5000)}{0.05} = \$-116{,}940$$

5. The total capitalized cost CC_T is obtained by adding the three CC values.

$$CC_T = -180{,}695 - 49{,}362 - 116{,}940 = \$-346{,}997$$

b. Equation [4.3] determines the A value forever.

$$A = CC_T(i) = \$-346{,}997(0.05) = \$-17{,}350$$

Correctly interpreted, this means Marin County officials have committed the equivalent of \$17,350 forever to operate and maintain the property appraisal software.

The CC evaluation of two or more alternatives compares them for the same number of years—infinity. The alternative with the smaller capitalized cost is the more economical one.

EXAMPLE 4.5 Two sites are currently under consideration for a bridge over a small river. The north site requires a suspension bridge. The south site has a much shorter span, allowing for a truss bridge, but it would require new road construction.

The suspension bridge will cost \$500 million with annual inspection and maintenance costs of \$350,000. In addition, the concrete deck would have to be resurfaced every 10 years at a cost of \$1,000,000. The truss bridge and approach roads are expected to cost \$250 million and have annual maintenance costs of \$200,000. This bridge would have to be painted every 3 years at a cost of \$400,000. In addition, the bridge would have to be sandblasted every 10 years at a cost of \$1,900,000. The cost of purchasing right-of-way is expected to be \$20 million for the suspension bridge and \$150 million for the truss bridge. Compare the alternatives on the basis of their capitalized cost if the interest rate is 6% per year.

Solution

Construct the cash flow diagrams over two cycles (20 years).

Capitalized cost of suspension bridge (CC_S):

$$\begin{aligned} CC_1 &= \text{capitalized cost of initial cost} \\ &= -500 - 20 = \$-520 \text{ million} \end{aligned}$$

The recurring operating cost is $A_1 = \$-350{,}000$, and the annual equivalent of the resurface cost is

$$A_2 = -1{,}000{,}000(A/F, 6\%, 10) = \$-75{,}870$$

$$CC_2 = \text{capitalized cost of recurring costs} = \frac{A_1 + A_2}{i}$$

$$= \frac{-350{,}000 + (-75{,}870)}{0.06} = \$-7{,}097{,}833$$

The total capitalized cost is

$$CC_S = CC_1 + CC_2 = \$-527.1 \text{ million}$$

Capitalized cost of truss bridge (CC_T):

$$\begin{aligned} CC_1 &= -250 + (-150) = \$-400 \text{ million} \\ A_1 &= \$-200{,}000 \\ A_2 &= \text{annual cost of painting} = -400{,}000(A/F,6\%,3) = \$-125{,}644 \\ A_3 &= \text{annual cost of sandblasting} = -1{,}900{,}000(A/F,6\%,10) = \$-144{,}153 \end{aligned}$$

$$CC_2 = \frac{A_1 + A_2 + A_3}{i} = \frac{\$-469{,}797}{0.06} = \$-7{,}829{,}950$$

$$CC_T = CC_1 + CC_2 = \$-407.83 \text{ million}$$

Conclusion: Build the truss bridge, since its capitalized cost is lower by \$119 million.

If a finite-life alternative (e.g., 5 years) is compared to one with an indefinite or very long life, capitalized costs can be used. To determine CC for the finite life alternative, calculate the A value for *one life cycle* and divide by the interest rate (Equation [4.2]).

EXAMPLE 4.6

APSco, a large electronics subcontractor for the Air Force, needs to immediately acquire 10 soldering machines with specially prepared jigs for assembling components onto circuit boards. More machines may be needed in the future. The lead production engineer has outlined two simplified, but viable, alternatives. The company's MARR is 15% per year and capitalized cost is the evaluation technique.

Alternative LT (long-term). For \$8 million now, a contractor will provide the necessary number of machines (up to a maximum of 20), now and in the future, for as long as APSco needs them. The annual contract fee is a total of \$25,000 with no additional per-machine annual cost. There is no time limit placed on the contract, and the costs do not escalate.

Alternative ST (short-term). APSco buys its own machines for \$275,000 each and expends an estimated \$12,000 per machine in annual operating cost (AOC). The useful life of a soldering system is 5 years.

Solution

For the LT alternative, find the CC of the AOC using Equation [4.2]. Add this amount to the initial contract fee, which is already a capitalized cost.

$$\begin{aligned} CC_{LT} &= \text{CC of contract fee} + \text{CC of AOC} \\ &= -8 \text{ million} - 25{,}000/0.15 = \$-8{,}166{,}667 \end{aligned}$$

For the ST alternative, first calculate the equivalent annual amount for the purchase cost over the 5-year life, and add the AOC values for all 10 machines. Then determine the total CC using Equation [4.2].

$$\begin{aligned} AW_{ST} &= \text{AW for purchase} + \text{AOC} \\ &= -2.75 \text{ million}\,(A/P,15\%,5) - 120{,}000 = \$-940{,}380 \\ CC_{ST} &= -940{,}380/0.15 = \$-6{,}269{,}200 \end{aligned}$$

The ST alternative has a lower capitalized cost by approximately \$1.9 million present value dollars.

4.5 EVALUATION OF INDEPENDENT PROJECTS

Podcast available

Consider a biomedical company that has a new genetics engineering product that it can market in three different countries (S, U, and R), including any combination of the three. The do-nothing (DN) alternative is also an option. All possible options are: S, U, R, SU, SR, UR, SUR, and DN. In general, for m independent projects, there are 2^m alternatives to evaluate. Selection from independent projects uses a fundamentally different approach from that for mutually exclusive (ME) alternatives. When selecting independent projects, each project's PW is calculated using the MARR. (In ME alternative evaluation, the projects compete with each other, and only one is selected.) The selection rule is quite simple for one or more *independent* projects:

Select all projects that have PW ≥ 0 at the MARR.

All projects must be developed to have revenue cash flows (not costs only) so that projects earning more than the MARR have positive PW values.

Unlike ME alternative evaluation, which assumes the need for the service over multiple life cycles, independent projects are considered one-time investments. This means the PW analysis is performed over the respective life of each project and the assumption is made that any leftover cash flows earn at the MARR when the project ends. As a result, the equal service requirement does not impose the use of a specified study period or the LCM method. The implied study period is that of the longest lived project.

There are two types of selection environments—unlimited and budget constrained.

- **Unlimited.** All projects that make or exceed the MARR are selected. Selection is made using the PW ≥ 0 guideline.
- **Budget constrained.** No more than a specified amount, b, of funds can be invested in all of the selected projects, and each project must make or exceed the MARR. Now the solution methodology is slightly more complex in that *bundles* of projects that do not exceed the investment limit b are the only ones evaluated using PW values. The procedure is:
  1. Determine all bundles that have total initial investments no more than b. (This limit usually applies in year 0 to get the project started).
  2. Find the PW value at the MARR for all projects contained in the bundles.
  3. Total the PW values for each bundle in (1).
  4. Select the bundle with the largest PW value.

EXAMPLE 4.7

Marshall Aqua Technologies has four separate projects it can pursue over the next several years. The required amounts to start each project (initial investments) now and the anticipated cash flows over the expected lives are estimated by the Project Engineering Department. At MARR = 15% per year, determine which projects should be pursued if initial funding is (*a*) not limited, and (*b*) limited to no more than \$15,000.

Project	Initial Investment	Annual Net Cash Flow	Life, Years
F	\$ −8,000	\$3870	6
G	−15,000	2930	9
H	−6,000	2080	5
J	−10,000	5060	3

Solution

a. Determine the PW value for each independent project and select all with PW ≥ 0 at 15%.

$$PW_F = -8000 + 3870(P/A,15\%,6) = \$6646$$
$$PW_G = -15{,}000 + 2930(P/A,15\%,9) = \$-1019$$
$$PW_H = -6000 + 2080(P/A,15\%,5) = \$973$$
$$PW_J = -10{,}000 + 5060(P/A,15\%,3) = \$1553$$

Select the three projects F, H, and J for a total investment of \$24,000.

TABLE 4.1 Present Worth Analysis of Independent Projects with Investment Limited to $15,000, Example 4.7

Bundle	Projects	Total Initial Investment	PW of Bundle at 15%
1	F	$ −8,000	$ 6646
2	G	−15,000	−1019
3	H	−6,000	973
4	J	−10,000	1553
5	FH	−14,000	7619
6	Do-nothing	0	0

b. Use the steps for a budget-constrained selection with b = $15,000.

1 and **2.** Of the $2^4 = 16$ possible bundles, Table 4.1 indicates that 6 are acceptable. These bundles involve all four projects plus do-nothing with $PW_{DN} = \$0$.

3. The PW value for a bundle is obtained by adding the respective project PW values. For example, $PW_5 = PW_F + PW_H = 6646 + 973 = \$7619$.

4. Select projects F and H, since their PW is the largest and both projects exceed the MARR, as indicated by PW > 0 at $i = 15\%$.

Comment: Budget-constrained selection from independent projects is commonly called the capital rationing or capital budgeting problem. It may be worked efficiently using a variety of techniques, one being the integer linear programming technique. Excel and its optimizing tool SOLVER handle this type of problem rather nicely.

4.6 USING SPREADSHEETS FOR PW ANALYSIS

Spreadsheet- or calculator-based evaluation of equal-life, mutually exclusive alternatives can be performed using the single-cell PV function when the annual amount A is the same. The general format to determine the PW is

$$= P - \text{PV}(i,n,A,F) \quad \textbf{[4.4]}$$

It is important to pay attention to the sign placed on the PV function in order to get the correct answer for the alternative's PW value. The spreadsheet function returns the opposite sign of the A series. Therefore, to retain the negative sense of a cost series A, place a minus sign immediately in front of the PV function. This is illustrated in the next example.

EXAMPLE 4.8

Cesar, a petroleum engineer, has identified two equivalent diesel-powered generators to be purchased for an offshore platform. Use $i = 12\%$ per year to determine which is the more economic. Solve using both spreadsheet and calculator functions.

	Generator 1	*Generator 2*
P, \$	$-80{,}000$	$-120{,}000$
S, \$	15,000	40,000
n, years	3	3
AOC, \$/year	$-30{,}000$	$-8{,}000$

Solution

Spreadsheet: Follow the format in Equation [4.4] in a single cell for each alternative. Figure 4.4 shows the details. Note the use of minus signs on P, the PV function, and AOC value. Generator 2 is selected with the smaller PW of costs (numerically larger value).

Calculator: The function and PW value for each alternative are:

Generator 1: $-80000 - \text{PV}(12,3,-30000,15000)$ $\quad \text{PW}_1 = \$-141{,}378$
Generator 2: $-120000 - \text{PV}(12,3,-8000,40000)$ $\quad \text{PW}_2 = \$-110{,}743$

As expected, the PW values and selection of Generator 2 are the same as the spreadsheet solution.

	A	B	C	D	E	F
1						
2	Generator	PW value	Function to determine PW			
3	1	-\$141,378	= -80000 - PV(12%,3,-30000,15000)			
4						
5	2	-\$110,743	= -120000 - PV(12%,3,-8000,40000)			
6						
7						
8						
9						
10						
11						

Minus on PV function maintains correct sense of PV value

FIGURE 4.4 Equal-life alternatives evaluated using the PV function, Example 4.8.

When different-life alternatives are evaluated, using the LCM basis, it is necessary to input all the cash flows for the LCM of the lives to ensure an equal-service evaluation. Develop the NPV function to find PW. If cash flow is identified by CF, the general format is

$$= P + \text{NPV}(i\%,\text{year\_1\_CF\_cell:last\_year\_CF\_cell}) \qquad \textbf{[4.5]}$$

It is very important that the *initial cost P not be included* in the cash flow series identified in the NPV function. Unlike the PV function, the NPV function returns the correct sign for the PW value.

EXAMPLE 4.9 Continuing with the previous example, once Cesar had selected generator 2 to purchase, he approached the manufacturer with the concerns that the first cost was too high and the expected life was too short. He was offered a lease arrangement for 6 years with a \$20,000 annual cost and an extra \$20,000 payment in the first and last years to cover installation and removal costs. Determine if generator 2 or the lease arrangement is better at 12% per year.

	A	B	C	D	E	F	G
1	Year	Generator 2	Lease				
2	0	-120,000	-40,000				
3	1	-8,000	-20,000				
4	2	-8,000	-20,000				
5	3	-88,000	-20,000				
6	4	-8,000	-20,000				
7	5	-8,000	-20,000				
8	6	32,000	-40,000				
9	PW value	-\$189,568	-\$132,361				
10							
11							
12							

Repurchase cash flow
= S - AOC - P
= 40,000 − 8,000 − 120,000

= −40000 + NPV(12%,C3:C8)

= −120000 + NPV(12%,B3:B8)

FIGURE 4.5 Different-life alternatives evaluated using the NPV function, Example 4.9.

Solution

Assuming that generator 2 can be repurchased 3 years hence and all estimates remain the same, PW evaluation over 6 years is correct. Figure 4.5 details the cash flows and NPV functions. The year 3 cash flow for generator 2 is $S - \text{AOC} - P = \$-88{,}000$. Note that the first costs are not included in the NPV function but are listed separately, as indicated in Equation [4.5]. The lease option is the clear winner for the next 6 years.

When evaluating alternatives for which the annual cash flows do not form an A series, the individual amounts must be entered on the spreadsheet and Equation [4.5] is used to find PW values. Also, remember that any zero-cash-flow year must be entered as 0 to ensure that the NPV function correctly tracks the years.

SUMMARY

This chapter explained the difference between mutually exclusive and independent alternatives, as well as revenue and cost cash flows. It discussed the use of present worth (PW) analysis to select the economically best alternative. In general, always choose an alternative with the largest PW value calculated at the MARR.

Important points to remember for mutually exclusive alternatives selection are:

1. Compare equal service alternatives over the same number of years using a specified study period. Alternatives with lives shortened by the study

period have as a "salvage value" the estimated market value. For longer lives, an equivalent-service cost must be estimated through the end of the study period.

2. PW evaluation over the least common multiple (LCM) of lives can be used to obtain equal service.
3. Capitalized cost (CC) analysis, an application of PW analysis with $n = \infty$, compares alternatives with indefinite or very long lives. In short, the CC value is determined by dividing the equivalent A value of all cash flows by the interest rate i.

For independent projects, select all with PW ≥ 0 at the MARR if there is no budget limitation. When funds are limited, form bundles of projects that do not exceed the limit and select the bundle that maximizes PW.

PROBLEMS

Alternative Formulation

4.1 State two conditions under which the do-nothing alternative is not an option.

4.2 When evaluating projects by the present worth method, how do you know which one(s) to select, if the (*a*) projects are independent, and (*b*) alternatives are mutually exclusive?

4.3 A biomedical engineer with Johnston Implants just received estimates for replacement equipment to deliver online selected diagnostic results to doctors performing surgery who need immediate information on the patient's condition. The cost is \$200,000, the annual maintenance contract costs \$5000, and the useful life (technologically) is 5 years.

a. What is the alternative if this equipment is not selected? What other information is necessary to perform an economic evaluation of the two?

b. What type of cash flow series will these estimates form?

c. What additional information is needed to convert the cash flow estimates to the other type of series?

4.4 The lead engineer at Bell Aerospace has \$1 million in research funds to commit this year. She is considering five separate R&D projects, identified as A through E. Upon examination, she determines that three of these projects (A, B, and C) accomplish exactly the same objective using different techniques.

a. Identify each project as mutually exclusive or independent.

b. If the selected alternative between A, B, and C is labeled X, list all viable options (bundles) for the five projects.

4.5 List all possible bundles for the four independent projects 1, 2, 3, and 4. Projects 3 and 4 cannot both be included in the same bundle.

Evaluation of Equal-Life Alternatives

4.6 What is meant by the term *equal service*?

4.7 An irrigation return flow drain has sampling equipment that can be powered by solar cells or by running an electric line to the site and using conventional power. Solar cells will cost \$14,000 to install with a useful life of 10 years. Annual costs for inspection, cleaning, etc. are expected to be \$1500. A new power line will cost \$12,000 to install and the power costs are estimated at \$600 per year. The salvage value of the solar cells is expected to be 25% of the first cost when the sampling project ends in 4 years. The electric line will stay in place, so its salvage value is considered to be zero. At an interest rate of 10% per year, which alternative should be selected?

4.8 Oil from a particular type of marine microalgae can be converted to biodiesel that can serve as an alternate transportable fuel for automobiles and trucks. If lined ponds are used to grow the algae, the construction cost will be \$13 million and the maintenance & operating (M&O) cost will be \$2.1 million per year. If long plastic tubes are used for growing the algae, the initial cost will be higher at \$18 million, but less contamination will render the M&O cost lower at \$0.41 million per year. At an interest rate of 10% per year and a 5-year project period, which system is better, ponds or tubes? Use a present worth analysis.

4.9 American Electric Power agreed to spend \$4.6 billion to clean up 46 coal-fired power plants that are believed to be contributing to acid rain. The plan is to reduce nitrogen oxide emissions by 69% by 2016 and sulfur dioxide emissions by 79% by 2018. Assume Plan A is to spend \$0.575 billion per year in years 1 through 4 and an additional \$0.575 billion per year in years 7 through 10. Plan B is to spend \$0.46 billion in each of years 1 through 10. At an interest rate of 8% per year, which plan is more economical to the company based on a present worth analysis?

4.10 The costs associated with manufacturing a multifunction portable gas analyzer are estimated. At an interest rate of 8% per year and a present worth analysis, which method should be selected?

	Manual	Robotic
First cost, \$	−425,000	−850,000
M&O cost, year 1, \$	−90,000	−10,000
Increase in M&O, \$/year	7,000	1,000
Salvage value, \$	80,000	300,000
Life, years	5	5

4.11 A pilot plant for conducting research related to reverse osmosis concentrate recovery via lime softening can be leased for the 4-month project duration for \$6,900 per month. Electrical work at the site will cost \$8500 now and the technician to install the electrical work will charge \$2000 now. Shipping will cost \$2300 each way (months 0 and 4). A technician for demobilization will cost \$1300 in month 4. At an interest rate of 6% per year compounded monthly, what is the present worth of the pilot plant project?

4.12 Biomet Implants is planning new online patient diagnostics for surgeons while they operate. The new system will cost \$300,000 to install in an operating room, \$5000 annually for maintenance, and have an expected life of 4 years. The revenue per system is estimated to be \$80,000 in year 1 and to increase by \$10,000 per year through year 4. Determine if the project is economically justified using PW analysis and an MARR of 10% per year.

4.13 An undergraduate engineering student and her husband operate a pet-sitting service to help make ends meet. They want to add a daily service of a photo placed online for pet owners who are traveling. The estimates are: equipment and setup cost \$950; net monthly income over costs \$70. Over a period of 3 years, will the service make at least 12% per year compounded monthly?

4.14 The CFO of Marta Aaraña Cement Industries knows that many of the diesel-fueled systems in its quarries must be replaced at an estimated cost of \$20 million 10 years from now. A fund for these replacements has been established with the commitment of \$1 million at the end of next year (year 1) with 10% increases through the 10th year. If the fund earns at 5.25% per year, will the company have enough to pay for the replacements? Solve using (*a*) tabulated factors, and (*b*) a spreadsheet.

4.15 Burling Water Cooperative currently contracts the removal of small amounts of hydrogen sulfide from its well water using manganese dioxide filtration prior to the addition of chlorine and fluoride. Contract renewal for 5 years will cost \$75,000 annually for the next 2 years and \$100,000 in years 3, 4, and 5. Assume payment is made at the end of each contract year. Burling Coop can install the filtration equipment for \$125,000 and perform the process for \$50,000 per year. At a discount rate of 6% per year, does the contract service still save money?

4.16 Halogen-free liquid crystal polymers are used for lead-free soldering without corrosion and maintenance issues. The polymers can be produced by either of two methods. Equipment for method A costs \$70,000 initially and has a \$15,000 salvage value after 3 years. The operating cost with this method will be \$20,000 per year. Method B will have a first cost of \$140,000, an operating cost of \$8000 per year, and a \$40,000 salvage value after its 3-year life. At an interest rate of 12% per year, which method should be used on the basis of a present worth analysis? Solve using (*a*) tabulated factors, and (*b*) a calculator.

4.17 A software package created by Navarro & Associates can be used for analyzing and designing three-sided guyed towers and three- and four-sided self-supporting towers. A single-user license will cost \$4000 per year. A site license has a one-time cost of \$15,000. A structural engineering consulting company is trying to decide between 2 alternatives: first, to buy one single-user license *now* and one each year for the next four years (which will provide five years of service), or second, to buy a site license now. Determine which strategy is more economical at an interest rate of 12% per year for a 5-year planning period. Apply the present worth method of evaluation.

4.18 The Bureau of Indian Affairs provides various services to American Indians and Alaskan Natives. The Director of Indian Health Services is working with chief physicians at some of the 230 clinics nationwide to select the better of two medical X-ray system alternatives to be located at secondary-level clinics. At 5% per year, select the more economical system. Solve using (*a*) tabulated factors, and (*b*) a spreadsheet.

	Del Medical	Siemens
First cost, $	−250,000	−224,000
Annual operating cost, $ per year	−231,000	−235,000
Overhaul in year 3, $	—	−26,000
Overhaul in year 4, $	−140,000	—
Salvage value, $	50,000	10,000
Expected life, years	6	6

4.19 The Briggs and Stratton Commercial Division designs and manufactures small engines for golf turf maintenance equipment. A robotics-based testing system will ensure that their new signature guarantee program entitled "Always Insta-Start" does indeed work for every engine produced. Compare the two systems at MARR = 10% per year. Solve using (*a*) tabulated factors, and (*b*) single-cell spreadsheet functions.

	Pull System	Push System
Robot and support equipment first cost, $	−1,500,000	−2,250,000
Annual M&O cost, $ per year	−700,000	−600,000
Rebuild cost in year 3, $	0	−500,000
Salvage value, $	100,000	50,000
Estimated life, years	8	8

4.20 Chevron Corporation has a capital and exploratory budget for oil and gas production of $19.6 billion in one year. The Upstream Division has a project in Angola for which three offshore platform equipment alternatives are identified. Use the present worth method to select the best alternative at 12% per year.

	A	B	C
First cost, $ million	−200	−350	−475
Annual cost, $ million per year	−450	−275	−400
Salvage value, $ million	75	50	90
Estimated life, years	20	20	20

4.21 The TechEdge Corporation offers two forms of 4-year service contracts on its closed-loop water purification system used in the manufacture of semiconductor packages for microwave and high-speed digital devices. The Professional Plan has an initial fee of $52,000 with annual fees starting at $1000 in contract year 1 and increasing by $500 each year. Alternatively, the Executive Plan costs $62,000 up front with annual fees starting at $5000 in contract year 1 and decreasing by $500 each year. The initial charge is considered a setup cost for which there is no salvage value expected. Evaluate the plans at a MARR of 9% per year. Solve using (*a*) factors, and (*b*) a spreadsheet. (*c*) How is the analysis performed using a financial calculator?

4.22 Allison and Joshua are engineers at Raytheon. Each has presented a proposal to track fatigue development in composite materials installed on special-purpose aircraft. Which is the better plan economically, if i = 12% per year compounded monthly?

	Allison's Plan	Joshua's Plan
Initial cost, $	−40,000	−60,000
Monthly M&O costs, $ per month	−5,000	—
Semiannual M&O cost, $ per 6-month	—	−13,000
Salvage value, $	10,000	8,000
Life, years	5	5

4.23 What is the present worth of a $40,000 bond that has a bond interest rate of 6% per year, payable semiannually? The bond matures in 20 years. The interest rate in the marketplace is 8% per year compounded semiannually.

4.24 The present worth of a $10,000 municipal bond due 6 years from now is $11,000. If the bond interest is payable quarterly and the interest rate used in discounting the cash flow is 8% per year compounded quarterly, what is the bond coupon rate b per year?

4.25 Jamal bought a 5% $1000 20-year bond for $925. He received a semiannual dividend for 8 years, then sold it immediately after the 16th dividend for $800. Did Jamal make the return of 5% per year compounded semiannually that he wanted? Solve using (*a*) factors, and (*b*) a spreadsheet.

4.26 An investor thought that market interest rates were going to decline. He paid $19,000 for a corporate bond with a face value of $20,000. The bond has an interest rate of 10% per year payable annually. If the investor plans to sell the bond immediately after receiving the 4th interest payment, how much will he have to receive in order to make a return of 14% per year? Solve using (*a*) tabulated factors, and (*b*) the GOAL SEEK tool on a spreadsheet.

4.27 An investor pays $30,000 for a convertible bond (one that can be converted into shares of corporate common stock). The bond conversion rate is 100 shares of stock anytime within the next five years. What will the stock price have to be in year 3 in order for the investor to make 10% per year on the investment? Assume the bond interest rate is 4% per year payable annually.

4.28 Atari needs $4.5 million in new investment capital to develop and market downloadable game software for its new GPS2-ZX system. The plan is to sell $10,000 face-value corporate bonds at a discount of $9000 now. A bond pays a dividend each 6 months based on a bond interest rate of 5% per year with the $10,000 face value returned after 20 years. Will a purchase make at least 6% per year compounded semiannually?

Evaluation of Different-Life Alternatives

4.29 Heidleman Industries is considering two types of materials for roofing its warehouses. EPDM is an elastomeric polymer synthesized from ethylene, propylene, and a small amount of diene monomer, compounded with carbon black processing oils and various cross-linking and stabilizing agents. The 75 mil thickness will cost $4.10 per square foot and will last for 25 years. A thin sheet aluminum roof will cost $6.00 per square foot, but it will last for 50 years. Using an interest rate of 10% per year and a present worth comparison, determine whether the company should install the polymer or the aluminum roof.

4.30 Benjamin is an engineer with the Lego Group in Bellund, Denmark, manufacturers of Lego toy construction blocks. He is responsible for the economic analysis of a new production method of special-purpose Lego parts. Method 1 will have an initial cost of $400,000, an annual operating cost of $140,000, and a life of three years. Method 2 will have an initial cost of $600,000, an operating cost of $100,000 per year, and a six-year life. Assume 10% salvage values for both methods. If Lego Industries uses a MARR of 15% per year, which method should it select on the basis of a present worth analysis?

4.31 A mechanical engineer is considering two types of pressure sensors for the low-pressure steam lines in several of the company plants. Piezoresistive sensors use the change in conductivity of semiconductors to measure the pressure. Fiber optic sensors use the properties of fiber optic interferometers to sense nanometer scale displacement of membranes. The costs for each system are shown below. Which should be selected based on a present worth comparison at an interest rate of 1% per month?

	Piezoresistive	Fiber Optic
Purchase cost, $	−13,650	−22,900
Maintenance cost, $/month	−200	−50
Salvage value, $	0	2,000
Life, years	2	4

4.32 Two mutually exclusive projects have the estimated cash flows shown. Use a present worth analysis to determine which should be selected at an interest rate of 10% per year.

	Project P	Project Q
First cost, $	−55,000	−95,000
Annual cost, $/year	−9,000	−5,000 year 1, increasing by $1000 per year
Salvage value, $	nil	4,000
Life, years	2	4

4.33 An industrial engineer is considering two robots for improving efficiency in a fiber-optic manufacturing company. Robot X will have a first cost of $85,000, an annual maintenance and operation

(M&O) cost of $30,000, and a $35,000 salvage value after its useful life of two years. A more sophisticated model, Robot Y will cost $157,000, have an annual M&O cost of $28,000, and a $60,000 salvage value after its four-year life. Select the better robot on the basis of a future worth comparison at an interest rate of 10% per year. Solve by (*a*) tabulated factors, and (*b*) calculator.

4.34 Virgin Galactic is considering two materials for certain parts in a re-useable space vehicle: carbon fiber reinforced plastic (CFRP) and fiber reinforced ceramic (FRC). The costs are shown below. Which should be selected on the basis of a present worth comparison at an interest rate of 10% per year? Solve using (*a*) tabulated factors, and (*b*) single-cell spreadsheet functions.

	CFRP	FRC
First cost, $	−205,000	−235,000
Maintenance cost, $/year	−29,000	−27,000
Salvage value, $	2,000	20,000
Life, years	2	4

4.35 A metallurgical engineer is considering the two ceramics estimated below for use in a high-temperature annealing furnace. (*a*) Which should be selected on the basis of a present worth comparison at an interest rate of 12% per year? (*b*) If the life of material XX is increased from 3 to 4 years, determine the number of re-purchases for both alternatives necessary for a present worth analysis based on the equal-service requirement.

	Material XX	Material ZZ
First cost, $	−230,000	−380,000
Maintenance cost, $/year	−9,000	−12,000
Salvage value, $	12,000	140,000
Life, years	3	6

4.36 An environmental engineer must recommend one of two methods for monitoring high colony counts of E. coli and other bacteria in watershed area "hot spots." Estimates are tabulated and the MARR is 10% per year. Use tabulated factors or a spreadsheet for your analysis.

a. Use present worth analysis to select the better method.

b. For a study period of 3 years, use PW analysis to select the better method.

	Method A	Method B
Initial cost, $	−100,000	−250,000
Annual operating cost, $ per year	−30,000 in year 1, increasing by $5000 each year	−20,000
Life, years	3	6

4.37 Allen Auto Group owns corner property that can be a parking lot for customers or sold for retail sales space. The parking lot option can use concrete or asphalt. Concrete will cost $375,000 initially, last for 20 years, and have an estimated annual maintenance cost of $200 starting at the end of the eighth year. Asphalt is cheaper to install at $250,000, but it will last 10 years and cost $2500 per year to maintain starting at the end of the second year. If asphalt is replaced after 10 years, the $2500 maintenance cost will be expended in its last year. There are no salvage values to be considered. Use i = 8% per year and PW analysis to select the more economic surface, provided the property is (*a*) used as a parking lot for 20 years, and (*b*) sold after 5 years and the parking lot is completely removed.

4.38 The manager of engineering at the 900-megawatt Hamilton Nuclear Power Plant has three options to supply personal safety equipment to employees. Two are vendors who sell the items, and the third alternative is to rent the equipment for $50,000 per year, but for no more than 3 years per contract. These items have relatively short lives due to constant use. The MARR is 10% per year.

	Vendor R	Vendor T	Rental
Initial cost, $	−75,000	−125,000	0
Annual upkeep, $ per year	−27,000	−12,000	0
Annual rental, $ per year	0	0	−50,000
Salvage value, $	0	30,000	0
Estimated life, years	2	3	Maximum of 3

a. Select from the two vendors using the LCM and PW analysis.

b. Determine which of the three options is cheaper over a study period of 3 years.

4.39 Akash Uni-Safe in Chennai, India, makes Terminator fire extinguishers. It needs replacement equipment to form the neck at the top of each extinguisher during production. Select between two metal-constricting systems. Use the corporate MARR of 15% per year with (*a*) present worth analysis, and (*b*) future worth analysis.

	Machine D	Machine E
First cost, $	−62,000	−77,000
Annual operating cost, $ per year	−15,000	−21,000
Salvage value, $	8,000	10,000
Life, years	4	6

4.40 HJ Heinz Corporation is constructing a distribution facility in Italy for products such as Heinz Ketchup, Jack Daniel's sauces, HP steak sauce, and Lea & Perrins Worcestershire sauce. A 15-year life is expected for the structure. The exterior of the building has not yet been selected. One alternative is to use concrete walls as the facade. This will require painting now and every 5 years at a cost of $80,000 each time. Another alternative is an anodized metal exterior attached to the concrete wall. This will cost $200,000 now and require only minimal maintenance of $500 every 3 years. A metal exterior is more attractive and will have a resale value of an estimated $25,000 more than concrete 15 years from now. Assume painting (for concrete) or maintenance (for metal) will be performed in the last year of ownership to promote selling the property. Use future worth analysis and $i = 12\%$ per year to select the exterior finish.

4.41 Three types of bits can be used in an automated drilling operation. A bright high-speed steel (HSS) bit is the least expensive to buy, but it has a shorter life than either gold oxide or titanium nitride bits. The HSS bits will cost $3500 to buy and will last for 3 months under the conditions of use. The operating cost for these bits will be $2000 per month. The gold oxide bits will cost $6500 to buy and will last for 6 months with an operating cost of $1500 per month. The titanium nitride bits will cost $7000 to buy and will last 6 months with an operating cost of $1200 per month. At an interest rate of 12% per year compounded monthly, which type of drill bit should be selected? Use a future worth analysis.

Life Cycle Cost

4.42 Three different plans were presented to the GAO by a high-tech facilities manager for operating an identity-theft scanning facility. Plan A involves renewable 1-year contracts with payments of $1 million at the beginning of each year. Plan B is a 2-year contract that requires four payments of $600,000 each, with the first one made *now* and the other three at 6-month intervals. Plan C is a 3-year contract that entails a payment of $1.5 million *now* and a second payment of $0.5 million 2 years from now. Assuming that the GAO could renew any of the plans under the same payment conditions, which plan is best on the basis of a present worth analysis at an interest rate of 6% per year compounded semiannually?

4.43 The U.S. Army received two proposals for a turnkey design/build project for barracks for infantry unit soldiers in training. Proposal A involves an off-the-shelf "bare-bones" design and standard grade construction of walls, windows, doors, and other features. With this option, heating and cooling costs will be greater, maintenance costs will be higher, and replacement will occur earlier than proposal B. The initial cost for A will be $750,000. Heating and cooling costs will average $6000 per month with maintenance costs averaging $2000 per month. Minor remodeling will be required in years 5, 10, and 15 at a cost of $150,000 each time in order to render the units usable for 20 years. They will have no salvage value. Proposal B will include tailored design and construction costs of $1.1 million initially with estimated heating and cooling costs of $3000 per month and maintenance costs of $1000 per month. There will be no salvage value at the end of the 20-year life. Which proposal should be accepted on the basis of a life-cycle cost analysis at an interest rate of 0.5% per month?

4.44 A medium-size municipality plans to develop a software system to assist in project selection during the next 10 years. A life-cycle cost approach has been used to categorize costs into development, programming, operating, and support costs for each alternative. There are three alternatives under consideration, identified as A (tailored system), B (adapted system), and C (current system). The costs are summarized on the next page. Perform a life-cycle cost analysis to identify the best alternative at 8% per year using (*a*) tabulated factors first, then (*b*) a spreadsheet to verify your selection.

Alternative	Cost Component	Cost Estimates
A	Development	\$250,000 now, \$150,000 years 1–4
	Programming	\$45,000 now, \$35,000 years 1,2
	Operation	\$50,000 years 1 through 10
	Support	\$30,000 years 1 through 5
B	Development	\$10,000 now
	Programming	\$45,000 year 0, \$30,000 years 1–3
	Operation	\$80,000 years 1 through 10
	Support	\$40,000 years 1 through 10
C	Operation	\$175,000 years 1 through 10

4.45 Recently introduced Gatorade Endurance Formula contains more electrolytes (such as calcium and magnesium) than the original sports drink formula, thus causing Endurance to taste saltier to some. It is important than the amount of electrolytes be precisely balanced in the manufacturing process. The currently installed system (called EMOST) can be upgraded to monitor the amount more precisely. It costs \$12,000 per year for equipment maintenance, \$45,000 a year for labor, and the upgrade will cost \$25,000 now. This can serve for 10 more years, the expected remaining time the product will be financially successful. A new system (UPMOST) will also serve for the 10 years and have the following estimated costs. All costs are per year for the indicated time periods.

Equipment: \$150,000 years 0 and 1
Development: \$120,000 years 1 and 2
Maintain and phaseout EMOST: \$20,000 years 1, 2, and 3
Maintain hardware and software: \$10,000 years 3 through 10
Personnel costs: \$90,000 years 3 through 10
Scrapped formula: \$30,000 years 3 through 10

Sales of Gatorade Endurance with the UPMOST system installed are expected to go up by \$150,000 per year beginning in year 3 and increase by \$50,000 per year through year 10. Use LCC analysis at an MARR of 20% per year to select the better electrolyte monitoring system. (Choose from tabulated factors, calculator, or spreadsheet to make your evaluation.)

Capitalized Cost

4.46 The Golden Gate bridge is maintained by 17 ironworkers, who replace corroding steel and rivets, and 38 painters. If the painters have an average wage of \$120,000 per year with benefits and the ironworkers get \$150,000, what is the capitalized cost today of all the future wages for bridge maintenance at an interest rate of 8% per year?

4.47 Determine the capitalized cost of \$100,000 now and \$50,000 per year in years one through infinity at an interest rate of 10% per year compounded continuously.

4.48 Determine the capitalized cost of \$1,000,000 at time 0, \$125,000 in years 1 through 10, and \$200,000 per year from year 11 on. Use an interest rate of 10% per year.

4.49 The cost of extending Park Road PR2 in Yellowstone National Park is \$1.7 million. Resurfacing and other maintenance is expected to cost \$350,000 every 3 years. What is the capitalized cost of the road extension at an interest rate of 6% per year?

4.50 John wants to have the financial ability to withdraw \$80,000 per year forever beginning 30 years from now. If his retirement account earns 8% per year interest and dividends, what is the required balance in (*a*) year 29, and (*b*) year 0?

4.51 What is the capitalized cost (absolute value) of the *difference* between the following two plans at an interest rate of 10% per year? Plan A requires an expenditure of \$50,000 every five years forever beginning in year 5. Plan B requires an expenditure of \$100,000 every 10 years forever beginning in year 10.

4.52 An alumna of Ohio State University wants to set up an endowment fund that can award scholarships to female engineering students totalling \$100,000 per year forever. The first scholarships are to be granted *now* and continue each year from now on. How much must the alumna donate now, if the endowment fund is expected to earn interest at a rate of 8% per year?

4.53 Field chlorination of reclaimed water can be accomplished via a low-cost system that uses calcium hypochlorite tables. System components include a 4 foot diameter pipe that is 4 inches long (\$70), a solenoid valve (\$50), a float switch (\$30), a chlorine analyzer (\$1500), and a programmable VFD solution pump (\$1900). Assume the following component lives: pipe – 10 years; solenoid valve – 2 years; float switch – 2 years; chlorine analyzer – 5 years; solution pump – 5 years. Calculate the capitalized cost of the system at an interest rate of 8% per year.

4.54 Compare the cost of the two types of composite materials on the basis of their capitalized costs. Use an interest rate of 10% per year.

	Material J1	Material K2
First cost, $	−55,000	−325,000
Maintenance cost, $/year	−6,000	−1,000
Salvage value	2,000	200,000
Life, years	3	∞

4.55 The president of Biomed Products is considering a long-term contract to outsource maintenance and operations that will significantly improve the energy efficiency of their imaging systems. The payment schedule has two large payments in the first years with continuing payments thereafter. The proposed schedule is $200,000 now, $300,000 four years from now, $50,000 every 5 years, and an annual amount of $8000 beginning 15 years from now and continuing indefinitely. Determine the capitalized cost at 8% per year.

4.56 UPS Freight plans to spend $100 million on new long-haul tractor-trailers. Some of these vehicles will include a new shelving design with adjustable shelves to transport irregularly sized freight that requires special handling during loading and unloading. Though the life is relatively short, the director wants a capitalized cost analysis performed on the two final designs. Compare the alternatives at the MARR of 10% per year using (*a*) tabulated factors, and (*b*) a spreadsheet.

	Design A: movable shelves	Design B: adaptable frames
First cost, $	−2,500,000	−1,100,000
AOC, $ per year	−130,000	−65,000
Annual revenue, $ per year	800,000	625,000
Salvage value, $	50,000	20,000
Life, years	6	4

4.57 A water supply cooperative plans to increase its water supply by 8.5 million gallons per day to meet increasing demand. One alternative is to spend $10 million to increase the size of an existing reservoir in an environmentally acceptable way. Added annual upkeep will be $25,000 for this option. A second option is to drill new wells and provide added pipelines for transportation to treatment facilities at an initial cost of $1.5 million and annual cost of $120,000. The reservoir is expected to last indefinitely, but the productive well life is only 10 years. Compare the alternatives at 5% per year.

4.58 Three alternatives to incorporate improved techniques to manufacture computer drives to play HD DVD optical disc formats have been developed and costed. Compare the alternatives below using capitalized cost and an interest rate of 12% per year compounded quarterly.

	Alternative E	Alternative F	Alternative G
First cost, $	−2,000,000	−3,000,000	−10,000,000
Net income, $ per quarter	300,000	100,000	400,000
Salvage value, $	50,000	70,000	—
Life, years	4	8	∞

Independent Projects

4.59 A small manufacturing company is considering the addition of one or more of four new product lines. If the total amount of investment capital available for new ventures is $800,000, which one(s) should the company undertake on the basis of a present worth analysis? Assume the company uses a 5-year project recovery period and a MARR of 20% per year. All cash flows are in $1000 units.

	Product Lines			
	R1	S2	T3	U4
First cost, $	−200	−400	−500	−700
M&O cost, $/year	−50	−200	−300	−400
Revenue, $/year	150	450	520	770

4.60 Determine which of the following independent projects should be selected for investment if $240,000 is available and the MARR is 10% per year. Use the PW method to evaluate mutually exclusive bundles to make the selection.

Project	Initial Investment, $	Net Cash Flow, $/year	Life, Years
A	−100,000	50,000	8
B	−125,000	24,000	8
C	−120,000	75,000	8
D	−220,000	39,000	8
E	−200,000	82,000	8

4.61 Feng Seawater Desalination Systems has established a capital investment limit of $800,000 for next year for projects that target improved recovery of highly brackish groundwater. Select any or all of the projects using a MARR of 10% per year. All projects have a 4-year life.

Project	Initial Investment, $	Net Cash Flow, $/year	Salvage Value, $
X	−250,000	50,000	45,000
Y	−300,000	90,000	−10,000
Z	−550,000	150,000	100,000

4.62 Dwayne has four independent vendor proposals to contract the nationwide oil recycling services for the Ford Corporation manufacturing plants. All combinations are acceptable, except that vendors B and C cannot both be chosen. Revenue sharing of recycled oil sales with Ford is a part of the requirement. Develop all possible mutually exclusive bundles under the additional following restrictions and select the best projects. The corporate MARR is 10% per year.

a. A maximum of $4 million can be spent.
b. A larger budget of $5.5 million is allowed, but no more than two vendors can be selected.
c. There is no limit on spending.

Vendor	Initial Investment, $	Life, Years	Annual Net Revenue, $ per Year
A	−1.5 million	8	360,000
B	−3.0 million	10	600,000
C	−1.8 million	5	620,000
D	−2.0 million	4	630,000

ADDITIONAL PROBLEMS AND FE EXAM REVIEW QUESTIONS

4.63 In the PW method of alternative evaluation, equal service means that:
a. all projects must start at the same time.
b. all projects are evaluated over the same time period.
c. all projects must have the same operating cost.
d. all projects have equal salvage values.

The following estimates are used in Problems 4.64 through 4.66.

The cost of money is 10% per year.

	Machine P	Machine Q
Initial cost, $	−35,000	−66,000
Annual cost, $/year	−20,000	−15,000
Salvage value, $	10,000	23,000
Life, years	2	4

4.64 In comparing the machines on a present worth basis, the present worth of machine P is closest to:
a. $−82,130
b. $−87,840
c. $−91,568
d. $−112,230

4.65 In comparing the machines on a present worth basis, the present worth of machine Q is closest to:
a. $−68,445
b. $−97,840
c. $−125,015
d. $−223,120

4.66 The capitalized cost of machine P is closest to:
a. $−35,405
b. $−97,840
c. $−354,050
d. $−708,095

4.67 The cost of maintaining a public monument in Washington, D.C. occurs as periodic outlays of

\$10,000 every 5 years. If the first outlay is 5 years from now, the capitalized cost of the maintenance at an interest rate of 10% per year is closest to:

a. \$−1638
b. \$−16,380
c. \$−26,380
d. \$−29,360

4.68 A grateful donor wishes to start an endowment at her alma mater that will provide scholarship money of \$40,000 per year beginning *now* (time 0) and continue indefinitely. If the funds earn 10% per year, the amount she must donate now is closest to:

a. \$340,000
b. \$400,000
c. \$440,000
d. \$493,800

4.69 A corporate bond has a face value of \$10,000, a bond interest rate of 8% per year payable semiannually, and a maturity date of 20 years from now. If a person purchases the bond for \$9000 when the interest rate in the market place is 8% per year compounded semiannually, the size and frequency of the interest payments the person will receive are:

a. \$270 every six months
b. \$300 every six months
c. \$360 every six months
d. \$400 every six months

The following estimates are used in Problems 4.70 and 4.71.

The MARR is 12% per year.

	Alternative 1	Alternative 2
First cost, \$	−40,000	−65,000
Annual cost, \$ per year	−20,000	−15,000
Salvage value, \$	10,000	25,000
Life, years	3	4

4.70 The relation that correctly calculates the present worth of alternative 2 when comparing it to alternative 1 is:

a. $-65{,}000 - 15{,}000(P/A,12\%,12) + 25{,}000(P/F,12\%,8) + 25{,}000(P/F,12\%,12)$
b. $-65{,}000 - 15{,}000(P/A,12\%,4) + 25{,}000(P/F,12\%,4)$
c. $-65{,}000 - 15{,}000(P/A,12\%,12) + 25{,}000(P/F,12\%,12)$
d. $-65{,}000 - 40{,}000[(P/F,12\%,4) + (P/F,12\%,8)] - 15{,}000(P/A,12\%,12) + 25{,}000(P/F,12\%,12)$

4.71 The number of life cycles for each alternative when performing a present worth evaluation based on the LCM for equal service is:

a. 2 for each alternative
b. 1 for each alternative
c. 3 for alternative 1; 4 for alternative 2
d. 4 for alternative 1; 3 for alternative 2