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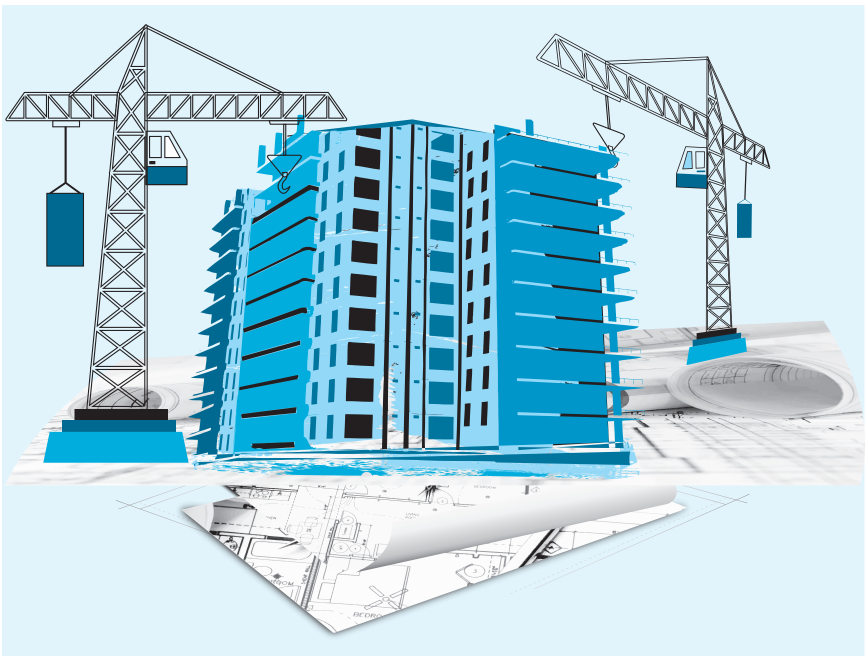
PART

Evaluating Business and Engineering Assets

CHAPTER FIVE

Present-Worth Analysis

"Coolness Factor" Draws Developers to East Austin, Texas[1]**.** The Endeavor Real Estate Group, the largest full-service commercial real estate developer in Central and South Texas, and Capital Metropolitan Transportation Authority, Austin's regional public transportation provider, have joined to turn an old 11-acre rail yard into a "transit-oriented development"—a dense mix of uses near public transportation. The plan calls for 800 apartments, 120,000 square feet of office space, and 110,000 square feet of stores and restaurants. The developers have agreed to lease the rail yard from Capital Metro for about $200 million over 99 years.



[1] Joe Gose, 'Coolness Factor' Draws Developers to East Austin, Texas, *The New York Times*, February 14, 2017.

The development plan calls for the office building to rise 125 feet. The Austin City Council gave it preliminary approval but eventaully asked to reduce it to 70 feet as the neighbors were unhappy over the Austin Planning Commission's initial decision, that is, to allow the office building to rise 125 feet. Recently property prices have climbed to around $350 per square foot, and the average office rental rate in East Austin is around $30 per square foot. Rates for office and retail space are quoted on a per square foot per year basis and developers say that skyrocketing property values in the neighborhood will require the development of denser projects to generate returns. Even if Endeavor completed the project today at $350 per square foot, the lease revenue of $30 per square foot over 99 years would generate *net present value* of $24.82 per square foot at an 8% interest rate. If the company requires a higher return on their investment, say 10%, the present value would be a loss of $50 per square foot, unless they raise the rents over the years. Capital Metro has said that maintaining it at 70 feet could further reduce additional lease revenue by $36 million over the life of the lease, or a *net present* value of $4 million (loss). Still, the Council anticipates that developers and residents may reach a compromise that could allow the office building to rise more than 70 feet, so that the developer's return would be more profitable.

The Endeavor's decision to develop the old rail yard complex is primarily based on an improved outlook (continued higher-than-expected retail demand) for public housing and office space. Then our immediate question is: Would there be enough housing and commercial space demand to recoup the initial investment? Even if the Endeavor believes that space demand could be at the higher end of its forecasted range, we can also pose the following questions:

- How long would it take to recover the initial investment?
- If the projected demand never materializes, what is the extent of financial risk?
- If a new competitor enters into the Austin housing market in the near future that could bring more intense price pressure, how would that affect the future investment decisions?

These are the essential types of questions to address in evaluating any business investment decision, where financial risk is by far the most critical element to consider.

The investments a company chooses today determines its future success. Project ideas can originate from many different levels in an organization; procedures for screening projects to ensure that the right investments are made, need to be established. As mentioned in Chapter 1, many large companies have a specialized project analysis division that actively searches for new ideas, projects, and ventures. The generation and evaluation of creative investment proposals is far too important a task to be left to just this project analysis group; instead, the task is the ongoing responsibility of all managers and engineers throughout the organization. A key aspect of the process is the financial evaluation of investment proposals.

Our treatment of measures of investment worth is divided into four chapters. This chapter begins with a consideration of the payback period, a project-screening tool that was the first formal method used to evaluate investment projects. Then we introduce two measures based on the basic cash flow equivalence technique of present-worth (PW) analysis or commonly known as discounted cash flow techniques. Since the annual-worth approach has many useful engineering applications related to estimating the unit cost, Chapter 6 is devoted to annual cash flow analysis. Chapter 7 presents measures of investment worth based on yield; these measures are known as rate-of-return analysis. Chapter 8 presents another measure based on index, known as benefit–cost ratio commonly used in evaluating public investments.

5.1 Loan versus Project Cash Flows

An investment made in a fixed asset is similar to an investment made by a bank when it lends money. The essential characteristic of both transactions is that funds are committed today in the expectation of their earning a return in the future. In the case of the bank loan, the future return takes the form of interest plus repayment of the principal. This return is known as the **loan cash flow**. In the case of the fixed asset, the future return takes the form of cash generated by productive use of the asset. The representation of these future earnings, along with the capital expenditures and annual expenses (such as wages, raw materials, operating costs, maintenance costs, and income taxes), is the **project cash flow**. The similarity between the loan cash flow and the project cash flow (see Figure 5.1) brings us to an important conclusion—that is, we can use the same equivalence techniques developed in earlier chapters to measure economic worth.

In Chapters 2 through 4, we presented the concept of the time value of money and developed techniques for establishing cash flow equivalence with compound-interest factors. This background provides the foundation for accepting or rejecting a capital investment—that is, for economically evaluating a project's desirability. The coverage of investment worthiness discussed in this chapter will allow us to step beyond accepting or rejecting an investment to making comparisons of alternative investments. We will determine how to compare alternatives on a common basis and select the alternative that is wisest from an economic standpoint.

We must also recognize that one of the most important parts of this capital-budgeting process is the estimation of relevant cash flows. For all examples in this chapter, as

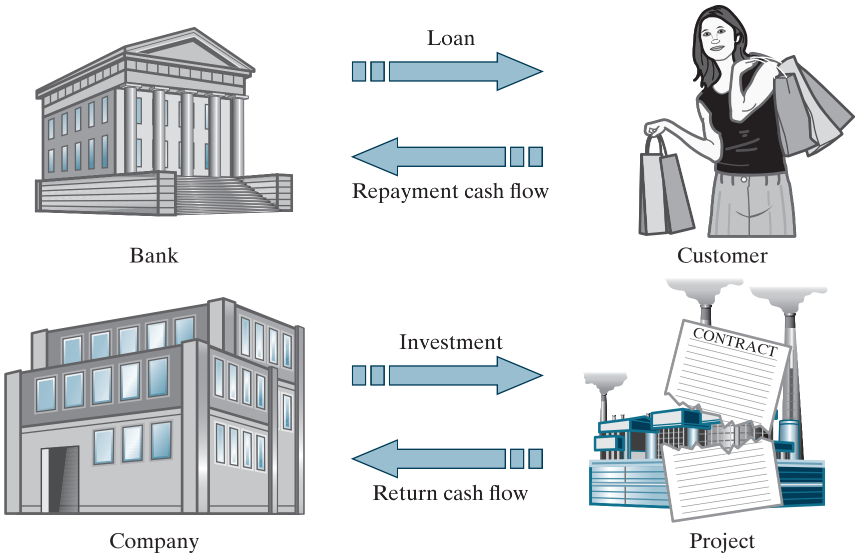


Figure 5.1 Loan versus project cash flows.

well as those in Chapters 6 and 7, net cash flows can be viewed as before-tax values or after-tax values for which tax effects have been recalculated. Since some organizations (e.g., governments and nonprofit organizations) are not subject to tax, the before-tax situation provides a valid base for this type of economic evaluation, as we will see in Chapter 8. Taking this view will allow us to focus on our main area of concern, the economic evaluation of investment projects. The procedures for determining after-tax net cash flows in taxable situations are developed in Part III. We will also assume that all cash flows are estimated in *actual dollars* unless otherwise mentioned. Also, all interest rates used in project evaluation are assumed to be *market interest rates* where any future inflationary effect has been reflected in this interest rate.

5.2 Initial Project Screening Methods

Before studying the formal measures of investment attractiveness, we will introduce a simple method that is commonly used to screen capital investments. Is it worth spending time and effort to consider the proposed projects? One of the primary concerns of most businesspeople is whether, and when, the money invested in a project can be recovered. The **payback method** screens projects on the basis of how long it takes for net future receipts to equal investment outlays:

- The payback period is calculated by adding the expected cash flows for each year until the sum is equal to or greater than zero. The cumulative cash flow equals zero at the point where cash inflows exactly match, or pay back, the cash outflows; thus, the project has reached the payback point. Once the cumulative cash flows exceed zero, the project has begun to generate a profit.

- This payback calculation can take one of two forms by either ignoring time-value-of-money considerations or including them. The former case is usually designated as the **conventional-payback method**, whereas the latter case is known as the **discounted-payback method**.
- A project does not merit consideration unless its payback period is *shorter* than some specified period of time. (This time limit is largely determined by management policy.)

For example, a high-tech firm, such as a computer chip manufacturer, would set a short time limit for any new investment because high-tech products rapidly become obsolete. If the payback period is within the acceptable range, a formal project evaluation (such as a present-worth analysis, which is the subject of this chapter) may begin. It is important to remember that **payback screening** is not an *end* in itself but a method of screening out certain obviously unacceptable investment alternatives before progressing to an analysis of potentially acceptable ones.

EXAMPLE 5.1 Conventional-Payback Period

A machine shop is considering combining machining and turning centers into a single Mazak Multi-Tasking® machine center. Multitasking in the machine world is the combining of processes that were traditionally processed on multiple machines onto one machine. The ultimate goal is to turn, mill, drill, tap, bore, and finish the part in a single setup. The total investment cost is $1.8M with following anticipated cost savings:

	Current Cost (% Saved)	Savings
Setup	$335,000 (70%)	$234,500
Scrap/Rework	$58,530 (85%)	$49,750
Operators	$220,000 (100%)	$220,000
Fixturing	$185,000 (85%)	$157,250
Programming Time	$80,000 (60%)	$48,000
Floor Space	$35,000 (65%)	$22,750
Maintenance	$45,000 (60%)	$27,000
Coolant	$15,000 (50%)	$7,500
Inspection	$120,000 (100%)	$120,000
Documentation	$5,000 (50%)	$2,500
Expediting	$25,000 (75%)	$18,750
	Total Annual Savings	**$908,000**

Most machine shops typically use seven years and assume a 20% residual value at the end of the project life. It is also very common for a learning curve to take place in operating a complex new machine. To allow for the learning curve, assume that only 50% of the full potential savings of $908,000 occur during the first year and 75% occur during the second year. Determine how long it would take to recover the initial investment without considering any time value of money.

DISSECTING THE PROBLEM

It is necessary to determine how long you can expect to reap a benefit from the investment.

Given: Initial cost = \$1,800,000, salvage (residual) value = 20% of initial investment, project life = 7 years; cash flow series as shown in the table below.
Find: Conventional-payback period.

METHODOLOGY

Create a chart reflecting the conventional payback period by developing a cumulative cash flow in each period.

SOLUTION

With the assumptions in the problem statement, the project cash flows are summarized below and also depicted in Figure 5.2.

Period	Cash Flow	Cumulative Cash Flow
0	−\$1,800,000	−\$1,800,000
1	\$454,000	−\$1,346,000
2	\$681,000	−\$665,000
3	\$908,000	\$243,000
4	\$908,000	\$1,151,000
5	\$908,000	\$2,059,000
6	\$908,000	\$2,967,000
7	\$1,268,000	\$4,235,000

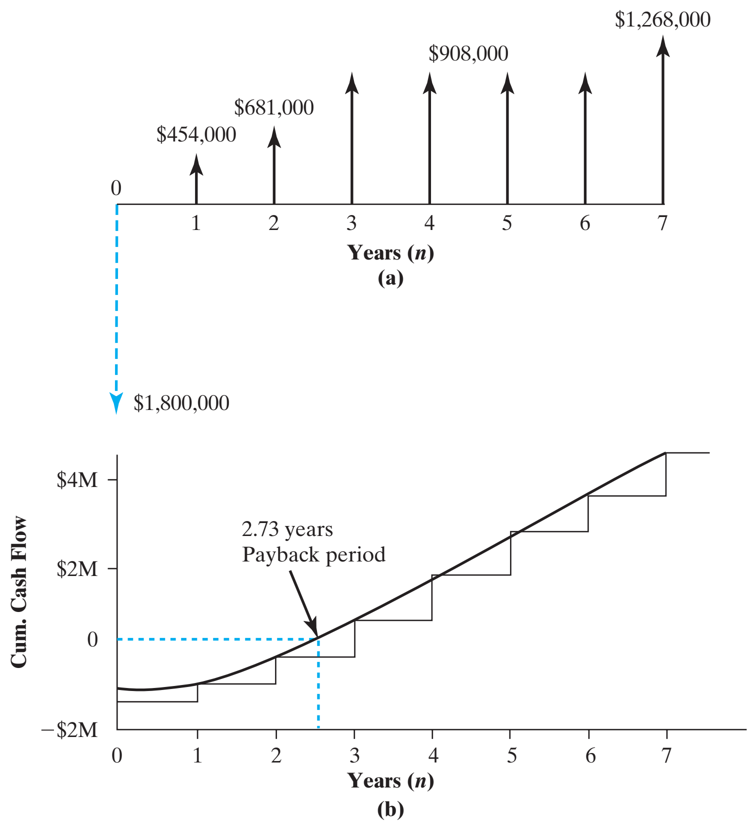


Figure 5.2 Illustration of conventional payback period—(a) annual project cash flow over the life of the project and (b) cumulative project cash flows over time.

As we see from the cumulative cash flow series in Figure 5.2(b), the total investment is recovered at the end of year 3. If the firm's stated maximum payback period is two years, the project would not pass the initial screening stage.

COMMENTS: In this example, we assumed that cash flows occur only in discrete lumps at the end of years. If cash flows occur continuously throughout the year, our calculation of the payback period needs adjustment. A negative balance of $665,000 remains at the end of year 2. If the $908,000 is reasonably expected to be a continuous flow during year 3, then the total investment will be recovered about three-quarters ($665,000/$908,000) of the way through the third year. In this situation, the prorated payback period is thus 2.73 years.

5.2.1 Benefits and Flaws of Payback Screening

The simplicity of the payback method is one of its most appealing qualities. Initial project screening by the payback method reduces the information search by focusing on that time at which the firm expects to recover the initial investment. The method may also eliminate some marginal projects, thus reducing a firm's need to make further analysis efforts on those alternatives. But the much-used payback method of investment screening has a number of serious drawbacks as well:

- The principal objection to the payback method is that it fails to measure profitability; it assumes that no profit is made during the payback period. Simply measuring how long it will take to recover the initial investment outlay contributes little to gauging the earning power of a project. (For instance, if you know that the money you borrowed for the multitasking machine center is costing you 15% per year, the payback method will not tell you how much your invested money is contributing toward your interest expense.)
- Because payback-period analysis ignores differences in the timing of cash flows, it fails to recognize the difference between the present and future value of money. By way of illustration, consider two investment projects:

n	Project 1	Project 2
0	−$10,000	−$10,000
1	$1,000	$9,000
2	$9,000	$1,000
3	$1,000	$2,000
Payback period:	2 years	2 years

Although the payback periods for both investments can be the same in terms of numbers of years, Project 2 is better because most investment recovered at the end of year 1 is worth more than that to be gained later. Because payback screening also ignores all proceeds after the payback period, it does not allow for the possible advantages of a project with a longer economic life.

5.2.2 Discounted-Payback Period

To remedy one of the shortcomings of the payback period described previously, we modify the procedure to consider the time value of money—that is, the cost of funds (interest) used to support the project. This modified payback period is often referred to as the **discounted-payback period**. In other words, we may define the discounted-payback period as the number of years required to recover the investment from *discounted* cash flows.

EXAMPLE 5.2 Discounted-Payback Periods

Consider the cash flow data given in Example 5.1. Assuming the firm's cost of funds (interest rate) to be 15%, compute the discounted-payback period.

DISSECTING THE PROBLEM

Given: $i = 15\%$ per year; cash flow data in Example 5.1.

Find: Discounted-payback period.

METHODOLOGY

Construct a project cash flow balance table. To determine the period necessary to recover both the capital investment and the cost of funds required to support the investment, we construct Table 5.1, which shows the cash flows and costs of funds to be recovered over the project's life. The cost of funds shown can be thought of as interest payments if the initial investment is financed by loan or as the opportunity cost of committing capital (commonly known as the cost of capital).

SOLUTION

To illustrate, let's consider the cost of funds during the first year. With \$1,800,000 committed at the beginning of the year, the interest in year 1 would be \$270,000(\$1,800,000 × 0.15). Therefore, the total commitment grows to \$2,070,000, but the \$454,000 cash flow in year 1 leaves a net commitment of \$1,616,000. The cost of funds during the second year would be \$242,400(\$1,616,000 × 0.15). But with the \$681,000 receipt from the project, the net commitment reduces to \$1,177,400. When this process repeats for the remaining project years, we find that the net commitment to the project ends during year 4. Depending on the cash flow assumption, the project must remain in use for about 3.56 years (continuous cash flows) or four years (year-end cash flows) in order for the company to cover its cost of capital and recover the funds invested in the project.

TABLE 5.1 Payback Period Calculation Considering the Cost of Funds at 15%

Period	Cash Flow	Cost of Funds (15%)	Cumulative Cash Flow
0	−\$1,800,000	0	−\$1,800,000
1	\$454,000	−1,800,000(0.15) = −270,000	−\$1,616,000
2	\$681,000	−1,616,000(0.15) = −242,400	−\$1,177,400
3	\$908,000	−1,177,400(0.15) = −176,610	−\$446,010
4	\$908,000	−446,010(0.15) = −66,902	\$395,089
5	\$908,000	395,089(0.15) = 59,263	\$1,362,352
6	\$908,000	1,362,352(0.15) = 204,353	\$2,474,705
7	\$1,268,000	2,474,705(0.15) = 371,206	\$4,113,911

COMMENTS: Inclusion of time-value-of-money effects has extended further the payback period for this example by 9.96 months (0.83 years) compared with the conventional payback period. Certainly, this modified measure is an improved one, but it, too, does not show the complete picture of the project's profitability.

5.3 Present-Worth Analysis

Until the 1950s, the payback method was widely used for making investment decisions. As flaws in this method were recognized, however, businesspeople began to search for methods to improve project evaluations. The result was the development of **discounted cash flow techniques (DCFs)**, which take into account the time value of money. One of the DCFs is the net-present-worth (or net-present-value) (NPW or NPV) method.

A capital-investment problem is essentially a matter of determining whether the anticipated cash inflows from a proposed project are sufficiently attractive to invest funds in the project. In developing the NPW criterion, we will use the concept of cash flow equivalence discussed in Chapter 2. As we observed there, the most convenient point at which to calculate the equivalent values is often at time zero, or commonly the point of investment decision. Under the PW criterion, the present worth of all cash inflows associated with an investment project is compared with the present worth of all cash outflows associated with that project. The difference between the two of these cash flows, referred to as the **net present worth** (NPW), determines whether the project is an acceptable investment. When two or more projects are under consideration, NPW analysis further allows us to select the best project by comparing their NPW figures directly–the larger the better.

5.3.1 Net-Present-Worth Criterion

We will first summarize the basic procedure for applying the net-present-worth criterion to a typical investment project, as well as for comparing alternative projects.

- **Evaluating a Single Project**

Step 1: Determine the return (interest rate) that the firm wishes to earn on its investments. The interest rate you choose represents the rate at which the firm can always invest the money in its **investment pool**, the value of capital available for lending and investing. This interest rate is often referred to as either a *required rate of return* or a *minimum attractive rate of return* (MARR). It is also commonly known as a **cost of capital** in the business cummunity. Usually, this selection is a policy decision made by top management. It is possible for the MARR to change over the life of a project, but for now we will use a single rate of interest when calculating PW.

Step 2: Estimate the service life of the project.

Step 3: Estimate the cash inflow for each period over the service life.

Step 4: Estimate the cash outflow for each period over the service life.

Step 5: Determine the net cash flows for each period (Net cash flow = Cash inflow– Cash outflow).

Step 6: Find the present worth of each net cash flow at the MARR. Add up these present-worth figures; their sum is defined as the project's NPW. That is,

$$\mathrm{PW}(i) = \frac{A_0}{(1+i)^0} + \frac{A_1}{(1+i)^1} + \frac{A_2}{(1+i)^2} + \cdots + \frac{A_N}{(1+i)^N}$$

$$= \sum_{n=0}^{N} \frac{A_n}{(1+i)^n} = \sum_{n=0}^{N} A_n(P/F, i, n), \tag{5.1}$$

where

$$\begin{aligned} PW(i) &= \text{NPW calculated at } i, \\ A_n &= \text{net cash flow at the end of period } n, \\ i &= \text{MARR (or cost of capital), and} \\ n &= \text{service life of the project.} \end{aligned}$$

A_n will be positive if the corresponding period has a net cash inflow and negative if the period has a net cash outflow.

Step 7: In this context, a positive PW(i) means that the equivalent worth of the inflows is more than the equivalent worth of the outflows so that the project makes a profit. Therefore, if the PW(i) is positive for a single project, the project should be accepted; if it is negative, the project should be rejected. The process of applying the NPW measure is shown in Figure 5.3 and is implemented with the following decision rule:

$$\begin{aligned} &\text{If } PW(i) > 0, \text{ accept the investment.} \\ &\text{If } PW(i) = 0, \text{ remain indifferent.} \\ &\text{If } PW(i) < 0, \text{ reject the investment.} \end{aligned}$$

Principle: Compute the equivalent net surplus at $n = 0$ for a given interest rate of i.
Decision Rule: Accept the project if the net surplus is positive.

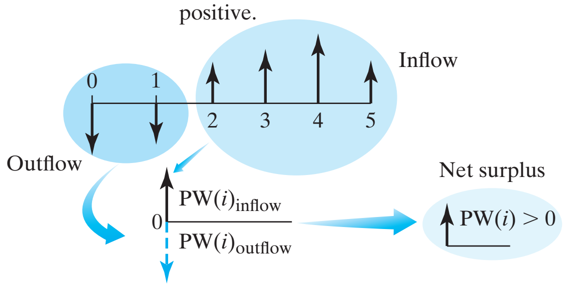


Figure 5.3 Illustration of how NPW decision rules work.

- **Comparing More than One Alternative**
  Note that the foregoing decision rule is for evaluation of a single project for which you can estimate the revenues as well as the costs.[2] The following guidelines should be used for evaluating and comparing more than one project:

1. If you need to select the best alternative, based on the net-present-worth criterion, select the one with the highest NPW, as long as all the alternatives have the same service lives. Comparison of alternatives with unequal service lives requires special assumptions as will be detailed in Section 5.4.
2. As you will find in Section 5.4, comparison of mutually exclusive alternatives with the same revenues is performed on a *cost-only basis*. In this situation, you should accept the project that results in the smallest PW of costs, or the least negative PW (because you are minimizing costs rather than maximizing profits).

[2] Some projects cannot be avoided–e.g., the installation of pollution-control equipment to comply with government regulations. In such a case, the project would be accepted even though its PW(i) < 0.

For now, we will focus on evaluating a single project. Techniques on how to compare multiple alternatives will be addressed in more detail in Section 5.4.

EXAMPLE 5.3 Net Present Worth—Uneven Flows

Consider the Multi-Tasking® machine center investment project in Example 5.1. Recall that the required initial investment of \$1,800,000 and the projected cash savings over a seven-year project life are as follows:[3]

End of Year	Cash Flow
0	−\$1,800,000
1	\$454,000
2	\$681,000
3	\$908,000
4	\$908,000
5	\$908,000
6	\$908,000
7	\$1,268,000

You have been asked by the president of the company to evaluate the economic merit of the acquisition. The firm's MARR is known to be 15% per year.

DISSECTING THE PROBLEM

Given: Cash flows as tabulated; MARR = 15% per year.
Find: NPW.

METHODOLOGY

Calculate the net present value of the Multi-Tasking® machine center. We could accomplish this task in two ways: (1) use Eq. (5.1) or (2) use Excel as shown in Table 5.2.

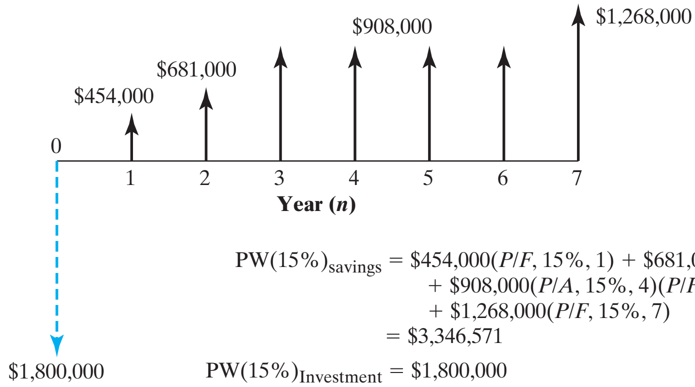
SOLUTION

If we bring each flow to its equivalent at time zero as shown in Figure 5.4, we find that

$$\begin{aligned} PW(15\%) &= -\$1{,}800{,}000 + \$454{,}000(P/F, 15\%, 1) \\ &\quad + \$681{,}000\,(P/F, 15\%, 2) \\ &\quad + \$908{,}000(P/A, 15\%, 4)(P/F, 15\%, 2) \\ &\quad + \$1{,}268{,}000(P/F, 15\%, 7) \\ &= \$1{,}546{,}571. \end{aligned}$$

Since the project results in a surplus of \$1,546,571, the project is acceptable. It is returning a profit greater than 15%.

[3] As we stated at the beginning of this chapter, we treat net cash flows in actual dollars as before-tax values or as having their tax effects precalculated. Explaining the process of obtaining cash flows requires an understanding of income taxes and the role of depreciation, which are discussed in Chapters 9 and 10.



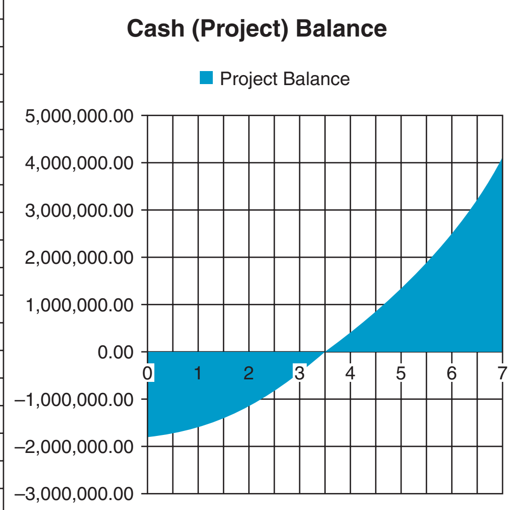
$$
\begin{aligned}
\text{PW}(15\%)_{\text{savings}} &= \$454{,}000(P/F, 15\%, 1) + \$681{,}000(P/F, 15\%, 2) \\
&\quad + \$908{,}000(P/A, 15\%, 4)(P/F, 15\%, 2) \\
&\quad + \$1{,}268{,}000(P/F, 15\%, 7) \\
&= \$3{,}346{,}571 \\
\text{PW}(15\%)_{\text{Investment}} &= \$1{,}800{,}000 \\
\text{PW}(15\%) &= \$3{,}346{,}571 - \$1{,}800{,}000 \\
&= \$1{,}546{,}571 > 0, \text{ Accept}
\end{aligned}
$$

Figure 5.4 Calculating the net present value of the Multi-Tasking® machine center project.

TABLE 5.2 An Excel Worksheet to Illustrate the Process of Computing the NPW

	A	B	C	D
2	Input			
3				
4	(*i*) MARR (%)			15%
5	(*N*) Project life			7
6				
7		Cash	Interest	Cash
8	Period	Flow	Earned/Charged	Balance
9				
10	0	$ (1,800,000)		$ (1,800,000)
11	1	$ 454,000	$ (270,000)	$ (1,616,000)
12	2	$ 681,000	$ (242,400)	$ (1,177,400)
13	3	$ 908,000	$ (176,610)	$ (446,010)
14	4	$ 908,000	$ (66,902)	$ 395,089
15	5	$ 908,000	$ 59,263	$ 1,362,352
16	6	$ 908,000	$ 204,353	$ 2,474,705
17	7	$ 1,268,000	$ 371,206	$ 4,113,910
18				
19		=D16*($D$4)		
20				
21			=D16+C17+B17	
22				
23				
24				
25				
26				

	F–J	L
2	Output	
4	(*P*) Net Present Worth	$ 1,546,571
5	(*F*) Net Future Worth	$ 4,113,910



COMMENTS: We could easily automate the process of computing the net present worth of any project cash flow series by using Excel. As shown in Table 5.2, we create two areas: one for inputs and the other for outputs. We can start to enter the periodic cash flows in cell B10. With Excel, we can easily enter some cash flow series with a specific pattern, such as equal payment, gradient, or geometric. In most cases, we assume a constant interest rate (MARR) in our NPW calculations. If more than one interest rate may apply to properly account for the time value of money, we simply enter these changing interest rates by creating a new column next to "Cash Flow" and compute the "Interest Earned" as a function of these interest rates. The project balance indicates a periodic cash (or project) balance at the end of each period. In the output area, we find the net present-worth figure along with the net future worth (which will be explained in Section 5.3.4). We can also observe a plot for a cash balance chart.

In Example 5.3, we computed the NPW of the project at a fixed interest rate of 15%. If we compute the NPW at varying interest rates, we obtain the data shown in Table 5.3. Plotting the NPW as a function of interest rate gives the graph in Figure 5.5, the present-worth profile.

Figure 5.5 indicates that the investment project has a positive NPW if the interest rate is below 36.32% and a negative PW if the interest rate is above 36.32%. As we will see in Chapter 7, this **break-even interest rate** is known as the **internal rate of return**. If the firm's MARR is 15%, the project's NPW is $1,546,571, so the $1.8M capital expenditure may be easily justified. The figure of $1,546,571 measures the equivalent immediate value creation in present worth to the firm following the acceptance of the project. On the other hand, at $i = 40\%$, $\text{PW}(40\%) = -\$151{,}293$, the firm should reject the project in this case (even though it is highly unlikely that a

TABLE 5.3 **Net Present-Worth Amounts at Varying Interest Rates**

	A	B	C	D	E	F	G	H	I	J
1										
2		Input					Output			
3										
4	(*i*) MARR (%)			15%		MARR (%)	NPW		MARR (%)	NPW
5	(*N*) Project life			7						
6						0	$4,235,000		26	$567,751
7		Cash	Interest	Project		2	$3,726,686		28	$437,522
8	Period	Flow	Earned	Balance		4	$3,277,023		30	$318,140
9						6	$2,877,892		32	$208,470
10	0	$ (1,800,000)		$ (1,800,000)		8	$2,522,454		34	$107,518
11	1	$ 454,000	$ (270,000)	$ (1,616,000)		10	$2,204,931		36	$14,407
12	2	$ 681,000	$ (242,400)	$ (1,177,400)		12	$1,920,417		38	($71,636)
13	3	$ 908,000	$ (176,610)	$ (446,010)		14	$1,664,735		40	($151,293)
14	4	$ 908,000	$ (66,902)	$ 395,089		16	$1,434,319		42	($225,170)
15	5	$ 908,000	$ 59,263	$ 1,362,352		18	$1,226,106		44	($293,803)
16	6	$ 908,000	$ 204,353	$ 2,474,705		20	$1,037,466		46	($357,671)
17	7	$ 1,268,000	$ 371,206	$ 4,113,910		22	$866,128		48	($417,201)
18						24	$710,125		50	($472,772)

=D16*($D$4)

=D16+C17+B17

=NPV(F18%,$B$11:$B$17)+$B$10

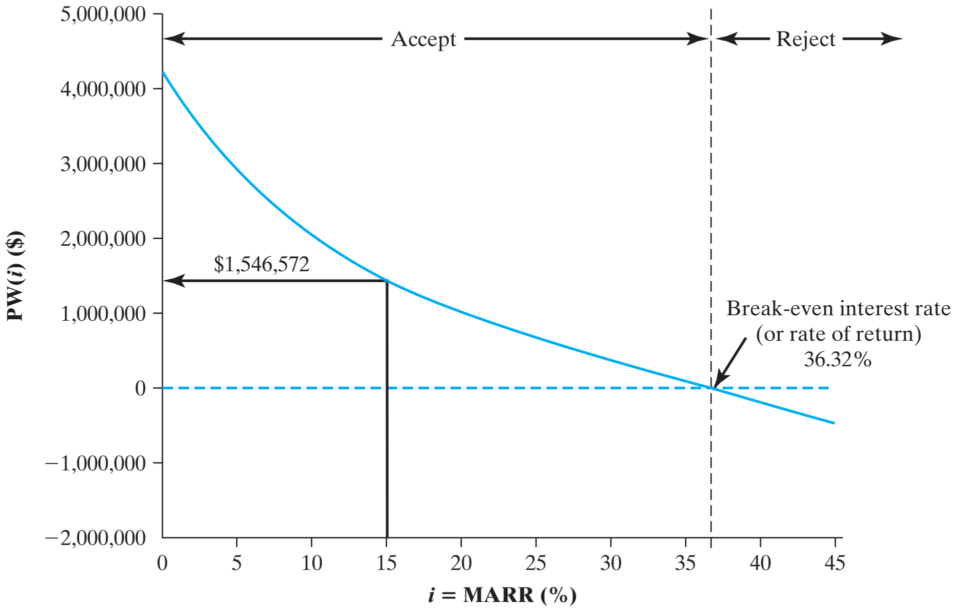


Figure 5.5 Net present-worth profile described in Example 5.3.

firm's MARR will be this high). Note that the decision to accept or reject an investment is influenced by the choice of a MARR, so it is crucial to understand how the MARR is determined. We will briefly describe the elements to consider when setting this interest rate for project evaluation.

5.3.2 Guidelines for Selecting a MARR

Return is what you get back in relation to the amount you invested. Return is one way to evaluate how your investments in financial assets or projects do in relation to each other and in relation to the performance of investments in general. Let us look first at how we may derive rates of return. Conceptually, the rate of return that we realistically expect to earn on any investment is a function of three components:

- Risk-free real return
- Inflation factor
- Risk premium(s)

Suppose you want to invest in a stock. First, you would expect to be compensated in some way for not being able to use your money while you hold the stock. Second, you would expect to be compensated for decreases in purchasing power between the time you invest and the time your investment is returned to you. Finally, you would demand additional rewards for having taken the risk of losing your money if the stock did poorly. If you did not expect your investment to compensate you for these factors, why would you tie up your money in this investment in the first place?

For example, if you were to invest $1,000 in risk-free U.S. Treasury bills for a year, you would expect a real rate of return of about 2%. Your risk premium would be zero. You probably think that this does not sound like much. However, you must also add an allowance for inflation. If you expect inflation to be about 4% during the

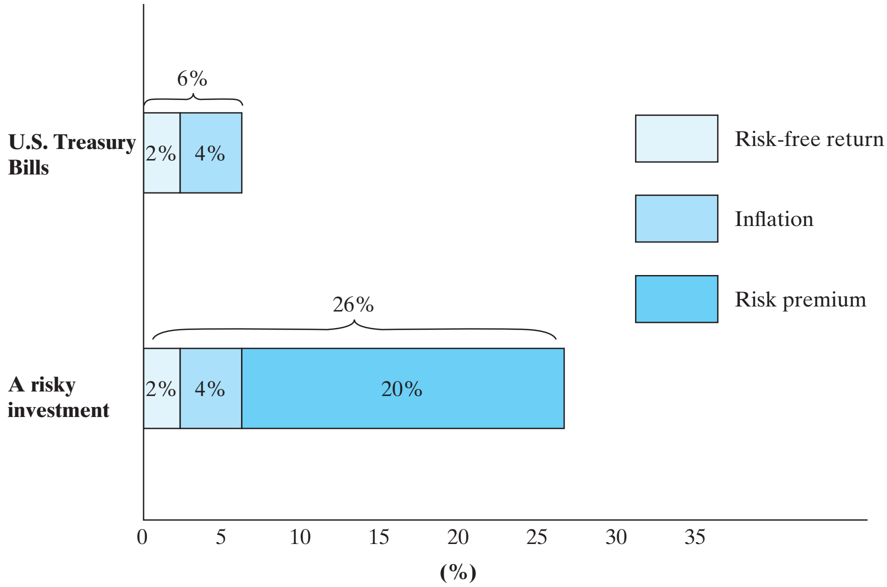


Figure 5.6 Elements of required return—establishing a MARR.

investment period, you should realistically expect to earn 6% during that interval (2% real return + 4% inflation factor + 0% for risk premium). This concept is illustrated in Figure 5.6.

How would it work out for a riskier investment, say, an Internet stock? As you would consider the investment to be a very volatile one, you would increase the risk premium to, say, 20%. So, you will not invest your money in such a stock unless you are reasonably confident of having it grow at an annual rate of 2% real return + 4% inflation factor + 20% risk premium = 26%. Again, the risk premium of 20% is a perceived value that can vary from one investor to another.

We use the same concept in selecting the interest rate for a project evaluation. If you consider a routine project where you can reasonably predict the future cash flows with a great deal of confidence, a lower interest (discount) will be prevailed. In Section 11.4, we will consider this special issue in more detail. For now, we will assume that the firm has established a single interest rate for project evaluation, considering all relevant risk inherent in the project, and we will use this rate to measure the project's worth.

5.3.3 Meaning of Net Present Worth

In present-worth analysis, we assume that all the funds in a firm's treasury can be placed in investments that yield a return equal to the MARR. We may view these funds as an *investment pool*. Alternatively, if no funds are available for investment, we assume that the firm can borrow them at the MARR from the capital markets (commonly known as a cost of capital). In this section, we will examine these two views when explaining the meaning of MARR in PW calculations.

Investment-Pool Concept

An investment pool is equivalent to a firm's treasury to collect and concentrate surplus funds from various departments and programs for investment purposes. It is where all fund transactions are administered and managed by the firm's comptroller. The firm may withdraw funds from this investment pool for other investment purposes, but if left in the pool, the funds will earn interest at the MARR. Thus, in investment analysis, net cash flows will be those that are relative to this investment pool. To illustrate the investment-pool concept, we consider again the project in Example 5.3, which required an investment of \$1,800,000.

If the firm did not invest in the project and instead left the \$1,800,000 in the investment pool for seven years, these funds would have grown as follows:

$$\$1{,}800{,}000(F/P, 15\%, 7) = \$4{,}788{,}036.$$

Suppose the company did decide to invest \$1,800,000 in the project described in Example 5.3. Then the firm would receive a stream of cash inflows during the project life of seven years in the following amounts:

End of Year (n)	Cash Flow (A_n)
1	\$454,000
2	\$681,000
3	\$908,000
4	\$908,000
5	\$908,000
6	\$908,000
7	\$1,268,000

Since the funds that return to the investment pool earn interest at a rate of 15%, it would be helpful to see how much the firm would benefit from this investment. For this alternative, the returns after reinvestment are as follows:

$$\begin{aligned}
\$454{,}000(F/P, 15\%, 6) &= \$1{,}050{,}130\\
\$681{,}000(F/P, 15\%, 5) &= \$1{,}369{,}734\\
\$908{,}000(F/A, 15\%, 4)(F/P, 15\%, 1) &= \$5{,}214{,}082\\
\$1{,}268{,}000(F/P, 15\%, 0) &= \underline{\$1{,}268{,}000}\\
& \$8{,}901{,}946.
\end{aligned}$$

These returns total \$8,901,946. The additional cash accumulation at the end of seven years from investing in the project is

$$\$8{,}901{,}946 - \$4{,}788{,}036 = \$4{,}113{,}910.$$

This \$4,113,910 surplus is also known as *net future worth of the project* at the project termination. If we compute the equivalent present worth of this net cash surplus at time 0, we obtain

$$\$4{,}113{,}910(P/F, 15\%, 7) = \$1{,}546{,}571,$$

which is exactly the same as the NPW of the project as computed by Eq. (5.1). Clearly, on the basis of its positive NPW, the alternative of purchasing the multitasking machine

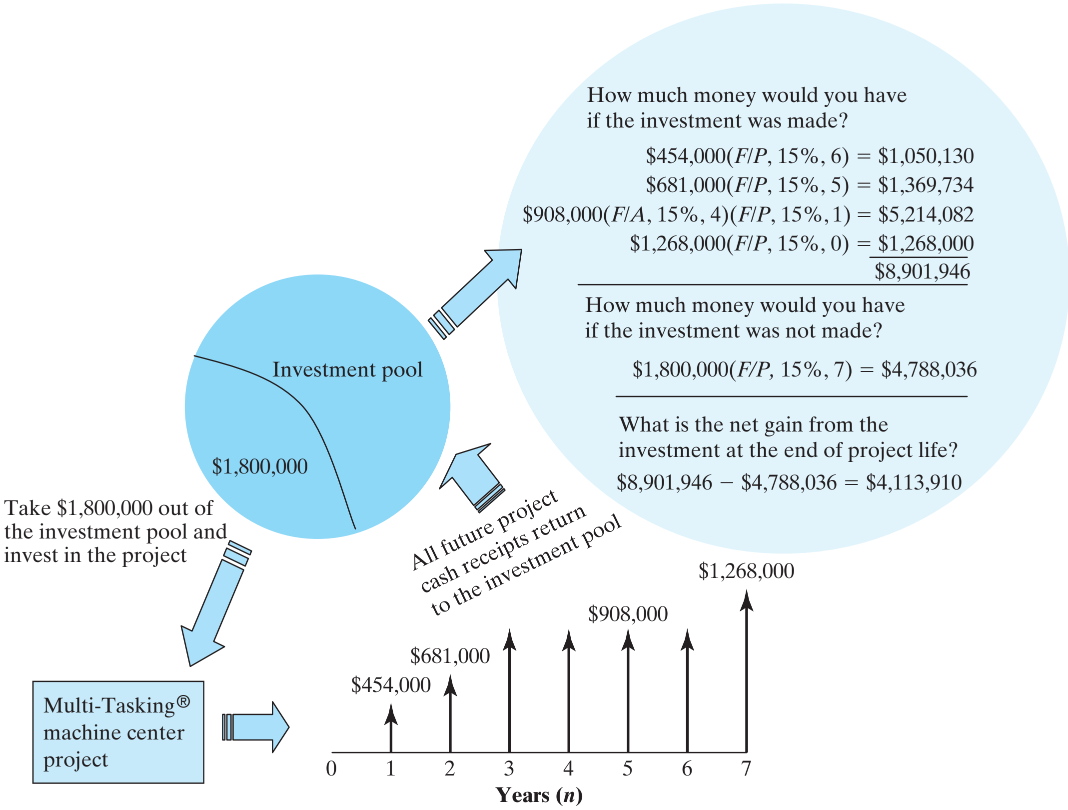


Figure 5.7 The concept of the investment pool with the company as a lender and the project as a borrower.

should be preferred to that of simply leaving the funds in the investment pool at the MARR. Thus, in NPW analysis, any investment is assumed to be returned at the MARR. If a surplus exists at the end of the project life, then we know that $\text{PW}(\text{MARR}) > 0$. Figure 5.7 summarizes the reinvestment concept as it relates to the firm's investment pool.

Borrowed-Funds Concept

Suppose that the firm does not have $1,800,000 at the outset. In fact, the firm does not have to maintain an investment pool at all. Let's further assume that the firm borrows all its capital from a bank at an interest rate of 15% per year, invests in the project, and uses the proceeds from the investment to pay off the principal and interest on the bank loan. How much is left over for the firm at the end of the project period?

At the end of the first year, the interest on the bank loan would be $1,800,000 (0.15) = 270,000. Therefore, the total loan balance grows to $1,800,000 (1.15) = 2,070,000. Then the firm receives $454,000 from the project and applies the entire amount to repay the loan portion. This repayment leaves a balance due of

$$\text{PB}(15\%)_1 = -\$1{,}800{,}000(1 + 0.15) + \$454{,}000 = -\$1{,}616{,}000.$$

This amount is also known as the **project balance**. We will use $\text{PB}(i)_n$ to denote the cash balance at the end of period n. As summarized in Table 5.4, this amount becomes the net amount the project is borrowing at the beginning of year 2.

TABLE 5.4 **Tabular Approach to Determining the Project Balances**

	A	B	C	D	E	F	G	H	I
1									
2	End of Year (*n*)	0	1	2	3	4	5	6	7
3									
4	Beginning Project Balance		($1,800,000)	($1,616,000)	($1,177,400)	($446,010)	$395,089	$1,362,352	$2,474,705
5	Interest Charged (15%)		($270,000)	($242,400)	($176,610)	($66,902)	$59,263	$204,353	$371,206
6	Payment Received	($1,800,000)	$454,000	$681,000	$908,000	$908,000	$908,000	$908,000	$1,268,000
7									
8	Project Balance	($1,800,000)	($1,616,000)	($1,177,400)	($446,010)	$395,089	$1,362,352	$2,474,705	$4,113,910
9									
10				=PV(15%,7,0,-I8,0)				E8	
11	Net Present Worth (15%)	$1,546,571							
12	Net Future Worth (15%)	$4,113,910	=I8				=SUM(F4:F6)	=F4*0.15	
13									
14									

At the end of year 2, the debt to the bank grows to $\$1{,}616{,}000(1.15) = \$1{,}858{,}400$. But with the receipt of $681,000, the project balance reduces to

$$PB(15\%)_2 = -\$1{,}616{,}000(1 + 0.15) + \$681{,}000 = -\$1{,}177{,}400.$$

The process continues, and eventually, at the end of year 4, the debt to the bank becomes $\$446{,}010(1.15) = \$512{,}912$. With the receipt of $908,000 from the project, however, the firm should be able to pay off the remaining debt and come out with a surplus in the amount of $395,089.

$$-\$446{,}010(1 + 0.15) + \$908{,}000 = \$395{,}089.$$

Once the firm pays off the bank loan, we will assume that any surplus generated from the project will go into its investment pool and earn interest at the same rate of 15%. Therefore, the project balance at the end of year 5 will be calculated as

$$\begin{aligned} n &= 5, \quad \$395{,}089(1 + 0.15) + \$908{,}000 = \$1{,}362{,}352 \\ n &= 6, \quad \$1{,}362{,}352(1 + 0.15) + \$908{,}000 = \$2{,}474{,}705 \\ n &= 7, \quad \$2{,}474{,}705(1 + 0.15) + \$1{,}268{,}000 = \$4{,}113{,}910. \end{aligned}$$

Note that the amount of the terminal project balance is $4,113,910, which is positive, indicating that the firm fully repays its initial bank loan and interest at the end of year 4, with a resulting profit of $4,113,910. Finally, if we compute the equivalent present worth of this net surplus at time 0, we obtain

$$PW(15\%) = \$4{,}113{,}910(P/F, 15\%, 7) = \$1{,}546{,}571.$$

The result is identical to the case where we directly computed the PW of the project at $i = 15\%$, shown in Example 5.3. The critical assumption here is that the firm will be able to borrow the funds when needed but invest any surplus returned to its investment pool earning at the same interest rate of 15%.

5.3.4 Net Future Worth and Project Balance Diagram

The terminal project balance in Table 5.4 ($4,113,910) is also known as the **net future worth** of the project, and we can use this number, just like the net present value, as a figure of investment worth to make an accept–reject decision on the project. In other words, if the net future worth is positive, indicating a surplus, we should accept the investment. Otherwise, we may reject the project. This decision rule will be consistent with the net present worth criterion, as we obtain the NPW of the project from its net future worth simply by applying the discounting factor, which is always nonnegative. Alternatively, we can show why the terminal project balance is equivalent to the net future worth of the project as follows:

$$
\begin{aligned}
n\text{: } 0 \rightarrow \mathrm{PB}(i)_0 &= A_0 \\
n\text{: } 1 \rightarrow \mathrm{PB}(i)_1 &= \mathrm{PB}(i)_0(1+i) + A_1 \\
&= A_0(1+i) + A_1 \\
n\text{: } 2 \rightarrow \mathrm{PB}(i)_2 &= \mathrm{PB}(i)_1(1+i) + A_2 \\
&= A_0(1+i)^2 + A_1(1+i) + A_2 \\
n\text{: } N \rightarrow \mathrm{PB}(i)_N &= \mathrm{PB}(i)_{N-1}(1+i) + A_N \\
&= A_0(1+i)^N + A_1(1+i)^{N-1} + \cdots + A_N \\
&= \mathrm{FW}(i). \qquad (5.2)
\end{aligned}
$$

Therefore, in our example we can calculate the net future worth of the project by using Eq. (5.2):

$$
\begin{aligned}
\mathrm{FW}(15\%) &= -\$1{,}800{,}000(1+0.15)^7 + \$454{,}000(1+0.15)^6 \\
&\quad + \$681{,}000(1+0.15)^5 + \cdots + \$1{,}268{,}000 \\
&= \$4{,}113{,}910.
\end{aligned}
$$

Figure 5.8 illustrates the project balance as a function of time. In this diagram, we can observe four important investment characteristics of the project:

- **The exposure to financial risk:** A negative project balance indicates the amount of investment to be recovered or exposed to risk of loss if the project is terminated at this point. The negative project balance area will increase if the cash received from the project is less than the interest owed for the period. If the other situation prevails, the negative area will decrease. Therefore, if other things are equal, we prefer a smaller area of negative project balance.
- **The discounted payback period:** This indicates how long it will be before the project breaks even. This condition occurs when the project balance becomes nonnegative. (In our example, this occurs at $n = 4$.) If the project is terminated after this discounted payback period, no economic loss is anticipated if there is no additional investment required to close the project. Clearly, we prefer a shorter discounted payback period if other things are equal.
- **The profit potential:** The area in light **blue** represents the area of positive project balance. Since the initial investment plus interest has been fully recovered at this phase of the project, any cash generated during this period directly contributes toward the final profitability of the project. Therefore, we prefer a larger area of positive project balance (if other things are equal) as this area indicates the magnitude of profits expected and the rate at which they will be accumulated. This information will be useful when we must decide on the right time to phase out the investment. (This decision is called the abandonment decision.)
- **The net future worth (surplus):** The terminal project balance indicates the surplus of the project at the end of the project life. If we borrowed money to finance the project, this figure would represent any additional cash generated from the project as well as reinvestment of the cash left over after we paid back the amount borrowed with all interest.

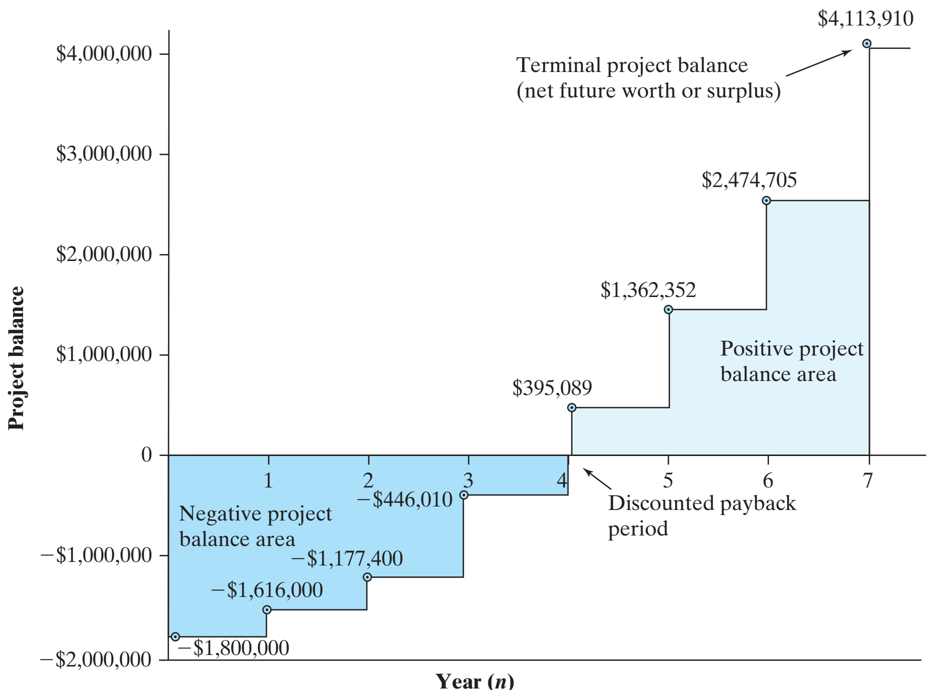


Figure 5.8 Project balance diagram as a function of investment period—(1) area of negative project balance, (2) discounted payback period, (3) area of positive project balance, and (4) terminal project balance (or net future worth of the investment).

Clearly, a project balance diagram provides important insights into the desirability of the investment and the ultimate profitability of the project (net present value). This additional information will be even more important when we need to compare various projects having similar profitability. For example, if two investment projects have the same or similar NPW, you may prefer the investment with a smaller area of negative project balance of shorter discounted payback period.

5.3.5 Capitalized-Equivalent Method

Let's consider a situation where the life of a proposed project is **perpetual** or the planning horizon is extremely long (say, 40 years or more). Many public projects such as bridge and waterway construction, irrigation systems, and hydroelectric dams are expected to generate benefits over an extended period of time (or forever). How do we calculate the PW for these projects? In this section, we examine the **capitalized-equivalent** [CE(i)] method, a special case of the NPW criterion, for evaluating such projects.

Perpetual Service Life

Consider the cash flow series shown in Figure 5.9. How do we determine the PW for an infinite (or almost infinite) uniform series of cash flows or a repeated cycle of cash flows? The process of computing the PW for this infinite series is referred to as the **capitalization** of project cost. The cost is known as the **capitalized cost**. The capitalized cost represents the amount of money that must be invested today in order to yield a

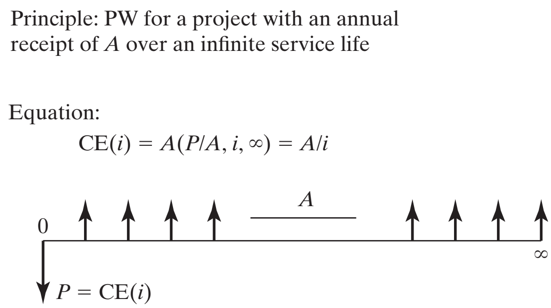


Figure 5.9 Capitalized-equivalent worth—a project with a perpetual service life.

certain return A at the end of each and every period, forever, assuming an interest rate of i. Observe the limit of the uniform-series present-worth factor as N approaches infinity:

$$\lim_{N\to\infty} (P/A, i, N) = \lim_{N\to\infty}\left[\frac{(1+i)^N - 1}{i(1+i)^N}\right] = \frac{1}{i}.$$

Thus, it follows that

$$\text{PW}(i) = A(P/A, i, N \to \infty) = \frac{A}{i}. \tag{5.3}$$

This is the same result shown in Section 2.5.5. Another way of looking at this concept is to ask what constant income stream could be generated by PW(i) dollars today in perpetuity. Clearly, the answer is $A = i\text{PW}(i)$. If withdrawals were higher than A, you would be eating into the principal, which would eventually reduce it to zero.

EXAMPLE 5.4 Capitalized-Equivalent Cost

An engineering school has just completed a new engineering complex worth \$50 million. A campaign targeting alumni is planned to raise funds for future maintenance costs, which are estimated at \$2 million per year. Any unforeseen costs above \$2 million per year would be obtained by raising tuition. Assuming that the school can create a trust fund that earns 8% interest annually, how much has to be raised now to cover the perpetual string of \$2 million annual costs?

DISSECTING THE PROBLEM

Given: $A = \$2$ million, $i = 8\%$ per year, and $N = \infty$.
Find: CE(8%).

METHODOLOGY

Calculate capitalized cost.

SOLUTION

The capitalized-cost equation is

$$\text{CE}(i) = \frac{A}{i}.$$

Substituting in our given values, we obtain

$$\begin{aligned} CE(8\%) &= \$2{,}000{,}000/0.08 \\ &= \$25{,}000{,}000. \end{aligned}$$

COMMENTS: It is easy to see that this lump-sum amount should be sufficient to pay maintenance expenses for the school forever. Suppose the school deposited \$25 million at a bank that paid 8% interest annually. At the end of the first year, the \$25 million would earn 8%(\$25 million) = \$2 million interest. If this interest were withdrawn, the \$25 million would remain in the account. At the end of the second year, the \$25 million balance would again earn 8%(\$25 million) = \$2 million. The annual withdrawal could be continued forever, and the endowment (gift funds) would always remain at \$25 million.

5.4 Methods to Compare Mutually Exclusive Alternatives

Until now, we have considered situations involving only a single project or projects that were independent of each other. In both cases, we made the decision to accept or reject each project individually according to whether it met the MARR requirements, evaluated by using the PW.

In the real world of engineering practice, however, it is typical for us to have two or more choices of projects for accomplishing a business objective. (As we shall see, even when it appears that we have only one project to consider, the implicit "do-nothing" alternative must be factored into the decision-making process.)

In this section, we extend our evaluation techniques to consider multiple projects that are mutually exclusive. Often, various projects or investments under consideration do not have the same duration or do not match the desired study period. Adjustments must be made when we compare multiple options in order to properly account for such differences. We also explain the concepts of an analysis period and the process of accommodating for different lifetimes as important considerations in selecting among several alternatives. In the first few subsections of this section, all available options in a decision problem are assumed to have equal lifetimes. In Section 5.4.4, this restriction is relaxed.

When alternatives are **mutually exclusive**, any one of them will fulfill the same need, and thus the selection of one alternative implies that the others will be excluded. Take, for example, buying versus leasing an automobile for business use: When one alternative is accepted, the other is excluded. We use the terms **alternative** and **project** interchangeably to mean decision option. *One of the fundamental principles in comparing mutually exclusive alternatives is that they must be compared over an equal time span (or* ***analysis period****)*. In this section, we will present some of the fundamental principles that should be applied in comparing mutually exclusive investment alternatives. In doing so, we will consider two cases: (1) one where the analysis period equals the project lives and (2) the other where the analysis period differs from the project lives. In each case, the required assumption for analysis can be varied. First, we will define some of the relevant terminology, such as "do-nothing alternative," "revenue project," and "service project."

5.4.1 Doing Nothing Is a Decision Option

Investment projects fall within two types. A project either is aimed at replacing (or improving) an existing asset or system or is a new endeavor. In either case, a do-nothing alternative may exist. If a process or system already in place to accomplish our business objectives is still adequate, then we must determine which, if any, new proposals are economical replacements. If none are feasible or economical, then we do nothing. On the other hand, if the existing system has terminally failed, the choice among proposed alternatives is mandatory (i.e., doing nothing is not an option).

New endeavors occur as alternatives to the do-nothing situation, which has zero revenues and zero costs. For most new endeavors, doing nothing is generally an alternative because we will not proceed unless at least one of the proposed alternatives is economically sound. In fact, undertaking even a single project entails making a decision between two alternatives when the project is optional because the do-nothing alternative is implicitly included. Occasionally, a new initiative *must* be undertaken, cost notwithstanding, and in this case, the goal is to choose the most economical alternative since doing nothing is not an option.

When the option of retaining an existing asset or system is available, there are two ways to incorporate it into the evaluation of the new proposals. One way is to treat the do-nothing option as a distinct alternative; this approach will be covered primarily in Chapter 12, where methodologies specific to replacement analysis are presented. The second approach, used in this chapter, is to generate the incremental cash flows of the new proposals relative to those of the do-nothing alternative—what additional costs and benefits can we expect from the new proposals? That is, for each new alternative, the **incremental costs** (and incremental savings or revenues if applicable) relative to those of the do-nothing alternative are used for the economic evaluation.

For a replacement-type problem, we calculate the incremental cash flow by subtracting the do-nothing cash flows from those of each new alternative. For new endeavors, the incremental cash flows are the same as the absolute amounts associated with each alternative since the do-nothing values are all zero.

5.4.2 Service Projects versus Revenue Projects

When comparing mutually exclusive alternatives, we need to classify investment projects as either service or revenue projects.

Service Projects

Suppose an electric utility company is considering building a new power plant to meet the peak-load demand during either hot summer or cold winter days. Two alternative service projects could meet this peak-load demand: a combustion turbine plant or a fuel-cell power plant. No matter which type of plant is selected, the firm will generate the same amount of revenue from its customers. The only difference is how much it will cost to generate electricity from each plant. If we were to compare these service projects, we would be interested in knowing which plant could provide cheaper power (lower production cost). Therefore, **service projects** are projects that generate revenues that do not depend on the choice of project but *must produce the same amount of output (revenue).* In this situation, we certainly want to choose an alternative with the least input (or cost). Further, if we were to use the PW criterion to compare these alternatives to minimize expenditures, *we would choose the alternative with the* ***lower present-value*** *production cost over the service life.*

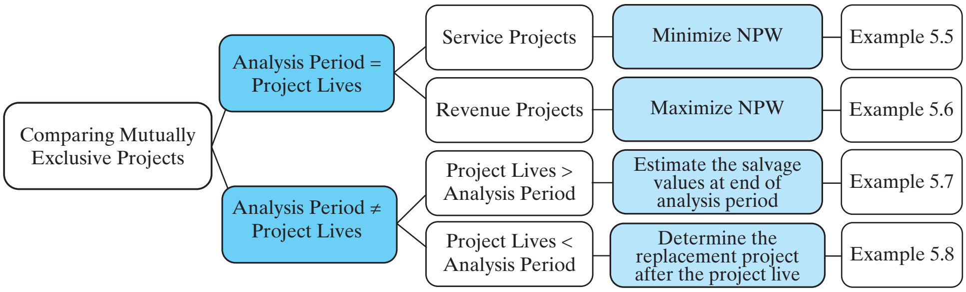


Figure 5.10 Analysis period implied in comparing mutually exclusive alternatives.

Revenue Projects

Suppose that a computer-monitor manufacturer is considering marketing two types of high-resolution monitors. With its present production capacity, the firm can market only one of them. Distinct production processes for the two models could incur very different manufacturing costs, and the revenues from each model would be expected to differ, due to divergent market prices and potentially different sales volumes. Clearly, these projects' revenues depend on the choice of alternative. For such **revenue projects**, we are not limiting the amount of input to the project or the amount of output that the project would generate. Therefore, we want to select the alternative with the largest net gains (output − input). In this situation, if we were to use the PW criterion, *we would select the model that promises to bring in the **largest net present worth***. Figure 5.10 summarizes the procedure required to compare mutually exclusive alternatives.

5.4.3 Analysis Period Equals Project Lives

Let us begin our analysis with the simplest situation in which the project lives equal the analysis period. In this case, we compute the PW for each project and select the one with the highest PW. Example 5.5 illustrates this point.

EXAMPLE 5.5 A Service Project with a "Do-Nothing" Alternative

Ansell, Inc., a medical-device manufacturer, uses compressed air in solenoids and pressure switches in its machines to control various mechanical movements. Over the years, the manufacturing floor layout has changed numerous times. With each new layout, more piping was added to the compressed-air delivery system in order to accommodate new locations of manufacturing machines. None of the extra, unused old piping was capped or removed; thus, the current compressed-air delivery system is inefficient and fraught with leaks. Because of the leaks in the current system, the compressor is expected to run 70% of the time that the plant will be in operation during the upcoming year. The compressor will require 260 kW of electricity at a rate of \$0.05/kWh. The plant runs 250 days a year, 24 hours per day. Ansell may address this issue in one of two ways:

- **Option 1:** Continue current operation or "do-nothing" alternative. If Ansell continues to operate the current air delivery system, the compressor's run time will increase by 7% per year for the next five years because of ever-worsening leaks. (After five years, the current system will not be able to meet the plant's compressed-air requirement, so it will have to be replaced.)

- **Option 2:** Replace old piping now. If Ansell decides to replace all of the old piping now, new piping will cost \$28,570. The compressor will still run for the same number of days; however, it will run 23% less (or will incur $70\%(1-0.23) = 53.9\%$ usage per day) because of the reduced air-pressure loss.

If Ansell's interest rate is 12% compounded annually, is it worth fixing the air delivery system now?

DISSECTING THE PROBLEM

Given: Current power consumption, $g = 7\%, i = 12\%$ per year, and $N = 5$ years.

Find: A_1 and P.

METHODOLOGY

Construct a chart comparing the options. In doing so, first determine the required annual power consumption with the current system. Then, calculate the estimated energy loss due to leaks from old the piping system.

SOLUTION

- **Step 1:** We need to calculate the cost of power consumption of the current piping system during the first year. The power consumption is determined as follows:

$$\begin{aligned}\text{Annual power cost} &= \text{\% of day operating} \times \text{days operating per year} \\ &\quad \times \text{ hours per day } \times \text{ kW} \times \$/\text{kWh} \\ &= (70\%) \times (250 \text{ days/year}) \times (24 \text{ hours/day}) \\ &\quad \times (260 \text{ kW}) \times (\$0.05/\text{kWh}) \\ &= \$54{,}600.\end{aligned}$$

- **Step 2:** Each year, if the current piping system is left in place, the annual power cost will increase at the rate of 7% over the previous year's cost. The anticipated power cost over the five-year period is summarized in Figure 5.11. The equivalent present lump-sum cost at 12% interest for this geometric gradient series is

$$\begin{aligned}P_{\text{Option 1}} &= \$54{,}600(P/A_1, 7\%, 12\%, 5) \\ &= \$54{,}600\left[\frac{1-(1+0.07)^5(1+0.12)^{-5}}{0.12-0.07}\right] \\ &= \$222{,}937.\end{aligned}$$

- **Step 3:** If Ansell replaces the current compressed-air delivery system with the new one, the annual power cost will be 23% less during the first year and will remain at that level over the next five years. The equivalent present lump-sum cost at 12% interest is

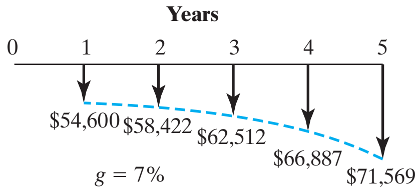
$$\begin{aligned}P_{\text{Option 2}} &= \$54{,}600(1-0.23)(P/A, 12\%, 5) \\ &= \$42{,}042(3.6048) \\ &= \$151{,}553.\end{aligned}$$

- **Step 4:** The net cost of not replacing the old system now is $\$71{,}384(= \$222{,}937 - \$151{,}553)$. Since the new system costs only \$28,570, the replacement should be made now.

- Option 1:

  $g = 7\%$
  $i = 12\%$
  $N = 5$ years
  $A_1 = \$54{,}600$

$$P_{\text{Option 1}} = \$54{,}600\left[\frac{1-(1+0.07)^5(1+0.12)^{-5}}{0.12-0.07}\right] = \$222{,}937$$



- Option 2:

$$\begin{aligned} P_{\text{Option 2}} &= \$54{,}600(1-0.23)(P/A, 12\%, 5) \\ &= \$42{,}042(P/A, 12\%, 5) \\ &= \$151{,}553 \end{aligned}$$

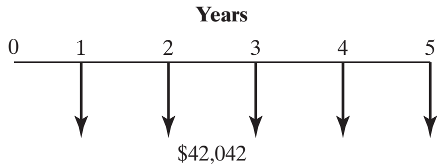


Figure 5.11 Comparing two mutually exclusive options.

EXAMPLE 5.6 Comparing Two Mutually Exclusive Revenue Projects

Monroe Manufacturing owns a warehouse that has been used for storing finished goods for electro-pump products. As the company is phasing out the electro-pump product line, the company is considering modifying the existing structure to use for manufacturing a new product line. Monroe's production engineer feels that the warehouse could be modified to handle one of two new product lines. The cost and revenue data for the two product alternatives are as follows:

	Product A	Product B
Initial cash expenditure:		
• Warehouse modification	\$115,000	\$189,000
• Equipment	\$250,000	\$315,000
Annual revenues	\$215,000	\$289,000
Annual O&M costs	\$126,000	\$168,000
Product life	8 years	8 years
Salvage value (equipment)	\$25,000	\$35,000

After eight years, the converted building will be too small for efficient production of either product line. At that time, Monroe plans to use it as a warehouse for storing raw materials as before. Monroe's required return on investment is 15%. Which product should be manufactured?

DISSECTING THE PROBLEM

Note that these are revenue projects, so we need to estimate the revenue streams for both product lines. Since the converted building will be used as a warehouse by the firm, there will be no salvage value associated with the building.

Given: Cash flows for the two products as shown in the proceeding table, analysis period = 8 years, and i = 15% per year.

Find: PW for each product; the preferred alternative.

METHODOLOGY

Construct a cash flow chart comparing the two products Since the service lives are the same for both products, compute the NPW for each product over the analysis period. (See Figure 5.12.)

SOLUTION

$$\begin{aligned} PW(15\%)_A &= -\$365{,}000 + \$89{,}000(P/A, 15\%, 8) \\ &\quad + \$25{,}000(P/F, 15\%, 8) \\ &= \$42{,}544. \end{aligned}$$

$$\begin{aligned} PW(15\%)_B &= -\$504{,}000 + \$121{,}000(P/A, 15\%, 8) \\ &\quad + \$35{,}000(P/F, 15\%, 8) \\ &= \$50{,}407. \end{aligned}$$

For revenue projects, we select the one with the largest NPW, so producing product B is more economical.

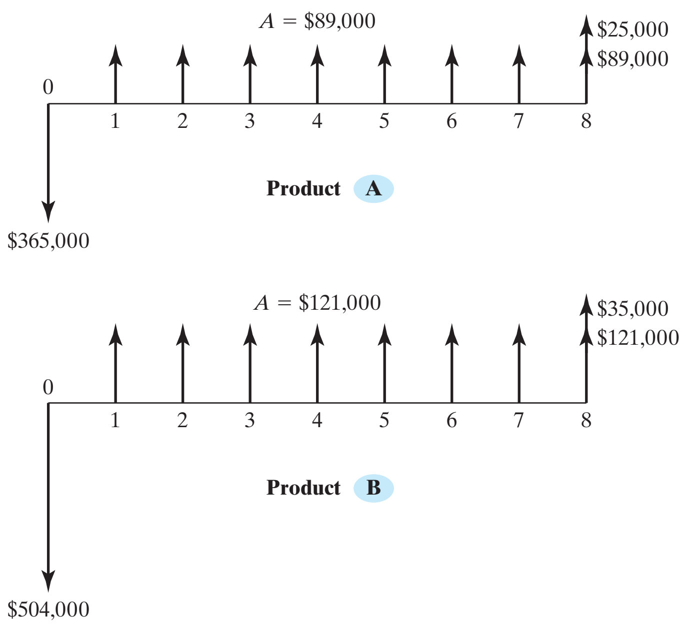


Figure 5.12 Cash flows associated with producing products A and B (revenue projects).

5.4.4 Analysis Period Differs from Project Lives

In Example 5.6, we assumed the simplest scenario possible when analyzing mutually exclusive projects. The projects had useful lives equal to each other and to the required service period. In practice, this is seldom the case. Often project lives do not match the required analysis period or do not match each other. For example, two machines may perform exactly the same function, but one lasts longer than the other, and both of them last longer than the analysis period for which they are being considered. In the upcoming sections and examples, we will develop some techniques for dealing with these complications.

Case I: Project's Life Is Longer than Analysis Period

Consider the case of a firm that undertakes a five-year production project (or plans to phase out the production at the end of five years) when all of the alternative equipment choices have useful lives of seven years. In such a case, we analyze each project only for as long as the required service period (in this case, five years). We are then left with some unused portion of the equipment (in this case, two years' worth), which we include as salvage value in our analysis. **Salvage value** is the amount of money for which the equipment could be sold after its service to the project has been rendered or the dollar measure of its remaining usefulness.

We often find this scenario (project lives that are longer than the analysis period) in the construction industry, where a building project may have a relatively short completion time, but the equipment purchased (power tools, tractors, etc.) has a much longer useful life.

EXAMPLE 5.7 Present-Worth Comparison: Project Lives Longer than the Analysis Period

Allan Company got permission to harvest southern pines from one of its timberland tracts. It is considering purchasing a feller-buncher, which has the ability to hold, saw, and place trees in bunches to be skidded to the log landing. The logging operation on this timberland tract must be completed in *three years*. Allan could speed up the logging operation, but doing so is not desirable because the market demand of the timber does not warrant such haste. Because the logging operation is to be done in wet conditions, this task requires a specially made feller-buncher with high-flotation tires and other devices designed to reduce site impact. There are two possible models of feller-buncher that Allan could purchase for this job: Model A is a two-year old used piece of equipment whereas Model B is a brand-new machine.

- Model A costs $205,000 and has a life of 10,000 hours before it will require any major overhaul. The operating cost will run $50,000 per year for 2,000 hours of operation. At this operational rate, the unit will be operable for five years, and at the end of that time, it is estimated that the salvage value will be $75,000.
- The more efficient Model B costs $275,000, has a life of 14,000 hours before requiring any major overhaul and costs $32,500 to operate for 2,000 hours per year in order to complete the job within three years. The estimated salvage value of Model B, at the end of seven years is $95,000.

Since the lifetime of either model exceeds the required service period of three years, Allan Company has to assume some things about the unused value of the equipment (salvage value) at the end of that time. Therefore, the engineers at Allan estimate that, after three years, the Model A unit could be sold for \$130,000 and the Model B unit for \$180,000. After considering all tax effects, Allan summarized the resulting cash flows (in thousands of dollars) for the projects as follows:

Period	Model A		Model B	
0		−\$205,000		−\$275,000
1		−\$50,000		−\$32,500
2		−\$50,000		−\$32,500
3	$\boxed{\$130{,}000}$	−\$50,000	$\boxed{\$180{,}000}$	−\$32,500
4		−\$50,000		−\$32,500
5	\$75,000	−\$50,000		−\$32,500
6				−\$32,500
7			\$95,000	−\$32,500

Here, the figures in the boxes represent the estimated salvage values at the end of the analysis period (end of year 3). Assuming that the firm's MARR is 15%, which option is more acceptable?

DISSECTING THE PROBLEM

First, note that these projects are service projects, so we can assume the same revenues for both configurations. Since the firm explicitly estimated the salvage values of the assets at the end of the analysis period (three years), we can compare the two models directly. Since the benefits (timber harvesting) are equal, we can concentrate on the costs.

Given: Cash flows for the two alternatives as shown in the preceding table, $i = 15\%$ per year.

Find: PW for each alternative and the preferred alternative.

METHODOLOGY

Construct a cash flow chart comparing the options, and compute the NPW for each model over the analysis period (three years). Any cash flows after the analysis period are irrelevant for both alternatives, and we can safely ignore them in the analysis.

SOLUTION

Concentrate the costs:

$$\begin{aligned} PW(15\%)_A &= -\$205{,}000 - \$50{,}000(P/A, 15\%, 3) \\ &\quad + \$130{,}000(P/F, 15\%, 3) \\ &= -\$233{,}684; \end{aligned}$$

$$\begin{aligned} PW(15\%)_B &= -\$275{,}000 - \$32{,}500(P/A, 15\%, 3) \\ &\quad + \$180{,}000(P/F, 15\%, 3) \\ &= -\$230{,}852. \end{aligned}$$

Model B is cheaper to operate and thus would be preferred. (See Figure 5.13.)

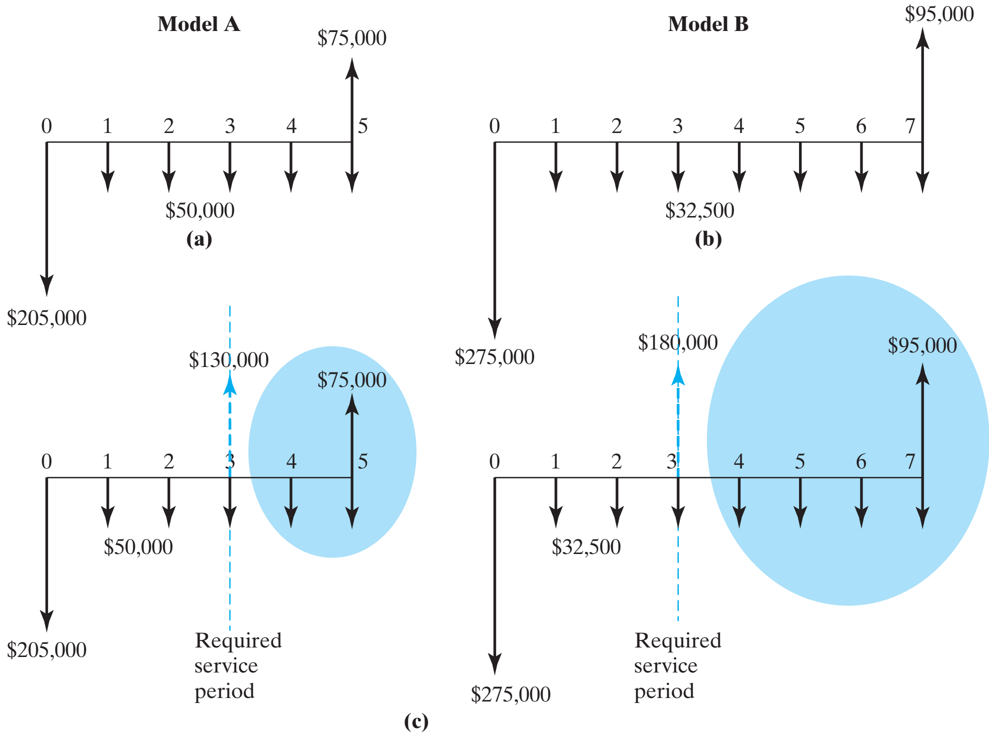


Figure 5.13 (a), (b) If models are not sold after the required service period; (c) if models are sold after the required service period. (Note that cash flows in shaded circle can be ignored in the analysis.)

COMMENTS: The decision heavily depends on the salvage value estimates at the end of the analysis period. Commonly, information about the salvage value of used equipment can be obtained from the equipment vendors because they are familiar with the secondary market for their equipment.

Case II: Project's Life Is Shorter than Analysis Period

When project lives are shorter than the required service period, we must consider how, at the end of a project's life, we will satisfy the rest of the required service period. Replacement projects—implemented when the initial project has reached the limits of its useful life—are needed in such a case. Sufficient replacement projects must be analyzed to match or exceed the required service period.

To simplify our analysis, we could assume that the replacement project will be exactly the same as the initial project with the same corresponding costs and benefits. In the case of an indefinitely ongoing service project, we typically select a finite analysis period by using the **lowest common multiple** of the project's life. For example, if alternative A has a three-year useful life and alternative B has a four-year useful life, we may select 12 years as the analysis period. Because this assumption is rather unrealistic in most real-world problems, we will not advocate the method in this book. However, if such an analysis is warranted, we will demonstrate how the annual-equivalent approach would simplify the mathematical aspect of the analysis in Example 6.7.

The assumption of an identical future replacement project is not necessary, however. For example, depending on our forecasting skills, we may decide that a different kind of technology—in the form of equipment, materials, or processes—will be a preferable and potential replacement. *Whether we select exactly the same alternative or a new technology as the replacement project, we are ultimately likely to have some unused portion of the equipment to consider as salvage value*, just as in the case when project lives are longer than the analysis period. On the other hand, we may decide to lease the necessary equipment or subcontract the remaining work for the duration of the analysis period. In this case, we can probably exactly match our analysis period and not worry about salvage values.

In any event, we must make some initial predictions at its outset concerning the method of completing the analysis period. Later, when the initial project life is closer to its expiration, we may revise our analysis with a different replacement project. This approach is quite reasonable, since economic analysis is an ongoing activity in the life of a company and an investment project, and we should always use the most reliable, up-to-date data we can reasonably acquire.

EXAMPLE 5.8 Present-Worth Comparison: Project Lives Shorter than the Analysis Period

Phoenix Manufacturing Company is planning to modernize one of its distribution centers located outside Denver, Colorado. Two options to move goods in the distribution center have been under consideration: a conveyor system and forklift trucks. The firm expects that the distribution center will be operational for the next 10 years, and then it will be converted into a factory outlet. The conveyor system would last eight years whereas the forklift trucks would last only six years. The two options will be designed differently but will have identical capacities and will do exactly the same job. The expected cash flows for the two options, including maintenance costs, salvage values, and tax effects, are as follows:

n	Conveyor System	Lift Trucks
0	−\$68,000	−\$40,000
1	−\$13,000	−\$15,000
2	−\$13,000	−\$15,000
3	−\$13,000	−\$15,000
4	−\$13,000	−\$15,000
5	−\$13,000	−\$15,000
6	−\$13,000	−\$15,000 + \$4,000
7	−\$13,000	
8	−\$13,000 + \$5,000	

With this scenario, which option should the firm select at MARR = 12%?

DISSECTING THE PROBLEM

Given: Cash flows for the two alternatives, analysis period of 10 years, and MARR = 12% per year.

Find: PW for each alternative and the preferred alternative.

METHODOLOGY

Compute cash flows for both models and conduct PW analysis.

SOLUTION

Since each option has a shorter life than the required service period (10 years), we need to make an explicit assumption of how the service requirement is to be met.

- If the company goes with the conveyor system, it will spend \$18,000 to overhaul the system to extend its service life beyond eight years. The expected salvage value of the system at the end of the required service period (10 years) will be \$6,000. The annual operating and maintenance costs will be \$13,000.
- If the company goes with the lift truck option, the company will consider leasing a comparable lift truck that has an annual lease payment of \$8,000, payable at the *beginning* of each year, with an annual operating cost of \$15,000 for the remaining required service period.

The anticipated cash flows for both models under this scenario are as shown in Figure 5.14. Table 5.5 is an Excel solution to the decision problem. As shown in Table 5.5, note that both alternatives now have the same required service period of 10 years. Therefore, we can use PW analysis:

$$\begin{aligned} PW(12\%)_{\text{Conveyor}} &= -\$68{,}000 - \$13{,}000(P/A, 12\%, 10) \\ &\quad - \$18{,}000(P/F, 12\%, 8) \\ &\quad + \$6{,}000(P/F, 12\%, 10) \\ &= -\$146{,}791; \end{aligned}$$

$$\begin{aligned} PW(12\%)_{\text{Lift Trucks}} &= -\$40{,}000 - \$15{,}000(P/A, 12\%, 10) \\ &\quad - \$8{,}000(P/A, 12\%, 4)(P/F, 12\%, 5) \\ &\quad + \$4{,}000(P/F, 12\%, 6) \\ &= -\$136{,}515. \end{aligned}$$

Since these projects are service projects, the lift truck option is the better choice.

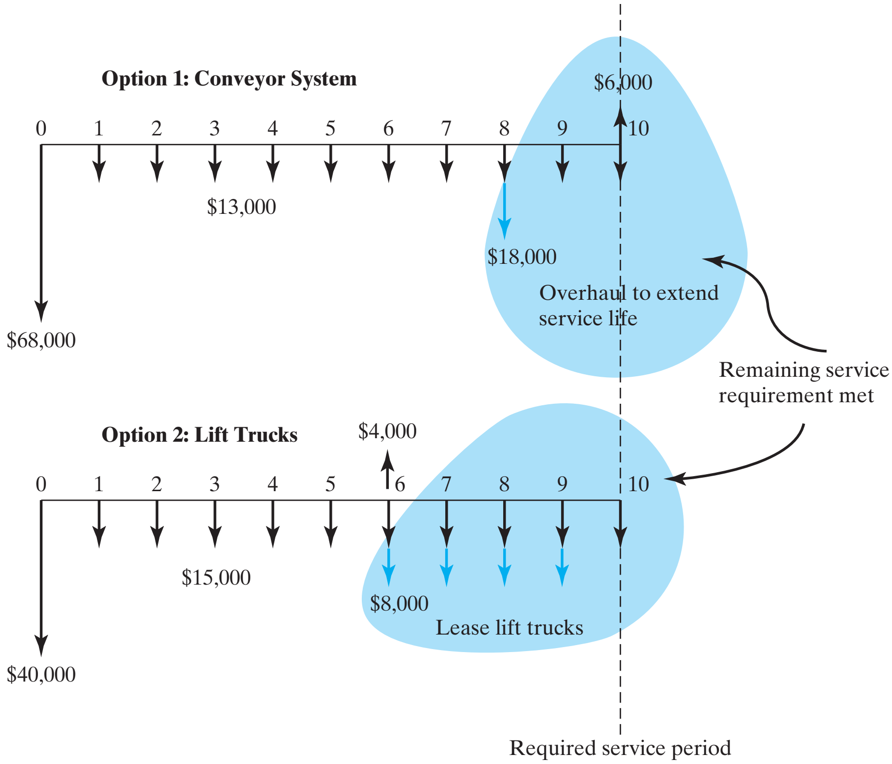


Figure 5.14 Comparison for mutually exclusive service projects with unequal lives when the required service period is longer than the individual project life.

TABLE 5.5 An Excel Worksheet to Compare Two Mutually Exclusive Alternatives

	A	B	C	D	E	F	G	H	I	J	K
2		Cash Flow									
3		Conveyor			Lift Trucks				Net Cash Flow		
4	Period	Investment	O&M	Overhaul	Investment	O&M	Lease		Period	Conveyor	Lift trucks
5	0	$ (68,000)			$ (40,000)				0	$ (68,000)	$ (40,000)
6	1		$ (13,000)			$ (15,000)			1	$ (13,000)	$ (15,000)
7	2		$ (13,000)			$ (15,000)			2	$ (13,000)	$ (15,000)
8	3		$ (13,000)			$ (15,000)			3	$ (13,000)	$ (15,000)
9	4		$ (13,000)			$ (15,000)			4	$ (13,000)	$ (15,000)
10	5		$ (13,000)			$ (15,000)			5	$ (13,000)	$ (15,000)
11	6		$ (13,000)		$ 4,000	$ (15,000)	$ (8,000)		6	$ (13,000)	$ (19,000)
12	7		$ (13,000)			$ (15,000)	$ (8,000)		7	$ (13,000)	$ (23,000)
13	8		$ (13,000)	$ (18,000)		$ (15,000)	$ (8,000)		8	$ (31,000)	$ (23,000)
14	9		$ (13,000)			$ (15,000)	$ (8,000)		9	$ (13,000)	$ (23,000)
15	10	$ 6,000	$ (13,000)			$ (15,000)			10	$ (7,000)	$ (15,000)
16									PW(12%)	$ (146,791)	$ (136,515)
17											

=NPV(12%,J6:J15)+J5

=NPV(12%,K6:K15)+K5

SUMMARY

In this chapter, we presented the concept of present-worth analysis based on cash flow equivalence along with the payback period. We observed the following important results:

- Present worth is an equivalence method of analysis in which a project's cash flows are discounted to a single present value. It is perhaps the most efficient analysis method we can use for determining project acceptability on an economic basis. Other analysis methods, which we will study in Chapters 6 and 7, are built on a sound understanding of present worth.
- The MARR, or minimum attractive rate of return, is the interest rate at which a firm can always earn or borrow money. It is generally dictated by management and is the rate at which PW analysis should be conducted.
- The project balance illustrates the amount of profit or loss if the project terminates at that particular point in time. Then, a project balance diagram provides important insights into the desirability of the investment and the ultimate profitability of the project (net present value). This additional information will be even more important when we need to compare various projects having similar profitability.
- Revenue projects are projects for which the income generated depends on the choice of project. Service projects are projects for which income remains the same regardless of which project is selected.
- The term **mutually exclusive** as applied to a set of alternatives that meet the same need means that when one of the alternatives is selected, the others will be rejected.
- When not specified by management or company policy, the analysis period for use in a comparison of mutually exclusive projects may be chosen by an individual analyst. Several efficiencies can be applied when we select an analysis period. In general, the analysis period should be chosen to cover the required service period.

SELF-TEST QUESTIONS

5s.1 An investment project costs $100,000. It is expected to have an annual net cash flow of $25,000 for five years. What is the project's payback period?

(a) 2 years (b) 3 years
(c) 4 years (d) 5 years

5s.2 Find the net present worth of the following cash flow series at an interest rate of 8%.

End of Period	Cash Flow
0	−$1,000
1	−$3,000
2	$5,000
3	$6,000
4	$7,500

(a) $7,840 (b) $8,741
(c) $10,784 (d) $17,841

5s.3 You are considering purchasing a CNC machine. This machine will have an estimated service life of 10 years with a salvage value of 15% of the investment cost. Its annual net revenues are estimated to be \$60,000. To expect a 14% rate of return on investment (MARR), what would be the maximum amount that you are willing to pay for the machine?

(a) \$312,065
(b) \$320,466
(c) \$326,161
(d) \$332,188

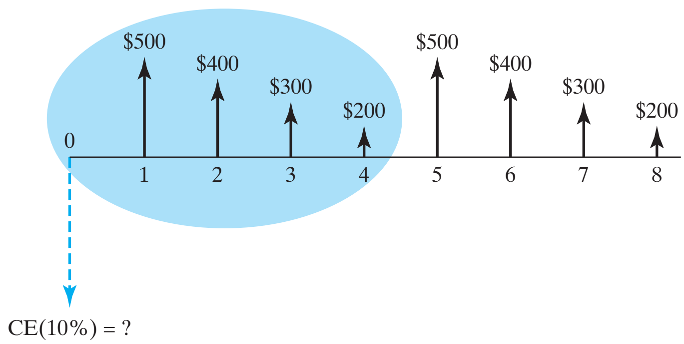
5s.4 What is the future worth, in year 10, of \$8,000 at $n = 0$, \$10,000 at $n = 5$ years, and \$5,000 at $n = 7$ years if the interest rate is 16% per year?

(a) \$64,099
(b) \$65,121
(c) \$68,365
(d) \$69,763

5s.5 You invested \$100,000 in a project and received \$40,000 at $n = 1$, \$40,000 at $n = 2$, and \$30,000 at $n = 3$ years. You need to terminate the project at the end of year 3. Your interest rate is 10%; what is the project balance at the time of termination?

(a) Gain of \$10,000
(b) Loss of \$8,039
(c) Loss of \$10,700
(d) Just break even

5s.6 Find the capitalized equivalent worth for the project cash flow series with repeating cycles at an interest rate of 10%.



(a) \$1,147
(b) \$1,679
(c) \$3,619
(d) \$6,381

5s.7 The following table contains a summary of expected changes to a project's balance over its five-year service life at 10% interest.

End of Period	Project Balance
0	−\$1,000
1	−\$1,500
2	\$600
3	\$900
4	\$1,500
5	\$2,000

Which of the following statements is incorrect?
(a) The required additional investment at the end of period 1 is \$400.
(b) The net present worth of the project at 10% interest is \$1,242.
(c) The net future of the project at 10% interest is \$2,000.
(d) Within two years, the company will recover all its investments and the cost of funds (interest) from the project.

5s.8 A&M Corporation purchased a vibratory finishing machine for \$20,000 in year 0. The machine's useful life is 10 years at the end of which the machine is estimated to have a zero salvage value. The machine generates net annual revenues of \$6,000. The annual operating and maintenance expenses are estimated to be \$1,000. If A&M's MARR is 15%, how many years does it take before this machine becomes profitable?
(a) 3 years $< n \leq$ 4 years
(b) 4 years $< n \leq$ 5 years
(c) 5 years $< n \leq$ 6 years
(d) 6 years $< n \leq$ 7 years

5s.9 You are considering buying an old warehouse that you will convert into an office building for rental. Assuming that you will own the property for 10 years, how much would you be willing to pay for the old house now given the following financial data?
- Remodeling cost at period 0 = \$550,000;
- Annual rental income = \$800,000;
- Annual upkeep costs (including taxes) = \$80,000;
- Estimated net property value (after taxes) at the end of 10 years = \$2,225,000;
- The time value of your money (interest rate) = 8% per year.

(a) \$4,445,770
(b) \$5,033,400
(c) \$5,311,865
(d) \$5,812,665

5s.10 Alpha Company is planning to invest in a machine, the use of which will result in the following:

- Annual revenues of \$10,000 in the first year and increases of \$5,000 each year, up to year 9. From year 10, the revenues will remain constant (\$52,000) for an indefinite period.
- The machine is to be overhauled every 10 years. The expense for each overhaul is \$40,000.

If Alpha expects a present worth of at least \$100,000 at a MARR of 10% for this project, what is the maximum investment that Alpha should be prepared to make?

(a) \$250,140
(b) \$674,697
(c) \$350,100
(d) \$509,600

5s.11 Consider the following two mutually exclusive investment alternatives:

	Net Cash Flow	
End of Year	Machine A	Machine B
0	−\$2,000	−\$1,000
1	−\$600	−\$900
2	−\$700	−\$1,000 + \$200
3	−\$800 + \$500	

Suppose that your firm needs either machine for only two years. The net proceeds from the sale of machine *B* are estimated to be \$200. What should be the required net proceeds from the sale of machine *A* in two years so that both machines could be considered economically indifferent at an interest rate of 10%?

(a) \$750
(b) \$780
(c) \$800
(d) \$850

5s.12 An investment project provides cash inflows of \$2,500 per year for five years. What is the payback period if the project requires \$4,000 at the beginning of the project?

(a) 0.8 years
(b) 1.6 years
(c) 1.8 years
(d) 2.0 years

5s.13 You are given the following financial data about a new system to be implemented at a company:

- Investment cost at $n = 0$: \$23,000
- Investment cost at $n = 1$: \$18,000
- Useful life: 10 years

- Salvage value (at the end of 11 years): $7,000
- Annual revenues: $19,000 per year
- Annual expenses: $6,000 per year
- MARR: 10%

Note: The first revenues and expenses will occur at the end of year 2.

Determine the discounted-payback period.

(a) 4 years
(b) 5 years
(c) 6 years
(d) 8 years

5s.14 You are in the mail-order business, selling computer peripherals, including high-speed Internet cables, various storage devices such as memory sticks, and wireless networking devices. You are considering upgrading your mail ordering system to make your operations more efficient and to increase sales. The computerized ordering system will cost $250,000 to install and $50,000 to operate each year. The system is expected to last eight years with no salvage value at the end of the service period. The new order system will save $120,000 in operating costs (mainly, reduction in inventory carrying cost) each year and bring in additional sales revenue in the amount of $40,000 per year for the next eight years. If your interest rate is 12%, what is the NPW of the investment?

(a) $296,440
(b) $312,535
(c) $333,168
(d) $352,413

5s.15 Consider the following project-balance profiles for proposed investment projects:

Project Balances

n	Project A	Project B	Project C
0	−$600	−$500	−$200
1	$200	$300	$0
2	$300	$650	$150
PW	?	$416	?
Rate used	15%	?	?

Now consider the following statements:

Statement 1: For Project A, the cash flow at the end of year 2 is $100.
Statement 2: The future value of Project C is $0.
Statement 3: The interest rate used in the Project B balance calculations is 25%.

Which of the preceding statements is (are) correct?

(a) Just statement 1.
(b) Just statement 2.
(c) Just statement 3.
(d) All of them.

5s.16 Consider the following cash flow data for two competing investment projects:

Cash Flow Data (thousands of $)

n	Project A	Project B
0	−$1,000,000	−$1,200,000
1	$700,000	$700,000
2	$700,000	$1,000,000

At $i = 22\%$, which project is chosen by the NPW rule?

5s.17 Consider the following two mutually exclusive projects:

n	A	B
0	−$12,000	−$10,000
1	$4,000	$$X$
2	$6,000	$3,000
3	$8,000	$$X$

What value of X would make the decision maker indifferent between A and B at an interest rate of 12%?

(a) $5,467
(b) $6,018
(c) $6,233
(d) $6,515

PROBLEMS

Note: Unless otherwise stated, all cash flows are in *actual dollars* with tax effects considered. The interest rate (MARR) is also given on an after-tax basis, considering the effects of inflation in the economy. This interest rate is equivalent to the market interest rate. Also, all interest rates are assumed to be compounded *annually*.

Identifying Cash Inflows and Outflows

5.1 Business at your design engineering firm has been brisk. To keep up with the increasing workload, you are considering the purchase of a new state-of-the art CAD/CAM system costing $525,000, which would provide 6,000 hours of productive time per year. Your firm puts a lot of effort into drawing new product designs. At present, this is all done by design engineers on an old CAD/CAM system installed five years ago. If you purchase the system, 40% of the productive time will be devoted to drawing (CAD) and the remainder to CAM. While drawing, the system is expected to out-produce the old CAD/CAM system by a factor of 3:1. You estimate that the additional annual out-of-pocket cost of maintaining the new CAD/CAM system will be $200,000, including any tax effects. The expected useful life of the system is eight years, after which the equipment will have no residual value. As an alternative, you could hire more design engineers. Each normally works 2,000 hours per year, and 60% of this time is productive. The total cost for a design engineer is \$50 per hour. There are four design engineers. Identify the net cash flows (benefits and costs) associated with the drawing activities if the CAD/CAM system is purchased instead of hiring more design engineers.

5.2 Camptown Togs, Inc., a children's clothing manufacturer, has always found payroll processing to be costly because it must be done by a clerk. The number of piece–goods coupons received by each employee is collected and the types of tasks performed by each employee are calculated. Not long ago, an industrial engineer designed a system that could partially automate the process by means of a scanner that reads the piece–goods coupons. Management is enthusiastic about this system, because it utilizes some personal computer systems that were purchased recently. It is expected that this new automated system will save \$52,000 per year in labor. The new system will cost about \$36,000 to build and test prior to operation. It is expected that operating costs, including income taxes, will be about \$8,000 per year. The system will have a five-year useful life. The expected net salvage value of the system is estimated to be \$4,000.

(a) Identify the cash inflows over the life of the project.

(b) Identify the cash outflows over the life of the project.

(c) Determine the net cash flows over the life of the project.

5.3 As a chief engineer, you need to come up with the cash flow estimate for a newly proposed production line. Initially, the system is designed to have a maximum capacity ($C_{\max}$) of six million parts to produce per year, but the demand is expected to grow at an annual compound rate of 10%. Whenever the annual demand reaches 80% of the maximum designed capacity, the maximum designed capacity must be doubled in the subsequent year. The cost of meeting these future demands, as well as other projected financial data, are as follows:

- Cost of building the production system as a function of maximum designed capacity:

$$1.5\text{ M} + 0.5(C_{\max})^{0.7}.$$

- Initial demand = 3 million parts per year.
- Demand growth rate = 10% per year.
- Project life = 15 years.
- Revenues per year = demand during year $n \times (5)^{1.05}$.
- Expenses per year = \$120,000 + demand during year $n \times (2)^{1.08}$.

Estimate the project cash flows over the project life.

Payback Period

5.4 If a project costs \$90,000 and is expected to return \$30,000 annually, how long does it take to recover the initial investment? What would be the discounted payback period at $i = 20\%$?

5.5 A project costs \$400,000 and is expected to generate \$500,000 annually.

(a) How long does it take to recover the initial investment?

(b) If the firm's interest rate is 10% after taxes, what would be the discounted payback period for this project?

5.6 J&M Manufacturing plans on purchasing a new assembly machine for \$30,000 to automate one of its current manufacturing operations. It will cost an additional \$2,000 to have the new machine installed. With the new machine, J&M expects to save \$12,000 in annual operating and maintenance costs. The machine will last five years with an expected salvage value of \$3,500.

(a) How long will it take to recover the investment (plus installation cost)?

(b) If J&M's interest rate is known to be 18%, determine the discounted payback period.

5.7 Consider the investment projects in Table P5.7, all of which have a four-year investment life.

TABLE P5.7

	Project's Cash Flow ($)			
n	A	B	C	D
0	−$2,500	−$3,500	−$2,800	−$2,300
1	$0	$1,600	−$1,800	−$1,000
2	$0	$2,800	−$900	$1,900
3	$0	$3,500	$4,500	$2,300
4	$6,200	$2,200	$4,500	$1,500

(a) What is the payback period of each project?

(b) What is the discounted payback period at an interest rate of 15% for each project?

NPW Criterion

5.8 Larson Manufacturing is considering purchasing a new injection-molding machine for $300,000 to expand its production capacity. It will cost an additional $52,000 to do the site preparation. With the new injection-molding machine installed, Larson Manufacturing expects to increase its revenue by $70,000. The machine will be used for six years, with an expected salvage value of $64,000. At an interest rate of 10%, would the purchase of the injection-molding machine be justified?

5.9 Consider the cash flows from an investment project.

Year	Cash Flows
0	−$25,500
1	$22,400
2	$24,800
3	$26,250
4	$38,840

(a) Compute the net present worth of the project at $i = 15\%$.

(b) Plot the present worth as a function of the interest rate (from 0% to 30%).

5.10 Your firm is considering purchasing an old office building with an estimated remaining service life of 25 years. Recently, the tenants signed a long-term lease, which leads you to believe that the current rental income of $250,000 per year will remain constant for the first five years. Then the rental income will increase by 10% for every five-year interval over the remaining life of the asset. That is, the annual rental income would be $275,000 for years 6 through 10, $302,500 for years 11 through 15, $332,750 for years 16 through 20, and $366,025 for years 21 through 25. You estimate that operating expenses, including income taxes, will be $85,000 for the first year and that they will increase by $5,000 each year thereafter. You also estimate that razing the building and selling the lot on which it stands will realize a net amount of $50,000 at the end of the 25-year period. If you had the opportunity to invest your money elsewhere and thereby earn interest at the rate of 12% per annum, what would be the maximum amount you would be willing to pay for the building and lot at the present time?

5.11 Consider the following set of investment projects, all of which have a three-year investment life:

Project Cash Flows

n	A	B	C	D
0	−$900	−$1,600	−$1,400	−$5,500
1	$0	$800	−$750	$1,100
2	$0	$1,000	$680	$2,600
3	$2,400	$1,400	$2,250	$2,800

(a) Compute the net present worth of each project at $i = 8\%$.

(b) Plot the present worth as a function of the interest rate (from 0% to 30%) for Project B.

5.12 Beloit Co. is a manufacturer of mini-doughnut machine makers. Early in 2018 a customer asked Beloit to quote a price for a custom-designed doughnut machine to be delivered by the end of 2018. Once it is purchased, the customer intends to place the machine in service in January 2019 and will use it for four years. The expected annual operating net cash flow is estimated to be $140,000. The expected salvage value of the equipment at the end of five years is about 12% of the initial purchase price. To expect an 18% required rate of return on investment, what is the maximum amount that should be spent on purchasing the doughnut machine?

5.13 You are considering the purchase of a parking deck close to your office building. The parking deck is a 15-year old structure with an estimated remaining service life of 25 years. The tenants have recently signed long-term leases, which leads you to believe that the current rental income of $250,000 per year will remain constant for the first five years. Then the rental income will increase by 10% for every five-year interval over the remaining asset life. Thus, the annual rental income would be $275,000 for years 6 through 10, $302,500 for years 11 through 15, $332,750 for years 16 through 20, and $366,025 for years 21 through 25. You estimate that operating expenses, including income taxes, will be $65,000 for the first year and that they will increase by $6,000 each year thereafter. You estimate that razing the building and selling the lot on which it stands will realize a net amount of $200,000 at the end of the 25-year period. If you had the opportunity to invest your money elsewhere and thereby earn interest at the rate of 15% per annum, what would be the maximum amount you would be willing to pay for the parking deck and lot at the present time?

5.14 Consider the following investment project:

n	A_n	i
0	−$6,400	8%
1	$4,800	10%
2	$4,400	12%
3	$1,800	14%
4	$3,200	11%
5	$5,100	10%

Suppose, as shown in the preceding table, that the company's reinvestment opportunities (that is, its MARR) change over the life of the project. For example, the company can invest funds available now at 8% for the first year, 10% for the second year, and so forth. Calculate the net present worth of this investment, and determine its acceptability.

5.15 A university is trying to determine how much it should charge for tickets to basketball games to help offset the expenses of the new arena. The cost to build the arena including labor, materials, etc. was $92 million. Each year the maintenance cost is expected to increase by 5% as the building gets older. The maintenance cost for the first year is $150,000. Utilities are expected to average about $200,000 per year and labor costs $300,000. The average attendance at basketball games over the year is expected to be 100,000 people (or 100,000 tickets sold to events). Assuming the arena has no other source of income besides regular ticket sales (not including student tickets) for basketball games, what should the university charge so that it can recover at least 6% cost of borrowing on its investment? The university expects the arena to be used for 40 years and to have no appreciable salvage value.

Future Worth and Project Balance

5.16 Consider the sets of investment projects in Table P5.16, all of which have a three-year investment life.

TABLE P5.16

Period	Project's Cash Flow			
(n)	A	B	C	D
0	−$10,000	−$12,500	$25,000	−$32,750
1	$8,700	−$4,000	−$10,500	$2,750
2	$6,400	$17,850	−$4,800	$8,800
3	$12,800	$12,250	$6,600	$15,550

(a) Compute the net future worth of each project at $i = 12\%$. Which project or projects are acceptable?

(b) Compute the terminal project balance for each project at $i = 12\%$, and compare them with the net future worth of the projects in (a). What conclusions can you reach?

5.17 Consider the project balances in Table P5.17 for a typical investment project with a service life of four years.

TABLE P5.17

n	A_n	Project Balance
0	−$12,000	−$12,000
1	—	−$8,900
2	—	−$7,000
3	$1,100	−$6,600
4	—	$1,800

(a) Determine the interest rate used in computing the project balance.
(b) Reconstruct the original cash flows of the project.
(c) Would the project be acceptable at $i = 15\%$?

5.18 Consider the following project balances for a typical investment project with a service life of four years:

n	A_n	Project Balance
0	−$1,000	−$1,000
1	( )	−$1,100
2	( )	−$800
3	$460	−$500
4	( )	$0

(a) Construct the original cash flows of the project.
(b) Determine the interest rate used in computing the project balance.
(c) Would this project be acceptable at a MARR of 12%?

5.19 A project has a service life of five years with the initial investment outlay of $200,000. If the discounted payback period occurs at the end of the project service life (say five years) at an interest rate of 10%, what can you say about the NFW of the project?

5.20 Consider the following cash flows and present-worth profile.
(a) Determine the values of X and Y.
(b) Calculate the terminal project balance of project 1 at MARR = 24%.
(c) Find the values of *a*, *b*, and *c* in the NPW plot.

TABLE P5.20

	Net Cash Flows ($)	
Year	**Project 1**	**Project 2**
0	−$1,000	−$1,000
1	$400	$300
2	$800	$$Y$
3	$$X$	$800

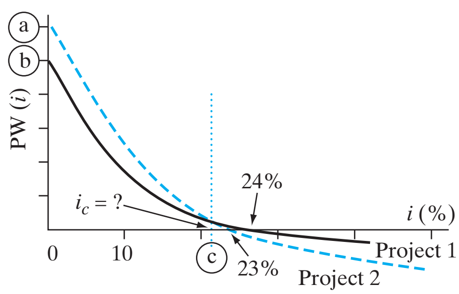


Figure P5.20

5.21 Consider the project balances for a typical investment project with a service life of five years, as shown in Table P5.21

(a) Determine the interest rate used in the project balance calculation.

(b) Construct the original cash flows of the project and the terminal balance, and fill in the blanks in Table P5.21.

TABLE P5.21 **Investment Project Balances**

n	A_n	Project Balance
0	−\$3,000	−\$3,000
1	a	−\$2,860
2	b	−\$1,660
3	\$1,770	−\$122
4	\$585	−\$446
5	c	\$1,183

5.22 Consider the following investment projects using the information in Table P5.22.

TABLE P5.22 **Project's Cash Flow**

n	A	B	C	D
0	−\$1,000	−\$1,000	−\$1,000	−\$1,000
1	\$0	\$594	\$687	\$500
2	\$0	\$594	\$588	\$600
3	\$1,965	\$594	\$487	\$700

(a) Compute the future worth at the end of life for each project at $i = 10\%$.

(b) Determine the discounted payback period for each project.

(c) Compare the area of negative project balance for each project.

(d) Which project would you prefer and why?

5.23 Consider the following set of independent investment projects:

Project Cash Flows

n	A	B	C
0	−$200	−$100	$120
1	$50	$40	−$40
2	$50	$40	−$40
3	$50	$40	−$40
4	−$100	$10	
5	$400	$10	
6	$400		

(a) For a MARR of 10%, compute the net present worth for each project, and determine the acceptability of each project.

(b) For a MARR of 10%, compute the net future worth of each project at the end of each project period, and determine the acceptability of each project.

(c) Compute the future worth of each project at the end of six years with variable MARRs as follows: 10% for $n = 0$ to $n = 3$ and 15% for $n = 4$ to $n = 6$.

5.24 Consider the project balance profiles for proposed investment projects in Table P5.24.

TABLE P5.24 Profiles for Proposed Investment Projects

	Project Balances		
n	A	B	C
0	−$1,000	−$1,000	−$1,000
1	−$800	−$680	−$530
2	−$600	−$302	$$X$
3	−$400	−$57	−$211
4	−$200	$233	−$89
5	$0	$575	$0
Interest rate used	0%	18%	12%

Project balance figures are rounded to the nearest dollar.

(a) Compute the net present worth of each investment.

(b) Determine the project balance for project C at the end of period 2 if $A_2 = \$500$.

(c) Determine the cash flows for each project.

(d) Identify the net future worth of each project.

Capitalized-Equivalent Worth

5.25 Maintenance money for an athletic complex has been sought. Mr. Vonnegut, the Athletic Director, would like to solicit a donation to cover all future expected maintenance costs for the building. These maintenance costs are expected to be \$1.2 million each year for the first five years, \$1.5 million each year for years 6 through 12, and \$2.1 million each year after that. (The building has an indefinite service life.)

If the money is placed in an account that will pay 7% interest compounded annually, how large should the gift be?

5.26 Consider an investment project, the cash flow pattern of which repeats itself every five years forever, as shown in the accompanying diagram (Figure P5.26). At an interest rate of 10%, compute the capitalized equivalent amount for this project.

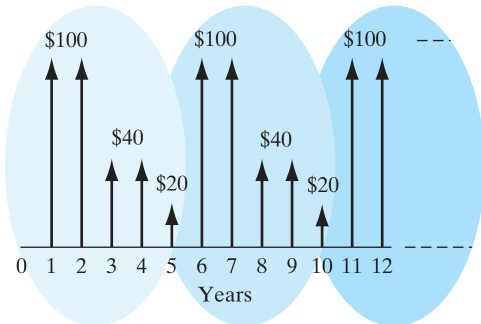


Figure P5.26

5.27 A group of concerned citizens has established a trust fund that pays 6% interest compounded monthly to preserve a historical building by providing annual maintenance funds of \$72,000 forever. Compute the capitalized equivalent amount for these building maintenance expenses.

5.28 A newly constructed bridge costs \$28,000,000. The same bridge is estimated to need renovation every 15 years at a cost of \$6,000,000. Annual repairs and maintenance are estimated to be \$1,200,000 per year.

(a) If the interest rate is 8%, determine the capitalized cost of the bridge.

(b) Suppose that in (a), the bridge must be renovated every 20 years, not every 15 years. What is the capitalized cost of the bridge?

(c) Repeat (a) and (b) with an interest rate of 10%. What can you say about the effect of interest on the results?

5.29 To decrease the costs of operating a lock in a large river, a new system of operation is proposed. The system will cost \$1,070,000 to design and build. It is estimated that it will have to be reworked every 10 years at a cost of \$140,000. In addition, an expenditure of \$70,000 will have to be made at the end of the fifth year for a new type of gear that will not be available until then. Annual operating costs are expected to be \$80,000 for the first 15 years and \$120,000 a year thereafter. Compute the capitalized cost of perpetual service at $i = 9\%$.

5.30 Consider a retired gentleman who starts to collect his Social Security benefits at the age of 66. The monthly check would be close to $4,260. Assuming that his interest rate is 9% compounded monthly, answer the following questions:

(a) If he lives 25 years after retirement, what would be the equivalent total Social Security benefit collected?

(b) If he lives 30 years after retirement, what would be the equivalent total Social Security benefit collected?

(c) Suppose he lives forever. What would be the total amount collected? Now, comparing this answer with that in (b), what can you conclude?

Comparing Mutually Exclusive Alternatives

5.31 Consider the following two mutually exclusive projects:

Net Cash Flow

End of Year	Project A	Project B
0	−$1,000	−$1,000
1	$912	$284
2	$684	$568
3	$456	$852
4	$228	$1,136

(a) At an interest rate of 25%, which project would you recommend choosing?

(b) Compute the area of negative project balance, discounted payback period, and area of positive project balance for each project. Which project is exposed to a higher risk of loss if either project terminates at the end of year 2?

5.32 Consider two mutually exclusive investment projects, each with MARR = 12%, as shown in Table P5.32. On the basis of the NPW criterion, which alternative would be selected?

TABLE P5.32 Two Mutually Exclusive Investment Projects

	Project's Cash Flow	
n	A	B
0	−$22,500	−$16,900
1	$18,610	$15,210
2	$15,930	$16,720
3	$16,300	$12,500

5.33 Consider the two mutually exclusive investment projects in Table P5.33. For what range of MARR would you prefer project B?

TABLE P5.33

	Project's Cash Flow	
n	A	B
0	−\$5,300	−\$7,300
1	\$900	\$2.200
2	\$14,000	\$15,500

5.34 Consider the following two investment alternatives given in Table P5.34.The firm's MARR is known to be 15%.

TABLE P5.34

	Project's Cash Flow	
n	A1	A2
0	−\$15,000	−\$25,000
1	\$9,500	\$0
2	\$12,500	\$*X*
3	\$7,500	\$*X*
PW(15%)	$\boxed{?}$	$\boxed{9{,}300}$

(a) Compute PW(15%) for project A1.
(b) Compute the unknown cash flow X in years 2 and 3 for project A2.
(c) Compute the project balance (at 15%) of project A1 at the end of period 3.
(d) If these two projects are mutually exclusive alternatives, which one would you select?

5.35 Consider the following after-tax cash flows:

	Project Cash Flows			
n	A	B	C	D
0	−\$2,500	−\$7,000	−\$5,000	−\$5,000
1	\$650	−\$2,500	−\$2,000	−\$500
2	\$650	−\$2,000	−\$2,000	−\$500
3	\$650	−\$1,500	−\$2,000	\$4,000
4	\$600	−\$1,500	−\$2,000	\$3,000
5	\$600	−\$1,500	−\$2,000	\$3,000
6	\$600	−\$1,500	−\$2,000	\$2,000
7	\$300		−\$2,000	\$3,000
8	\$300			

(a) Compute the project balances for Projects A and D, as a function of project year, at $i = 10\%$.
(b) Compute the future worth values for Projects A and D at $i = 10\%$ at the end of service life.
(c) Suppose that Projects B and C are mutually exclusive. Assume also that the required service period is eight years and that the company is considering leasing comparable equipment that has an annual lease expense of $3,000 for the remaining years of the required service period. Which project is the better choice?

5.36 Consider the two mutually exclusive service projects in Table P5.36.

TABLE P5.36

	Project's Cash Flow	
n	A	B
0	−$22,000	−$27,000
1	$17,500	$20,500
2	$17,000	$28,000
3	$15,000	—

Assuming that you need service of either machine for an indefinite period, which project would be selected at $i = 16\%$? Assume that both types of machine are available with the same costs and benefits during the planning horizon.

5.37 Consider the two mutually exclusive investment projects in Table P5.37, which have unequal service lives.

TABLE P5.37

	Project's Cash Flow	
n	A1	A2
0	−$900	−$1,800
1	−$400	−$300
2	−$400	−$300
3	−$400 + $200	−$300
4	—	−$300
5	—	−$300
6	—	−$300 + $500

(a) What assumption(s) do you need in order to compare a set of mutually exclusive service projects with unequal service lives?
(b) With the assumption(s) defined in part (a) and using 10%, determine which project should be selected.
(c) If your analysis period (study period) is just three years, what should be the salvage value of project A2 at the end of year 3 to make the two alternatives economically indifferent?

5.38 Consider the two mutually exclusive projects in Table P5.38.

TABLE P5.38

	B1		B2	
n	Cash Flow	Salvage Value	Cash Flow	Salvage Value
0	−\$20,000	—	−\$17,000	—
1	−\$2,000	\$10,000	−\$2,500	\$9,000
2	−\$2,000	\$8,000	−\$2,500	\$6,000
3	−\$2,000	\$5,000	−\$2,500	\$3,000
4	−\$2,000	\$3,000	—	—
5	−\$2,000	\$2,000	—	—

Salvage values represent the net proceeds (after tax) from disposal of the assets if they are sold at the end of each year. Both projects B1 and B2 will be available (or can be repeated) with the same costs and salvage values for an indefinite period.

(a) Assuming an infinite planning horizon, which project is a better choice at MARR = 12%?

(b) With a 10-year planning horizon, which project is a better choice at MARR = 12%?

5.39 Two methods of carrying away surface runoff water from a new subdivision are being evaluated.

- **Method A.** Dig a ditch. The first cost would be \$50,000, and \$24,000 of re-digging and shaping would be required at five-year intervals forever.
- **Method B.** Lay a concrete pipe. The first cost would be \$140,000, and a replacement would be required at 50-year intervals at a net cost of \$175,000 forever.

At $i = 14\%$, which method is the better one?

5.40 A local car dealer is advertising a standard 24-month lease of \$1,150 per month for its new XT 3000 series sports car. The standard lease requires a down payment of \$4,500, plus a \$1,000 refundable initial deposit *now*. The first lease payment is due at the beginning of month 1. In addition, the company offers a 24-month lease plan that has a single up-front payment of \$29,500, plus a refundable initial deposit of \$1,000. Under both options, the initial deposit will be refunded at the end of month 24. Assume an interest rate of 6% compounded monthly. With the present-worth criterion, which option is preferred?

5.41 You are considering two types of machines for a manufacturing process.

- **Machine A** has a first cost of \$75,200, and its salvage value at the end of six years of estimated service life is \$21,000. The operating costs of this machine are estimated to be \$6,800 per year. Extra income taxes are estimated at \$2,400 per year.

- **Machine B** has a first cost of $44,000, and its salvage value at the end of six years' service is estimated to be negligible. The annual operating costs will be $11,500.

Compare these two mutually exclusive alternatives by the present-worth method at $i = 13\%$.

5.42 An electric motor is rated at 10 horsepower (HP) and costs $1,200. Its full-load efficiency is specified to be 85%. A newly designed high-efficiency motor of the same size has an efficiency of 90%, but it costs $1,600. It is estimated that the motors will operate at a rated 10 HP output for 2,000 hours a year, and the cost of energy will be $0.09 per kilowatt-hour. Each motor is expected to have a 15-year life. At the end of 15 years, the first motor will have a salvage value of $50 and the second motor will have a salvage value of $100. Consider the MARR to be 8%. (*Note*: 1 HP = 0.7457 kW.)

(a) Use the NPW criterion to determine which motor should be installed.

(b) In part (a), what if the motors operated 1,000 hours a year instead of 2,000 hours a year? Would the motor you chose in part (a) still be the best choice?

5.43 Consider the cash flows for two types of models given in Table P5.43.

TABLE P5.43

	Project's Cash Flow	
n	**Model A**	**Model B**
0	−$8,000	−$15,000
1	$3,500	$10,000
2	$3,500	$10,000
3	$3,500	—

Both models will have no salvage value upon their disposal (at the end of their respective service lives). The firm's MARR is known to be 12%.

(a) Notice that the models have different service lives. However, model A will be available in the future with the same cash flows, whereas Model B is available at one time only. If you select model B now, you will have to replace it with model A at the end of year 2. If your firm uses the present worth as a decision criterion, which model should be selected, assuming that the firm will need either model for an indefinite period?

(b) Suppose that your firm will need either model for only two years. Determine the salvage value of model A at the end of year 2 that makes both models indifferent (equally likely).

5.44 An electric utility is taking bids on the purchase, installation, and operation of microwave towers. Table P5.44 has some details associated with the two bids that were received.

TABLE P5.44

	Cost per Tower	
	Bid A	**Bid B**
Equipment cost	$112,000	$98,000
Installation cost	$25,000	$30,000
Annual maintenance and inspection fee	$2,000	$2,500
Annual extra income taxes	—	$800
Life	40 years	35 years
Salvage value	$0	$0

(a) Which is the most economical bid if the interest rate is considered to be 11%? Neither tower will have any salvage value after 20 years of use.

(b) Use the NPW method to compare these two mutually exclusive plans.

5.45 A mall with two levels is under construction. The plan is to install only 9 escalators at the start, although the ultimate design calls for 16. The question arises as to whether to provide necessary facilities (stair supports, wiring conduits, motor foundations, etc.) that would permit the installation of the additional escalators at the mere cost of their purchase and installation or to defer investment in these facilities until the escalators need to be installed.

- **Option 1:** Provide these facilities now for all seven future escalators at $300,000.
- **Option 2:** Defer the investment in the facility as needed. Install two more escalators in two years, three more in five years, and the last two in eight years. The installation of these facilities at the time they are required is estimated to cost $140,000 in year 2, $160,000 in year 5, and $180,000 in year 8.

Additional annual expenses are estimated at $7,000 for each escalator facility installed. Assume that these costs begin one year subsequent to the actual addition. At an interest rate of 12%, compare the net present worth of each option over eight years.

5.46 A large refinery–petrochemical complex is to manufacture caustic soda, which will use feedwater of 10,000 gallons per day. Two types of feedwater storage installation are being considered over the 40 years of their useful life.

- **Option 1:** Build a 20,000-gallon tank on a tower. The cost of installing the tank and tower is estimated to be $164,000. The salvage value is estimated to be negligible.
- **Option 2:** Place a tank of 20,000-gallon capacity on a hill, which is 150 yards away from the refinery. The cost of installing the tank on the hill, including the extra length of service lines, is estimated to be $120,000 with negligible salvage value. Because of the tank's location on the hill, an additional investment of $12,000 in pumping equipment is required. The pumping equipment is expected to have a service life of 20 years with a salvage value of $1,000 at the end of that time. The annual operating and maintenance cost (including any income tax effects) for the pumping operation is estimated at $1,000.

If the firm's MARR is known to be 12%, which option is better on the basis of the present-worth criterion?

5.47 Consider the following two mutually exclusive service projects with project lives of three years and two years, respectively. (The mutually exclusive service projects will have identical revenues for each year of service.) The interest rate is known to be 12%.

	Net Cash Flow	
End of Year	Project A	Project B
0	−$1,000	−$800
1	−$400	−$200
2	−$400	−$200 + $0
3	−$400 + $200	

If the required service period is six years and both projects can be repeated with the given costs and better service projects are unavailable in the future, which project is better and why? Choose from the following options:

(a) Select Project B because it will save you $344 in present worth over the required service period.

(b) Select Project A because it will cost $1,818 in NPW each cycle, with only one replacement, whereas Project B will cost $1,138 in NPW each cycle with two replacements.

(c) Select Project B because its NPW exceeds that of Project A by $680.

(d) None of the above.

Short Case Studies with Excel

5.48 An electrical utility is experiencing sharp power demand, which continues to grow at a high rate in a certain local area. Two alternatives to address this situation are under consideration. Each alternative is designed to provide enough capacity during the next 25 years. Both alternatives will consume the same amounts of fuel, so fuel cost is not considered in the analysis. The alternatives are detailed as follows:

- **Alternative *A*:** Increase the generating capacity now so that the ultimate demand can be met with additional expenditures later. An initial investment of $30 million would be required, and it is estimated that this plant facility would be in service for 25 years and have a salvage value of $0.85 million. The annual operating and maintenance costs (including income taxes) would be $0.4 million.

- **Alternative *B*:** Spend $10 million now, and follow this expenditure with additions during the 10th year and the 15th year. These additions would cost $18 million and $12 million, respectively. The facility would be sold 25 years from now with a salvage value of $1.5 million. The annual operating and maintenance costs (including income taxes) initially will be $250,000 increasing to $350,000 after the first addition (from the 11th year to the 15th year) and to $450,000 during the final 10 years. (Assume that these costs begin one year subsequent to the actual addition.)

If the firm uses 15% as a MARR, which alternative should be undertaken based on the present-worth criterion?

5.49 Apex Corporation requires a chemical finishing process for a product under contract for a period of six years. Three options are available. Neither Option 1 nor Option 2 can be repeated after its process life. However, Option 3 will always be available from H&H Chemical Corporation at the same cost during the contract period. The details of each option are as follows:

- **Option 1:** Process device A, which costs \$100,000, has annual operating and labor costs of \$60,000, and has a useful service life of four years with an estimated salvage value of \$10,000.
- **Option 2:** Process device B, which costs \$150,000, has annual operating and labor costs of \$50,000, and has a useful service life of six years with an estimated salvage value of \$30,000.
- **Option 3:** Subcontract the process out at a cost of \$100,000 per year.

According to the present-worth criterion, which option would you recommend at $i = 12\%$?

5.50 H-Robotic Incorporated (HRI), a world leader in the robotics industry, produces a line of industrial robots and peripheral equipment that performs many routine assembly-line tasks. However, increased competition, particularly from Japanese firms, has caused HRI's management to be concerned about the company's growth potential in the future. HRI's research and development department has been applying the industrial robot technology to develop a line of household robots. The household robot is designed to function as a maid, mainly performing such tasks as vacuuming floors and carpets. This effort has now reached the stage where a decision on whether to go forward with production must be made. The engineering department has estimated that the firm would need a new manufacturing plant with the following construction schedule:

- The plant would require a 35-acre site, and HRI currently has an option to purchase a suitable tract of land for \$2.5 million. The building construction would begin in early 2018 and continue through 2019. The building would cost \$10.5 million in total, but a \$3.5 million payment would be made to the contractor on December 31, 2018, and another \$7 million payable on December 31, 2019.
- The necessary manufacturing equipment would be installed late in 2019 and would be paid for on December 31, 2019. The equipment would cost \$18.5 million, including transportation, plus another \$500,000 for installation.
- As of December 31, 2017, the company has spent \$12 million on research and development associated with the household robot.

(a) What is the equivalent total investment cost (future worth) at the time of completion (December 31, 2019), assuming that HRI's MARR is 15%?

(b) If the product life is 10 years, what is the required minimum annual net cash flow (after all expenses) that must be generated to just break even? (Ignore any tax considerations.)

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