chapter 11

The Basics of Capital Budgeting: Evaluating Cash Flows

In 1970, the Adolph Coors Company was a small brewer serving a regional market, but because of its quality products and aggressive marketing, by 1990 Coors had risen to the number three brand in the U.S. beer market. During this high-growth phase, the corporate emphasis was on marketing, technology, engineering, and capacity additions. When investing in new equipment or factories, Coors always went "the Cadillac route," with little scrutiny of proposed projects. In effect, their motto was "If you build it, they will come," and indeed, for two decades consumers did come to Coors.

However, the brewing industry began to experience major problems in the 1990s. Many consumers were drawn to wine, causing growth in beer sales to fall below 1% per year. In addition, large numbers of microbreweries opened, providing beer drinkers with an alternative to the national brands. These events proved particularly painful to Coors, whose lack of financial discipline had led to a frivolous use of capital and thus to a high-cost infrastructure.

In 1995 Coors hired a new CFO, Timothy Wolf, who soon learned that Coors had a low return on invested capital, a negative free cash flow, and an unreliable planning/forecasting process. Wolf quickly created an in-house education program to teach managers and engineers how to conduct rational project analyses. Even more important, he began to shift the corporate culture from a focus on undisciplined growth and high-technology engineering to creating shareholder value. This new focus was put to the test when Coors reexamined its plans for a major new bottle-washing facility in Virginia. Using the capital budgeting processes established by Wolf, the project team was able to reduce the cost of the investment by 25% even as they implemented design changes that led to lower operating costs.

In 2005, Coors merged with Molson Inc. to form Coors Molson Brewing Company, and Wolf became the Global CFO of the combined brewery. With a continued focus on free cash flow and return on invested capital, the value of a share of Coors' stock has climbed from about $14 when Wolf joined in 1995 to over $68 in July 2006, an annualized average gain of more than 15%.

Capital budgeting is the process of evaluating a company's potential investments and deciding which ones to accept. This chapter provides an overview of the capital budgeting process and explains the basic techniques used to evaluate potential projects, given that their expected cash flows have already been estimated. Chapter 12 then explains how to estimate a project's cash flows and analyze its risk.

11.1 Overview of Capital Budgeting

Capital budgeting is the decision process that managers use to identify those projects that add to the firm's value, and as such it is perhaps the most important task faced by financial managers and their staffs. First, a firm's capital budgeting decisions define its strategic direction because moves into new products, services, or markets must be preceded by capital expenditures. Second, the results of capital budgeting decisions continue for many years, reducing flexibility. Third, poor capital budgeting can have serious financial consequences. If the firm invests too much, it will waste investors' capital on excess capacity. On the other hand, if it does not invest enough, its equipment and computer software may not be sufficiently modern to enable it to produce competitively. Also, if it has inadequate capacity, it may lose market share to rival firms, and regaining lost customers requires heavy selling expenses, price reductions, or product improvements, all of which are costly.

A firm's growth, and even its ability to remain competitive and to survive, depends on a constant flow of ideas for new products, for ways to make existing products better, and for ways to operate at a lower cost. Accordingly, a well-managed firm will go to great lengths to encourage good capital budgeting proposals from its employees. If a firm has capable and imaginative executives and employees, and if its incentive system is working properly, many ideas for capital investment will be advanced. Some ideas will be good ones, but others will not.

Corporate Valuation and Capital Budgeting

You can calculate the free cash flows (FCF) for a project in much the same way as for a firm. When the project's free cash flows are discounted at the appropriate risk-adjusted rate, the result is the project's value. One difference between valuing a firm and valuing a project is the rate that is used to discount cash flows. For a firm, it is the overall weighted cost of capital; for a project, it is r, the project's risk-adjusted cost of capital.

Subtracting the initial cost of the project gives the net present value (NPV). If a project has a positive NPV, then it adds value to the firm. In fact, the firm's market value added (MVA) is the sum of all its projects' NPVs. Therefore, the process for evaluating projects, called **capital budgeting,** is critical for a firm's success.

$$ \text{NPV} = \left[\frac{\text{FCF}_1}{(1+r)^1} + \frac{\text{FCF}_2}{(1+r)^2} + \cdots + \frac{\text{FCF}_N}{(1+r)^N} \right] - \text{Initial cost} $$

Therefore, companies must screen projects for those that add value, the primary topic of this chapter.

Screening capital expenditure proposals is not a costless operation—analysis provides benefits, but it also has a cost in terms of the time it requires. Larger investments and riskier projects require increasingly detailed analysis and approval at a higher level within the firm. Thus, a plant manager might be authorized to approve routine maintenance expenditures up to $10,000 on the basis of a relatively unsophisticated analysis, but the full board of directors might have to approve decisions that involve either amounts over $1 million or expansions into new products or markets.

Six key methods are used to evaluate projects and to decide whether or not they should be accepted: (1) net present value (NPV), (2) internal rate of return (IRR), (3) modified internal rate of return (MIRR), (4) profitability index (PI), (5) payback, and (6) discounted payback. We explain how each method is applied, and then we evaluate how well each performs in terms of identifying those projects that will maximize the firm's stock price.

The first, and most difficult, step in project analysis is estimating the relevant cash flows, a step that Chapter 12 explains in detail. Our present focus is on the different evaluation methods, so we provide the cash flows used in this chapter, starting with the expected cash flows of Projects S and L in Panel A of Figure 11-1 (we will explain Panel B when we discuss the evaluation methods shown in the next sections). These projects are equally risky, and the cash flows for each year, CF_t, reflect purchase cost, investments in working capital, taxes, depreciation, and salvage values. As we show in Chapter 12, this definition of project cash flows is equivalent to the definition of free cash flows as defined in Chapter 3, except the

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Web Extension 11A at the textbook's Web site explains a seventh method, the accounting rate of return (ARR) approach. The ARR approach has major flaws, and the Web Extension explains why it should not be used.

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See *FM12 Ch 11 Tool Kit.xls* at the textbook's Web site for all calculations.

Figure 11-1

Net Cash Flows and Selected Evaluation Criteria for Projects S and L (CF$_t$)

	A	B	C	D	E	F
23	**Panel A: Project Cash Flows and Cost of Capital**					
24						
25	**Project S:**	**0**	**1**	**2**	**3**	**4**
26						
27		-$1,000	$500	$400	$300	$100
28						
29	**Project L:**	**0**	**1**	**2**	**3**	**4**
30						
31		-$1,000	$100	$300	$400	$600
32						
33		**Project cost of capital = r =**		**10%**		
34						
35	**Panel B: Summary of Selected Evaluation Criterion**					
36						
37			**Project**			
38			**S**	**L**		
39		**NPV:**	**$78.82**	**$49.18**		
40		**IRR:**	**14.5%**	**11.8%**		
41		**MIRR:**	**12.1%**	**11.3%**		
42		**PI:**	**1.08**	**1.05**		

cash flows are for the project and not the entire firm. Finally, we assume that all cash flows occur at the end of the designated year. Incidentally, the S stands for *short* and the L for *long*: Project S is a short-term project in the sense that its cash inflows come in sooner than L's.

Why are capital budgeting decisions so important?

What are some ways firms get ideas for capital projects?

Which types of projects receive the most analysis?

11.2 Net Present Value (NPV)

The **net present value (NPV) method** is based upon the **discounted cash flow (DCF) technique.** To implement this approach, we proceed as follows:

1. Find the present value of each cash flow, including the initial cash flow, discounted at the project's cost of capital, r.
2. Sum these discounted cash flows; this sum is defined as the project's NPV.

The equation for the NPV is as follows:

$$NPV = CF_0 + \frac{CF_1}{(1+r)^1} + \frac{CF_2}{(1+r)^2} + \cdots + \frac{CF_N}{(1+r)^N}$$

$$= \sum_{t=0}^{N} \frac{CF_t}{(1+r)^t}.$$

(11-1)

Here CF_t is the expected net cash flow at Period t, r is the project's cost of capital, and n is its life. Cash outflows (expenditures such as the cost of buying equipment or building factories) are treated as *negative* cash flows. In evaluating Projects S and L, only CF_0 is negative, but for many large projects such as the Alaska Pipeline, an electric generating plant, or a new Boeing jet aircraft, outflows occur for several years before operations begin and cash flows turn positive.

Application of the NPV Method

At a 10% cost of capital, Project S's NPV is $78.82:
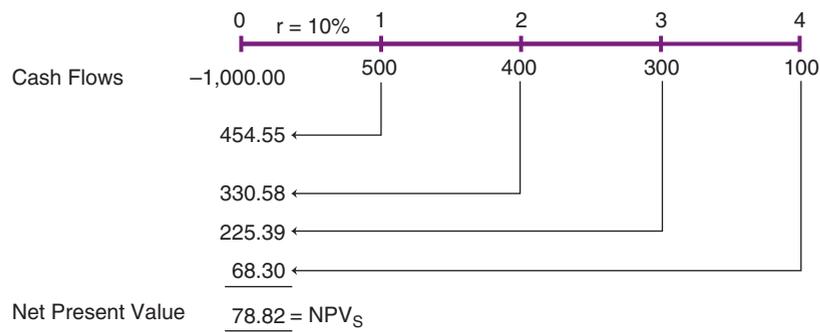
By a similar process, we find $NPV_L = \$49.18$.

If the projects were *mutually exclusive*, the one with the higher NPV should be accepted and the other rejected. S would be ranked over L and thus accepted because S has the higher NPV. **Mutually exclusive** means that if one project is taken on, the other must be rejected. For example, a conveyor-belt system to move goods in a warehouse and a fleet of forklifts for the same purpose illustrates mutually exclusive projects—accepting one implies rejecting the other. **Independent projects** are those whose cash flows are independent of one another. If Wal-Mart were considering a new store in Boise and another in Atlanta, those projects would be independent of one another. If our Projects S and L were independent, then both should be accepted because both have a positive NPV and thus add value to the firm. If they were mutually exclusive, then S should be chosen because it has the higher NPV.

Calculating the NPV by using Equation 11-1 and a regular calculator becomes tedious and error-prone for projects with many cash flows. It is much more efficient to use a financial calculator or a spreadsheet. Different calculators are set up somewhat differently, but they all have a section of memory called the "cash flow register" that is used for uneven cash flows such as those in Projects S and L (as opposed to equal annuity cash flows). A solution process for Equation 11-1 is literally programmed into financial calculators, and all you have to do is enter the cash flows (being sure to observe the signs), along with the value of $r = I/YR$. At that point, you have (in your calculator) this equation:

$$NPV_S = -1{,}000 + \frac{500}{(1.10)^1} + \frac{400}{(1.10)^2} + \frac{300}{(1.10)^3} + \frac{100}{(1.10)^4}.$$

Note that the equation has one unknown, NPV. Now all you need to do is to ask the calculator to solve the equation for you, which you do by pressing the NPV button (and, on some calculators, the "compute" button). The answer, 78.82, will appear on the screen.[1]

Most projects last for more than 4 years, and, as you will see in Chapter 12, we must go through quite a few steps to develop the estimated cash flows. Therefore, financial analysts generally use spreadsheets for project analysis. The cash flows for Projects S and L are shown in the spreadsheet in Panel A of Figure 11-1. In Panel B, we used the *Excel* NPV function to calculate the projects' NPVs. To access the NPV function in *Excel*, you can click the function wizard, f_x, then Financial, then NPV, and then OK. Input D33 as the first argument in the NPV function; this is the rate for *Excel* to use in discounting the cash flows. Then input the range of future cash flows, C27:F27, in the NPV function as "Value 1." Click OK, and the result is $1,078.82. Despite its name, the NPV function actually finds the PV of future cash flows, not the NPV. To find the NPV, edit the cell by adding B27 to the NPV result. The resulting formula in Cell C39 is **=B27+NPV(D33,C27:F27)**, and it gives a value of $78.82. Note that you cannot enter the initial cash flow of −$1,000 as part of the NPV range because the *Excel* NPV function assumes that the first cash flow in the range occurs at $t = 1$. Also be aware that if you input a value for the rate, it must be the actual number. For example, we could have entered a rate of "0.10" or "10%," but if we entered "10," *Excel* would interpret it as 1000%. This is exactly opposite the convention used in financial calculators, where you would enter 10.

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[1]The keystrokes for finding the NPV are shown for several calculators in the calculator tutorials provided at the textbook's Web site.

Rationale for the NPV Method

The rationale for the NPV method is straightforward. An NPV of zero signifies that the project's cash flows are exactly sufficient to repay the invested capital and to provide the required rate of return on that capital. If a project has a positive NPV, then it is generating more cash than is needed to service the debt and to provide the required return to shareholders, and this excess cash accrues solely to the firm's stockholders. Therefore, if a firm takes on a project with a positive NPV, the wealth of the stockholders increases. In our example, shareholders' wealth would increase by $78.82 if the firm takes on Project S, but by only $49.18 if it takes on Project L. Viewed in this manner, it is easy to see why S is preferred to L, and it is also easy to see the logic of the NPV approach.[2]

There is also a direct relationship between NPV and EVA (economic value added, as discussed in Chapter 3)—NPV is equal to the present value of the project's future EVAs. Therefore, accepting positive NPV projects should result in a positive EVA and a positive MVA (Market Value Added, or the excess of the firm's market value over its book value). So, a reward system that compensates managers for producing positive EVA is consistent with the use of NPV for making capital budgeting decisions.

Why is the NPV regarded as being the primary capital budgeting decision criterion?

What is the difference between "independent" and "mutually exclusive" projects?

A project has the following expected cash flows: $CF_0 = -\$500$, $CF_1 = \$200$, $CF_2 = \$200$, and $CF_3 = \$400$. If the project cost of capital is 9%, what is the NPV? **($160.70)**

11.3 Internal Rate of Return (IRR)

In Chapter 5 we presented procedures for finding the yield to maturity, or rate of return, on a bond—if you invest in a bond, hold it to maturity, and receive all of the promised cash flows, you will earn the YTM on the money you invested. Exactly the same concepts are employed in capital budgeting when the **internal rate of return (IRR) method** is used. The IRR is defined as the discount rate that forces the NPV to equal zero:

$$CF_0 + \frac{CF_1}{(1 + IRR)^1} + \frac{CF_2}{(1 + IRR)^2} + \cdots + \frac{CF_N}{(1 + IRR)^N} = 0$$

$$NPV = \sum_{t=0}^{n} \frac{CF_t}{(1 + IRR)^t} = 0.$$

(11-2)

Application of the IRR Method

For our Project S, here is the time line setup:

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[2]This description of the process is somewhat oversimplified. Both analysts and investors anticipate that firms will identify and accept positive NPV projects, and current stock prices reflect these expectations. Thus, stock prices react to announcements of new capital projects only to the extent that such projects were not already expected.
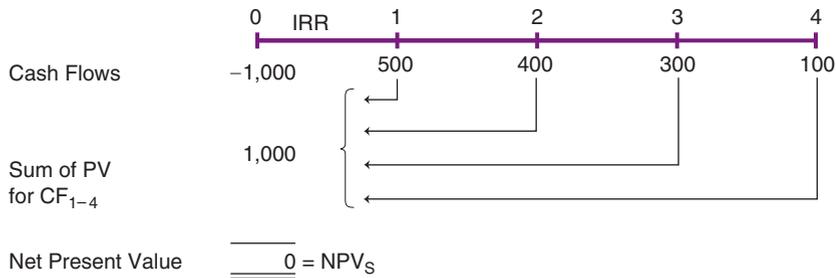
$$-1000 + \frac{500}{(1 + \text{IRR})^1} + \frac{400}{(1 + \text{IRR})^2} + \frac{300}{(1 + \text{IRR})^3} + \frac{100}{(1 + \text{IRR})^4} = 0$$

Thus, we have an equation with one unknown, IRR, and we need to solve for IRR.

Although it is relatively easy to find the NPV without a financial calculator, this is *not* true of the IRR. If the cash flows are constant from year to year, then we have an annuity, and we can use annuity formulas to find the IRR. However, if the cash flows are not constant, as is generally the case in capital budgeting, then it is difficult to find the IRR without a financial calculator. Without a calculator, you must solve Equation 11-2 by trial and error: Try some discount rate and see if the equation solves to zero, and if it does not, try a different discount rate, and continue until you find the rate that forces the equation to equal zero. The discount rate that causes the equation (and the NPV) to equal zero is defined as the IRR. For a realistic project with a fairly long life, the trial-and-error approach is a tedious, time-consuming task.

Fortunately, it is easy to find IRRs with a financial calculator. You follow procedures almost identical to those used to find the NPV. First, you enter the cash flows as shown on the preceding time line into the calculator's cash flow register. In effect, you have entered the cash flows into the equation shown below the time line. Note that we have one unknown, IRR, which is the discount rate that forces the equation to equal zero. The calculator has been programmed to solve for the IRR, and you activate this program by pressing the button labeled "IRR." Then the calculator solves for IRR and displays it on the screen. Here are the IRRs for Projects S and L as found with a financial calculator:

$$\text{IRR}_\text{S} = 14.5\%$$
$$\text{IRR}_\text{L} = 11.8\%.$$

It is also easy to find the IRR using the same spreadsheet we used for the NPV, shown in Panel B of Figure 11-1. With *Excel*, we simply enter this formula in Cell C40: =**IRR(B27:F27).** For Project S, the result is 14.5%.[3]

If both projects have a cost of capital, or **hurdle rate,** of 10%, then the internal rate of return rule indicates that if the projects are independent, both should be accepted—they are both expected to earn more than the cost of the capital needed to finance them. If they are mutually exclusive, S ranks higher and should be accepted, so L should be rejected. If the cost of capital is above 14.5%, both projects should be rejected.

Notice that the internal rate of return formula, Equation 11-2, is simply the NPV formula, Equation 11-1, solved for the particular discount rate that forces the NPV to equal zero. Thus, the same basic equation is used for both methods, but in the NPV method the discount rate, r, is specified and the NPV is found, whereas

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[3]Note that the full range is specified, because *Excel's* IRR function assumes that the first cash flow (the negative $1,000) occurs at t = 0. You can use the function wizard if you don't have the formula memorized.

in the IRR method the NPV is specified to equal zero, and the interest rate that forces this equality (the IRR) is calculated.

Mathematically, the NPV and IRR methods will always lead to the same accept/reject decisions for independent projects. This occurs because if NPV is positive, IRR must exceed r. However, NPV and IRR can give conflicting rankings for mutually exclusive projects. This point will be discussed in more detail in a later section.

Rationale for the IRR Method

Why is the particular discount rate that equates a project's cost with the present value of its receipts (the IRR) so special? The reason is based on this logic: (1) The IRR on a project is its expected rate of return. (2) If the internal rate of return exceeds the cost of the funds used to finance the project, a surplus will remain after paying for the capital, and this surplus will accrue to the firm's stockholders. (3) Therefore, taking on a project whose IRR exceeds its cost of capital increases shareholders' wealth. On the other hand, if the internal rate of return is less than the cost of capital, then taking on the project will impose a cost on current stockholders. It is this "break-even" characteristic that makes the IRR useful in evaluating capital projects.

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In what sense is the IRR on a project related to the YTM on a bond?

A project has the following expected cash flows: $CF_0 = -\$500$, $CF_1 = \$200$, $CF_2 = \$200$, and $CF_3 = \$400$. What is the IRR? (24.1%)

11.4 Comparison of the NPV and IRR Methods

In many respects the NPV method is better than IRR, so it is tempting to explain NPV only, to state that it should be used to select projects, and to go on to the next topic. However, the IRR is familiar to many corporate executives, it is widely entrenched in industry, and it does have some virtues. Therefore, it is important for you to understand the IRR method but also to be able to explain why, at times, a project with a lower IRR may be preferable to a mutually exclusive alternative with a higher IRR.

NPV Profiles

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See **FM12 Ch 11 Tool Kit.xls** at the textbook's Web site for all calculations.

A graph that plots a project's NPV against the cost-of-capital rates is defined as the project's **net present value profile;** profiles for Projects L and S are shown in Figure 11-2. To construct NPV profiles, first note that at a zero cost of capital, the NPV is simply the total of the projects' undiscounted cash flows. Thus, at a zero cost of capital $NPV_S = \$300$ and $NPV_L = \$400$. These values are plotted as the vertical axis intercepts in Figure 11-2. Next, we calculate the projects' NPVs at three costs of capital, 5, 10, and 15%, and plot these values. The four points plotted on our graph for each project are shown at the bottom of the figure.

Recall that the IRR is defined as the discount rate at which a project's NPV equals zero. Therefore, *the point where its net present value profile crosses the horizontal axis indicates a project's internal rate of return.* Since we calculated IRR_S and IRR_L in an earlier section, we can confirm the validity of the graph.

When we plot a curve through the data points, we have the net present value profiles. NPV profiles can be very useful in project analysis, and we will use them often in the remainder of the chapter.

Figure 11-2

Net Present Value Profiles: NPVs of Projects S and L at Different Costs of Capital
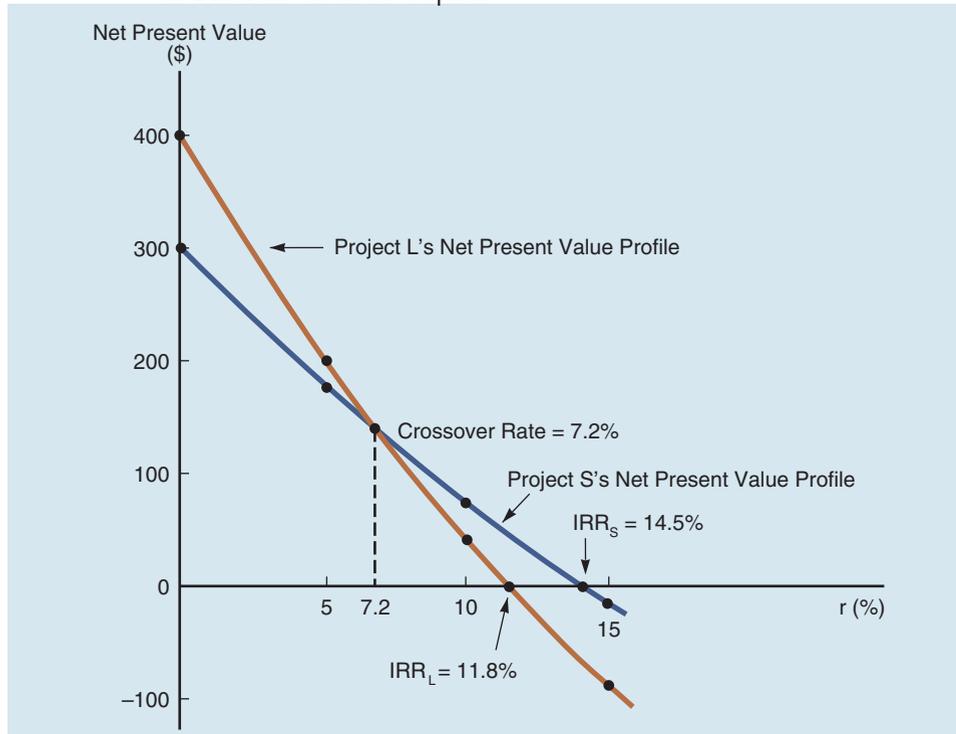
r	NPV_S	NPV_L
0%	$300.00	$400.00
5	180.42	206.50
10	78.82	49.18
15	(8.33)	(80.14)

NPV Rankings Depend on the Cost of Capital

Figure 11-2 shows that the NPV profiles of both Project L and Project S decline as the cost of capital increases. But notice in the figure that Project L has the higher NPV when the cost of capital is low, while Project S has the higher NPV if the cost of capital is greater than the 7.2% crossover rate. Notice also that Project L's NPV is "more sensitive" to changes in the cost of capital than is NPV_S; that is, Project L's net present value profile has the steeper slope, indicating that a given change in r has a greater effect on NPV_L than on NPV_S.

Recall that a long-term bond has greater sensitivity to interest rates than a short-term bond. Similarly, if a project has most of its cash flows coming in the early years, its NPV will not decline very much if the cost of capital increases, but a project whose cash flows come later will be severely penalized by high capital costs. Accordingly, Project L, which has its largest cash flows in the later years, is hurt badly if the cost of capital is high, while Project S, which has relatively rapid cash flows, is affected less by high capital costs. Therefore, Project L's NPV profile has the steeper slope.

Evaluating Independent Projects

If *independent* projects are being evaluated, then the NPV and IRR criteria always lead to the same accept/reject decision: If NPV says accept, IRR also says accept. To see why this is so, assume that Projects L and S are independent, look at Figure 11-2, and notice (1) that the IRR criterion for acceptance for either project is that the project's cost of capital is less than (or to the left of) the IRR and (2) that whenever a project's cost of capital is less than its IRR, its NPV is positive. Thus, at any cost of capital less than 11.8%, Project L will be acceptable by both the NPV and the IRR criteria, while both methods reject Project L if the cost of capital is greater than 11.8%. Project S—and all other independent projects under consideration—could be analyzed similarly, and it will always turn out that if the IRR method says accept, then so will the NPV method.

Evaluating Mutually Exclusive Projects

Now assume that Projects S and L are *mutually exclusive* rather than independent. That is, we can choose either Project S or Project L, or we can reject both, but we cannot accept both projects. Notice in Figure 11-2 that as long as the cost of capital is *greater than* the crossover rate of 7.2%, then (1) NPV_S is larger than NPV_L and (2) IRR_S exceeds IRR_L. Therefore, if r is *greater than* the crossover rate of 7.2%, the two methods both lead to the selection of Project S. However, if the cost of capital is *less than* the crossover rate, the NPV method ranks Project L higher, but the IRR method indicates that Project S is better. *Thus, a conflict exists if the cost of capital is less than the crossover rate.*[4] NPV says choose mutually exclusive L, while IRR says take S. Which is correct? Logic suggests that the NPV method is better, because it selects the project that adds the most to shareholder wealth. But what causes the conflicting recommendations?

Two basic conditions can cause NPV profiles to cross, and thus conflicts to arise between NPV and IRR: (1) when *project size (or scale) differences* exist, meaning that the cost of one project is larger than that of the other, or (2) when *timing differences* exist, meaning that the timing of cash flows from the two projects differs such that most of the cash flows from one project come in the early years while most of the cash flows from the other project come in the later years, as occurred with our Projects L and S.

When either size or timing differences are present, the firm will have different amounts of funds to invest in the various years, depending on which of the two mutually exclusive projects it chooses. For example, if one project costs more than the other, then the firm will have more money at t = 0 to invest elsewhere if it selects the smaller project. Similarly, for projects of equal size, the one with the larger early cash inflows—in our example, Project S—provides more funds for reinvestment in the early years. Given this situation, the rate of return at which differential cash flows can be invested is a critical issue.

The key question in resolving conflicts between mutually exclusive projects is this: How useful is it to generate cash flows sooner rather than later? The value of early cash flows depends on the return we can earn on those cash flows, that is, the rate at which we can reinvest them. *The NPV method implicitly assumes that the rate at which cash flows can be reinvested is the cost of capital, whereas the IRR method*

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[4]The crossover rate is easy to calculate. Simply go back to Figure 11-1, where we set forth the two projects' cash flows, and calculate the difference in those flows in each year. The differences are $CF_S - CF_L = \$0$, $+\$400$, $+\$100$, $-\$100$, and $-\$500$, respectively. Enter these values in the cash flow register of a financial calculator, press the IRR button, and the crossover rate, 7.17% ≈ 7.2%, appears. Be sure to enter $CF_0 = 0$, or you will not get the correct answer.

assumes that the firm can reinvest at the IRR. These assumptions are inherent in the mathematics of the discounting process. The cash flows may actually be withdrawn as dividends by the stockholders and spent on beer and pizza, but the NPV method still assumes that cash flows can be reinvested at the cost of capital, while the IRR method assumes reinvestment at the project's IRR.

Which is the better assumption—that cash flows can be reinvested at the cost of capital, or that they can be reinvested at the project's IRR? The best assumption is that projects' cash flows can be reinvested at the cost of capital, which means that the NPV method is more reliable.

We should reiterate that, when projects are independent, the NPV and IRR methods both lead to exactly the same accept/reject decision. However, *when evaluating mutually exclusive projects, especially those that differ in scale and/or timing, the NPV method should be used*.

Describe how NPV profiles are constructed, and define the crossover rate.

How does the "reinvestment rate" assumption differ between the NPV and IRR methods?

If a conflict exists, should the capital budgeting decision be made on the basis of the NPV or the IRR ranking? Why?

11.5 Multiple IRRs

There is another instance in which the IRR approach may not be reliable—when projects have nonnormal cash flows. A project has **normal cash flows** if it has one or more cash outflows (costs) followed by a series of cash inflows. Notice that normal cash flows have only one change in sign—they begin as negative cash flows, change to positive cash flows, and then remain positive.[5] **Nonnormal cash flows** occur when there is more than one change in sign. For example, a project may begin with negative cash flows, switch to positive cash flows, and then switch back to negative cash flows. This cash flow stream has two sign changes—negative to positive and then positive to negative—so it is a nonnormal cash flow. Projects with nonnormal cash flows can actually have two or more IRRs, or *multiple IRRs!*

To see this, consider the equation that one solves to find a project's IRR:

$$\sum_{t=0}^{N} \frac{CF_t}{(1 + IRR)^t} = 0. \qquad \text{(11-2)}$$

Notice that Equation 11-2 is a polynomial of degree N, so it may have as many as N different roots, or solutions. All except one of the roots are imaginary numbers when investments have normal cash flows (one or more cash outflows followed by cash inflows), so in the normal case, only one value of IRR appears. However, the possibility of multiple real roots, hence multiple IRRs, arises when the project has nonnormal cash flows (negative net cash flows occur during some year after the project has been placed in operation).

To illustrate, suppose a firm is considering the expenditure of $1.6 million to develop a strip mine (Project M). The mine will produce a cash flow of $10 million at the end of Year 1. Then, at the end of Year 2, $10 million must be expended to

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[5]Normal cash flows can also begin with positive cash flows, switch to negative cash flows, and then remain negative. The key is that there is only one change in sign.

Figure 11-3

NPV Profile for Project M
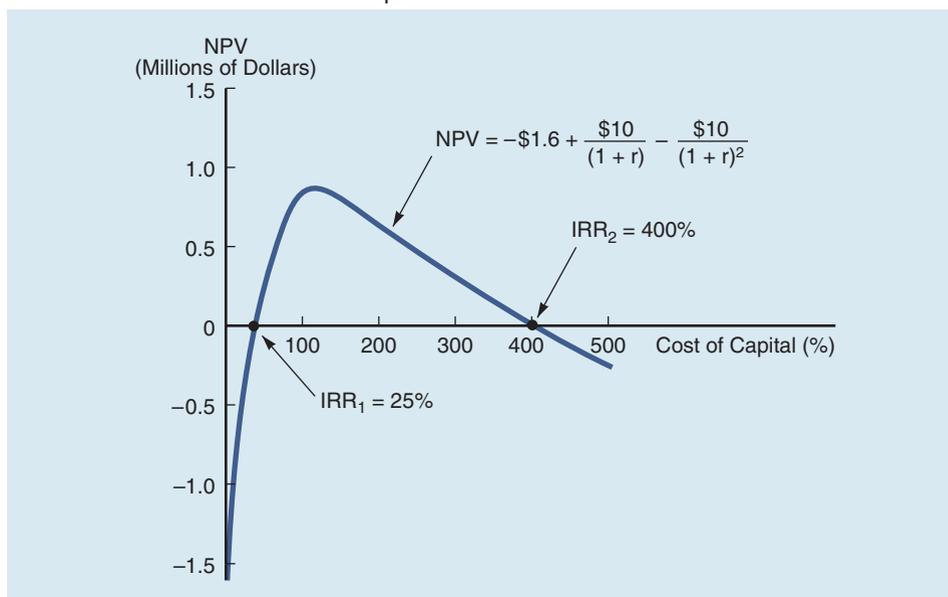
restore the land to its original condition. Therefore, the project's expected net cash flows are as follows (in millions of dollars):

Expected Net Cash Flows

Year 0	End of Year 1	End of Year 2
−$1.6	+$10	−$10

These values can be substituted into Equation 11-2 to derive the IRR for the investment:

$$NPV = \frac{-\$1.6 \text{ million}}{(1 + IRR)^0} + \frac{\$10 \text{ million}}{(1 + IRR)^1} + \frac{-\$10 \text{ million}}{(1 + IRR)^2} = 0.$$

When solved, we find that NPV = 0 when IRR = 25% and also when IRR = 400%.[6] Therefore, the IRR of the investment is both 25% and 400%. This relationship is depicted graphically in Figure 11-3. Note that no dilemma would arise if the NPV method were used; we would simply use Equation 11-1, find the NPV, and use the result to evaluate the project. If Proje%ct M's cost of capital were 10%, then its NPV would be −$0.77 million, and the project should be rejected. If r were between 25 and 400%, the NPV would be positive.

[6]If you attempted to find the IRR of Project M with many financial calculators, you would get an error message. This same message would be given for all projects with multiple IRRs. However, you can still find Project M's IRR by first calculating its NPV using several different values for r and then plotting the NPV profile. The intersection with the x-axis gives a rough idea of the IRR value. Finally, you can use trial and error to find the exact value of r that forces NPV = 0.

The IRR function in spreadsheets begins its trial-and-error search for a solution with an initial guess. If you omit the initial guess, the *Excel* default starting point is 10%. Now suppose the values −1.6, +10, and −10 were in Cells A1:C1. You could use this *Excel* formula, =**IRR(A1:C1,10%)**, where 10% is the initial guess, and it would produce a result of 25%. If you used a guess of 300%, you would have this formula, =**IRR(A1:C1,300%)**, and it would produce a result of 400%.

The example illustrates how multiple IRRs can arise when a project has non-normal cash flows. In contrast, the NPV criterion can easily be applied, and this method leads to conceptually correct capital budgeting decisions.

SELF-TEST

Explain the difference between normal and nonnormal cash flows, and their relationship to the "multiple IRR problem."

A project has the following cash flows: $CF_0 = -\$1,100$, $CF_1 = \$2,100$, $CF_2 = \$2,100$, and $CF_3 = =\$3,600$. How many positive IRRs might this project have? If you set the starting trial value to 10% in either your calculator or an *Excel* spreadsheet, what is the IRR? If you set the starting trial value to 400%? What is the NPV of the project with a very low cost of capital, such as r = 0%? Does this suggest that the project should or should not be accepted? (18.2%; 106.7%; −$500)

11.6 Modified Internal Rate of Return (MIRR)

In spite of a strong academic preference for NPV, surveys indicate that many executives prefer IRR over NPV. Apparently, managers find it intuitively more appealing to evaluate investments in terms of percentage rates of return than dollars of NPV. Given this fact, can we devise a percentage evaluator that is better than the regular IRR? The answer is yes—we can modify the IRR and make it a better indicator of relative profitability, hence better for use in capital budgeting. The new measure is called the **modified IRR,** or **MIRR,** and it is defined as follows:

$$\sum_{t=0}^{N} \frac{COF_t}{(1+r)^t} = \frac{\sum_{t=0}^{N} CIF_t(1+r)^{N-1}}{(1+MIRR)^N}$$

$$\text{PV of costs} = \frac{\text{Terminal value}}{(1+MIRR)^N}$$

$$= \text{PV of terminal value.}$$

(11-3)

Here COF refers to cash outflows (negative numbers) or the cost of the project, CIF refers to cash inflows (positive numbers), and r is the cost of capital. The left term is simply the present value of the investment outlays when discounted at the cost of capital, and the numerator of the right term is the compounded future value of the inflows, assuming that the cash inflows are reinvested at the cost of capital. The compounded future value of the cash inflows is also called the **terminal value,** or **TV.** The discount rate that forces the present value of the TV to equal the present value of the costs is defined as the MIRR.[7]

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[7]There are several alternative definitions for the MIRR. The differences primarily relate to whether negative cash flows that occur after positive cash flows begin should be compounded and treated as part of the TV or discounted and treated as a cost. A related issue is whether negative and positive flows in a given year should be netted or treated separately. For a complete discussion, see William R. McDaniel, Daniel E. McCarty, and Kenneth A. Jessell, "Discounted Cash Flow with Explicit Reinvestment Rates: Tutorial and Extension," *The Financial Review*, August 1988, pp. 369–385; and David M. Shull, "Interpreting Rates of Return: A Modified Rate of Return Approach," *Financial Practice and Education*, Fall 1993, pp. 67–71.

We can illustrate the calculation with Project S:
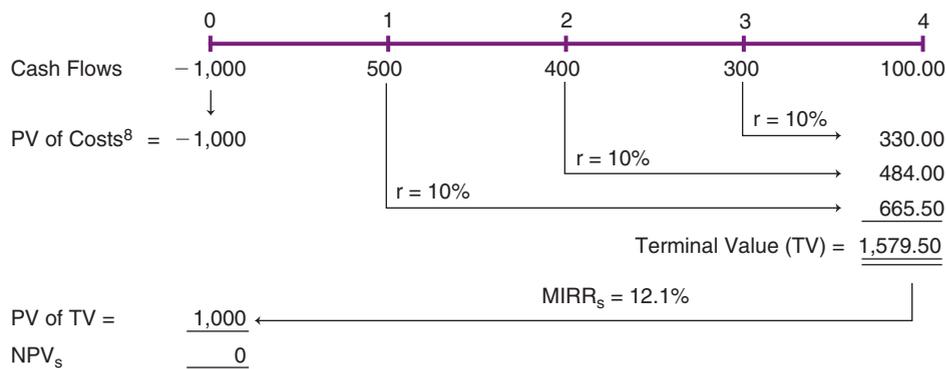
Using the cash flows as set out on the time line, first find the terminal value by compounding each cash inflow at the 10% cost of capital. Then enter N = 4, PV = −1000, PMT = 0, FV = 1579.5, and then press the I/YR button to find $MIRR_S$ = 12.1%. Similarly, we find $MIRR_L$ = 11.3%.

Excel has a function for the MIRR. Using the cash flows in Panel A of Figure 11-1, the formula in C41 is **=MIRR(B27:F27,D33,D33).** The first argument in the function is the range of cash flows, beginning with CF_0. The second argument is the cost of capital used for discounting cash outflows, and the third argument is the rate used for compounding inflows (i.e., the reinvestment rate). In our definition of the MIRR, we assume that reinvestment is at the cost of capital, so we enter the project cost of capital percent twice. The result is an MIRR of 12.1%.

The modified IRR has a significant advantage over the regular IRR. MIRR assumes that cash flows from all projects are reinvested at the cost of capital, while the regular IRR assumes that the cash flows from each project are reinvested at the project's own IRR. Because reinvestment at the cost of capital is generally more correct, the modified IRR is a better indicator of a project's true profitability. The MIRR also eliminates the multiple IRR problem. To illustrate, with r = 10%, Project M (the strip mine project) has MIRR = 5.6% versus its 10% cost of capital, so it should be rejected. This is consistent with the decision based on the NPV method, because at r = 10%, NPV = −$0.77 million.

Is MIRR as good as NPV for choosing between mutually exclusive projects? If two projects are of equal size and have the same life, then NPV and MIRR will always lead to the same decision. Thus, for any set of projects like our Projects S and L, if $NPV_S > NPV_L$, then $MIRR_S > MIRR_L$, and the kinds of conflicts we encountered between NPV and the regular IRR will not occur. Also, if the projects are of equal size, but differ in lives, the MIRR will always lead to the same decision as the NPV if the MIRRs are both calculated using as the terminal year the life of the longer project. (Just fill in zeros for the shorter project's missing cash flows.) However, if the projects differ in size, then conflicts can still occur. For example, if we were choosing between a large project and a small mutually exclusive one, then we might find $NPV_L > NPV_S$, but $MIRR_S > MIRR_L$.

Our conclusion is that the MIRR is superior to the regular IRR as an indicator of a project's "true" rate of return, or "expected long-term rate of return," but the NPV method is still the best way to choose among competing projects because

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[8]In this example, the only negative cash flow occurs at t = 0, so the PV of costs is equal to CF_0.

it provides the best indication of how much each project will add to the value of the firm.

11.7 Profitability Index

Another method used to evaluate projects is the **profitability index (PI):**

$$\text{PI} = \frac{\text{PV of future cash flows}}{\text{Initial cost}} = \frac{\displaystyle\sum_{t=1}^{N} \frac{CF_t}{(1 + r)^t}}{CF_0}. \qquad \text{(11-4)}$$

Here CF_t represents the expected future cash flows, and CF_0 represents the initial cost. The PI shows the *relative* profitability of any project, or the present value per dollar of initial cost. The PI for Project S, based on a 10% cost of capital, is 1.08:

$$\text{PI}_S = \frac{\$1078.82}{\$1000} = 1.08.$$

Thus, on a present value basis, Project S is expected to produce $1.08 for each $1 of investment. Project L, with a PI of 1.05, should produce $1.05 for each dollar invested.

In Panel B of Figure 11-1, we calculate the PI using the NPV function. Our formula in Cell C42 is **=NPV(D33,C27:F27)/(−B27).**

A project is acceptable if its PI is greater than 1.0, and the higher the PI, the higher the project's ranking. Therefore, both S and L would be accepted by the PI criterion if they were independent, and S would be ranked ahead of L if they were mutually exclusive.

Mathematically, the NPV, IRR, MIRR, and PI methods will always lead to the same accept/reject decisions for *independent* projects: If a project's NPV is positive, its IRR and MIRR will always exceed r, and its PI will always be greater than 1.0. However, these methods can give conflicting rankings for *mutually exclusive* projects, for the same reasons that IRR can give conflicting rankings.

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11.8 Payback Methods

NPV and IRR are the most widely used methods today, but the earliest selection criterion was the payback methods. We now discuss the regular payback period and the discounted payback period.

Payback Period

The **payback period,** defined as the expected number of years required to recover the original investment, was the first formal method used to evaluate capital budgeting projects. The basic idea is to start with the project's cost, determine the number of years prior to full recovery of the cost, and then determine the fraction of the next year that is required for full recovery, assuming cash flows occur evenly during the year:

$$\text{Payback} = \begin{array}{c}\text{Number of}\\ \text{years prior to}\\ \text{full recovery}\end{array} + \frac{\text{Unrecovered cost at start of year}}{\text{Cash flow during full recovery year}}. \quad \text{(11-5)}$$

The payback calculation for Project S is diagrammed in Figure 11-4 and is explained below.

The cumulative net cash flow at t = 0 is just the initial cost of −$1,000. At Year 1 the cumulative net cash flow is the previous cumulative of −$1,000 plus the Year 1 cash flow of $500: −$1,000 + $500 = −$500. Similarly, the cumulative for Year 2 is the previous cumulative of −$500 plus the Year 2 inflow of $400, resulting in −$100. We see that by the end of Year 3 the cumulative inflows have more than recovered the initial outflow. Thus, the payback occurred during the third year. If the $300 of inflows comes in evenly during Year 3, then the exact payback period can be found as follows:

$$\text{Payback}_S = 2 + \frac{\$100}{\$300} = 2.33 \text{ years.}$$

Applying the same procedure to Project L, we find $\text{Payback}_L = 3.33$ years.

The shorter the payback period, the better. If the projects were mutually exclusive, S would be ranked over L because S has the shorter payback.

The payback has three main flaws: (1) Dollars received in different years are all given the same weight—a dollar in Year 4 is assumed to be just as valuable as a dollar in Year 1. (2) Cash flows beyond the payback year are given no consideration whatsoever, regardless of how large they might be. (3) Unlike the NPV, which tells

Figure 11-4

Payback Period for Projects S and L

	A	B	C	D	E	F	G	H
398	Project S		Year:	0	1	2	3	4
399								
400			Cash flow:	-1,000	500	400	300	100
401			Cumulative cash flow:	-1,000	-500	-100	200	300
402			Percent of year required for payback:		1.00	1.00	0.33	0.00
403			Payback =	2.33				
404								
405	Project L		Year:	0	1	2	3	4
406								
407			Cash flow:	-1,000	100	300	400	600
408			Cumulative cash flow:	-1,000	-900	-600	-200	400
409			Percent of year required for payback:		1.00	1.00	1.00	0.33
410			Payback =	3.33				

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us by how much the project should increase shareholder wealth, and the IRR, which tells us how much a project yields over the cost of capital, the payback merely tells us when we get our investment back. There is no necessary relationship between a given payback and investor wealth maximization, so we don't know how to set the "right" payback.

Discounted Payback Period

Some firms use a variant of the regular payback, the **discounted payback period,** which is similar to the regular payback period except that the expected cash flows are discounted by the project's cost of capital. Thus, the discounted payback period is defined as the number of years required to recover the investment from *discounted* net cash flows. Figure 11-5 contains the discounted net cash flows for Projects S and L, assuming both projects have a cost of capital of 10%. To construct Figure 11-5, each cash inflow is divided by $(1 + r)^t = (1.10)^t$, where t is the year in which the cash flow occurs and r is the project's cost of capital. After 3 years, Project S will have generated $1,011 in discounted cash inflows. Because the cost is $1,000, the discounted payback is just under 3 years, or, to be precise, 2 + ($214.9/$225.4) = 2.95 years. Project L's discounted payback is 3.88 years:

$$\text{Discounted payback}_S = 2.0 + \$214.9/\$225.4 = 2.95 \text{ years.}$$

$$\text{Discounted payback}_L = 3.0 + \$360/\$410 = 3.88 \text{ years.}$$

For Projects S and L, the rankings are the same regardless of which payback method is used; that is, Project S is preferred to Project L. Often, however, the regular and the discounted paybacks produce conflicting rankings.

Evaluating Payback and Discounted Payback

The discounted payback approach corrects the first flaw of the regular payback method because it considers the time value of the cash flows. However, it too fails

Figure 11-5

Projects S and L: Discounted Payback Period

	A	B	C	D	E	F	G	H
422	**Figure 11-5. Projects S and L: Discounted Payback Period (r = 10%)**							
423								
424	**Project S**		Year:	0	1	2	3	4
425								
426			Cash flow:	(1,000)	500	400	300	100
427			Discounted cash flow:	(1,000)	455	331	225	68
428			Cumulative discounted CF:	(1,000)	(545)	(215)	11	79
			Percent of year required					
429			for payback:		1.00	1.00	0.95	0.00
430			Discounted Payback:	2.95				
431								
432	**Project L**		Year:	0	1	2	3	4
433								
434			Cash flow:	(1,000)	100	300	400	600
435			Discounted cash flow:	(1,000)	91	248	301	410
436			Cumulative discounted CF:	(1,000)	(909)	(661)	(361)	49
			Percent of year required					
437			for payback:		1.00	1.00	1.00	0.88
438			Discounted Payback:	**3.88**				

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to consider cash flows occurring after the payback year and, as with regular payback, there is no relationship between discounted payback and wealth maximization.

Although the payback methods have serious faults as ranking criteria, they do provide information on how long funds will be tied up in a project. Thus, the shorter the payback period, other things held constant, the greater the project's *liquidity*. Also, since cash flows expected in the distant future are generally riskier than near-term cash flows, the payback is often used as an indicator of a project's *risk*.

SELF-TEST

What two pieces of information does the payback convey that are absent from the other capital budgeting decision methods?

What three flaws does the regular payback have? Does the discounted payback correct these flaws?

A project has the following expected cash flows: $CF_0 = -\$500$, $CF_1 = \$200$, $CF_2 = \$200$, and $CF_3 = \$400$. If the project's cost of capital is 9%, what are the project's payback period and discounted payback period? **(2.25; 2.48)**

11.9 Conclusions on Capital Budgeting Methods

We have discussed six capital budgeting decision methods, compared the methods with one another, and highlighted their relative strengths and weaknesses. In the process, we probably created the impression that "sophisticated" firms should use only one method in the decision process, NPV. However, virtually all capital budgeting decisions are analyzed by computer, so it is easy to calculate and list all the decision measures: payback and discounted payback, NPV, IRR, modified IRR (MIRR), and profitability index (PI). In making the accept/reject decision, most large, sophisticated firms calculate and consider all of the measures, because each one provides decision makers with a somewhat different piece of relevant information.

NPV is important because it gives a direct measure of the dollar benefit of the project to shareholders. Therefore, we regard NPV as the best single measure of *profitability*. IRR also measures profitability, but here it is expressed as a percentage rate of return, which many decision makers prefer. Further, IRR contains information concerning a project's "safety margin." To illustrate, consider the following two projects: Project S (for small) costs $10,000 and is expected to return $16,500 at the end of one year, while Project L (for large) costs $100,000 and has an expected payoff of $115,500 after one year. At a 10% cost of capital, both projects have an NPV of $5,000, so by the NPV rule we should be indifferent between them. However, Project S has a much larger margin for error. Even if its realized cash inflow were 39% below the $16,500 forecast, the firm would still recover its $10,000 investment. On the other hand, if Project L's inflows fell by only 13% from the forecasted $115,500, the firm would not recover its investment. Further, if no inflows were generated at all, the firm would lose only $10,000 with Project S, but $100,000 if it took on Project L.

The NPV provides no information about either of these factors—the "safety margin" inherent in the cash flow forecasts or the amount of capital at risk. However, the IRR does provide "safety margin" information—Project S's IRR is a whopping 65%, while Project L's IRR is only 15.5%. As a result, the realized return could fall substantially for Project S, and it would still make money. The modified IRR has all the virtues of the IRR, but (1) it incorporates a better reinvestment rate assumption, and (2) it avoids the multiple rate of return problem.

The PI measures profitability relative to the cost of a project—it shows the "bang per buck." Like the IRR, it gives an indication of the project's risk, because a high PI means that cash flows could fall quite a bit and the project would still be profitable.

Payback and discounted payback provide an indication of both the *risk* and the *liquidity* of a project: A long payback means (1) that the investment dollars will be locked up for many years—hence the project is relatively illiquid—and (2) that the project's cash flows must be forecasted far out into the future—hence the project is probably quite risky. A good analogy for this is the bond valuation process. An investor should never compare the yields to maturity on two bonds without also considering their terms to maturity, because a bond's risk is affected by its maturity.

The different measures provide different types of information to decision makers. Since it is easy to calculate all of them, all should be considered in the decision process. For any specific decision, more weight might be given to one measure than another, but it would be foolish to ignore the information provided by any of the methods.

Just as it would be foolish to ignore these capital budgeting methods, it would also be foolish to make decisions based *solely* on them. One cannot know at Time 0 the exact cost of future capital, or the exact future cash flows. These inputs are simply estimates, and if they turn out to be incorrect, then so will be the calculated NPVs and IRRs. *Thus, quantitative methods provide valuable information, but they should not be used as the sole criteria for accept/reject decisions* in the capital budgeting process. Rather, managers should use quantitative methods in the decision-making process but also consider the likelihood that actual results will differ from the forecasts. Qualitative factors, such as the chances of a tax increase, or a war, or a major product liability suit, should also be considered. *In summary, quantitative methods such as NPV and IRR should be considered as an aid to informed decisions but not as a substitute for sound managerial judgment.*

In this same vein, managers should ask sharp questions about any project that has a large NPV, a high IRR, or a high PI. In a perfectly competitive economy, there would be no positive NPV projects—all companies would have the same opportunities, and competition would quickly eliminate any positive NPV. Therefore, positive NPV projects must be predicated on some imperfection in the marketplace, and the longer the life of the project, the longer that imperfection must last. Therefore, managers should be able to identify the imperfection and explain why it will persist before accepting that a project will really have a positive NPV. Valid explanations might include patents or proprietary technology, which is how pharmaceutical and software firms create positive NPV projects. Pfizer's Lipitor® (a cholesteral-reducing medicine) and Microsoft's Windows XP® operating system are examples. Companies can also create positive NPV by being the first entrant into a new market or by creating new products that meet some previously unidentified consumer needs. The Post-it® notes invented by 3M are an example. Similarly, Dell developed procedures for direct sales of microcomputers, and in the process created projects with enormous NPV. Also, companies such as Southwest Airlines have managed to train and motivate their workers better than their competitors, and this has led to positive NPV projects. In all of these cases, the companies developed some source of competitive advantage, and that advantage resulted in positive NPV projects.

This discussion suggests three things: (1) If you can't identify the reason a project has a positive projected NPV, then its actual NPV will probably not be positive. (2) Positive NPV projects don't just happen—they result from hard work to develop some competitive advantage. At the risk of oversimplification, the

primary job of a manager is to find and develop areas of competitive advantage. (3) Some competitive advantages last longer than others, with their durability depending on competitors' ability to replicate them. Patents, the control of scarce resources, or large size in an industry where strong economies of scale exist can keep competitors at bay. However, it is relatively easy to replicate nonpatentable features on products. The bottom line is that managers should strive to develop nonreplicable sources of competitive advantage, and if such an advantage cannot be demonstrated, then you should question projects with high NPV, especially if they have long lives.

SELF-TEST

Describe the advantages and disadvantages of the six capital budgeting methods discussed in this chapter.

Should capital budgeting decisions be made solely on the basis of a project's NPV?

What are some possible reasons that a project might have a large NPV?

11.10 Business Practices

Surveys designed to find out which of the criteria managers actually use have been taken over the years. Surveys taken prior to 1999 asked companies to indicate their primary criterion (the method they gave the most weight to), while the most recent one, in 1999, asked what method or methods managers calculated and used. The summary of the results as shown in Table 11-1 reveals some interesting trends.

First, the NPV criterion was not used significantly before the 1980s, but by 1999 it was close to the top in usage. Moreover, informal discussions with companies suggest that if 2005 data were available, NPV would have moved to the top. Second, the IRR method is widely used, but its recent growth is much less dramatic than that of NPV. Third, payback was the most important criterion 40 years ago, but its use as the primary criterion had fallen drastically by 1980. Companies still use payback because it is easy to calculate and it does provide some information,

Table 11-1

Capital Budgeting Methods Used in Practice

	Primary Criterion			Calculate and Use
	1960	1970	1980	1999
NPV	0%	0%	15%	75%
IRR	20	60	65	76
Payback	35	15	5	57
Discounted Payback	NA	NA	NA	29
Other	45	25	15	NA
Totals	100%	100%	100%	

Sources: The 1999 data are from John R. Graham and Campbell R. Harvey, "The Theory and Practice of Corporate Finance: Evidence from the Field," *Journal of Financial Economics,* 2001, pp. 187–244. Data from prior years are our estimates based on averaging data from these studies: J. S. Moore and A. K. Reichert, "An Analysis of the Financial Management Techniques Currently Employed by Large U.S. Corporations," *Journal of Business Finance and Accounting,* Winter 1983, pp. 623–645; and M. T. Stanley and S. B. Block, "A Survey of Multinational Capital Budgeting," *The Financial Review,* March 1984, pp. 36–51.

but it is rarely used today as the primary criterion. Fourth, "other methods," which are generally offshoots of NPV and/or IRR, have been fading as a primary criterion due to the increased use of IRR and especially NPV.

These trends are consistent with our evaluation of the various methods. NPV is the best single criterion, but all of the methods provide useful information, all are easy to calculate, and thus all are used, along with judgment and common sense.[9]

SELF-TEST ───

What trends in capital budgeting methodology can be seen from Table 11-1?

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11.11 Special Applications of Cash Flow Evaluation

Misapplication of the NPV method can lead to errors when two mutually exclusive projects have unequal lives. There are also situations in which an asset should not be operated for its full life. The following sections explain how to evaluate cash flows in these situations.[10]

Comparing Projects with Unequal Lives

Note that a replacement decision involves comparing two mutually exclusive projects: retaining the old asset versus buying a new one. When choosing between two mutually exclusive alternatives with significantly different lives, an adjustment is necessary. For example, suppose a company is planning to modernize its production facilities, and it is considering either a conveyor system (Project C) or some forklift trucks (Project F) for moving materials. The first two sections of Figure 11-6 show the expected net cash flows, NPVs, and IRRs for these two mutually exclusive alternatives. We see that Project C, when discounted at the firm's 11.5% cost of capital, has the higher NPV and thus appears to be the better project.

Although the NPV shown in Figure 11-6 suggests that Project C should be selected, this analysis is incomplete, and the decision to choose Project C is actually incorrect. If we choose Project F, we will have an opportunity to make a similar investment in 3 years, and if cost and revenue conditions continue at the Figure 11-6 levels, this second investment will also be profitable. However, if we choose Project C, we cannot make this second investment. Two different approaches can be used to correctly compare Projects C and F, as shown below.

Replacement Chains The key to the **replacement chain (common life) approach** is to analyze both projects using a common life. In this example, we will find the NPV of Project F over a 6-year period, and then compare this extended NPV with

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[9]For additional articles that discuss capital budgeting methods used in practice, see Suk H. Kim, Trevor Crick, and Seung H. Kim, "Do Executives Practice What Academics Preach?" *Management Accounting*, November 1986, pp. 49–52; Tarun K. Mukherjee, "Capital Budgeting Surveys: The Past and the Future," *Review of Business and Economic Research*, Spring 1987, pp. 37–56.; Tarun K. Mukherjee, "The Capital Budgeting Process of Large U.S. Firms: An Analysis of Capital Budgeting Manuals," *Managerial Finance*, Number 2/3, 1988, pp. 28–35; Marc Ross, "Capital Budgeting Practices of Twelve Large Manufacturers," *Financial Management*, Winter 1986, pp. 15–22; L. R. Runyan, "Capital Expenditure Decision Making in Small Firms," *Journal of Business Research*, September 1983, pp. 389–397; and Samuel C. Weaver, Donald Peters, Roger Cason, and Joe Daleiden, "Capital Budgeting," *Financial Management*, Spring 1989, pp. 10–17.

[10]For additional discussion of other special applications, see Paul K. Chaney, "Moral Hazard and Capital Budgeting," *Journal of Financial Research*, Summer 1989, pp. 113–128; Edward M. Miller, "Safety Margins and Capital Budgeting Criteria," *Managerial Finance*, Number 2/3, 1988, pp. 1–8; and John C. Woods and Maury R. Randall, "The Net Present Value of Future Investment Opportunities: Its Impact on Shareholder Wealth and Implications for Capital Budgeting Theory," *Financial Management*, Summer 1989, pp. 85–92.

Figure 11-6

Analysis of Projects C and F (r = 11.5%)

	A	B	C	D	E	F	G	H
465	Project C:							
466								
467	Year (t)							
468	CF$_t$ for C	($40,000)	$8,000	$14,000	$13,000	$12,000	$11,000	$10,000
469								
470		NPV$_C$ =	$7,165		IRR$_C$ =	17.5%		
471								
472	Project F:							
473								
474	Year (t)	0	1	2	3			
475	CF$_t$ for F	($20,000)	$7,000	$13,000	$12,000			
476								
477		NPV$_F$ =	$5,391		IRR$_F$ =	25.2%		
478								
479	Common Life Approach with F Repeated (Project FF):							
480								
481	Year (t)	0	1	2	3	4	5	6
482	CF$_t$ for F	($20,000)	$7,000	$13,000	$12,000			
483	CF$_t$ for F				($20,000)	$7,000	$13,000	$12,000
484	CF$_t$ for FF	($20,000)	$7,000	$13,000	($8,000)	$7,000	$13,000	$12,000
485								
486		NPV$_{FF}$ =	$9,281		IRR$_{FF}$ =	25.2%		

Project C's NPV over the same 6 years. The NPV for Project C as calculated in Figure 11-6 is already over the 6-year common life. For Project F, however, we must add in a second project to extend the overall life of the combined projects to 6 years, as shown in the third section of Figure 11-6. Here we assume (1) that Project F's cost and annual cash inflows will not change if the project is repeated in 3 years and (2) that the cost of capital will remain at 11.5%.

The NPV of this extended Project FF is $9,281, and its IRR is 25.2%. (The IRR of two Project Fs is the same as the IRR for one Project F.) Since the $9,281 extended NPV of Project F over the 6-year common life is greater than the $7,165 NPV of Project C, Project F should be selected.[11]

Equivalent Annual Annuities (EAA) Electrical engineers designing power plants and distribution lines were the first to encounter the unequal life problem. They could use transformers and other equipment that had relatively low initial costs but short lives, or they could use equipment that had higher initial costs but longer lives. The services would be required on into the indefinite future, so this was the issue: Which choice would result in the higher NPV in the long run? The engineers converted the annual cash flows under the alternative investments into a constant cash flow stream whose NPV was equal to, or equivalent to, the NPV of the initial stream. This was called the **equivalent annual annuity (EAA) method.** To apply the EAA method to Projects C and F, for each project we

---

[11]Alternatively, we could recognize that the value of the cash flow stream of two consecutive Project Fs can be summarized by two NPVs: one at Year 0 representing the value of the initial project, and one at Year 3 representing the value of the replication project:

```
      0     1     2     3     4     5     6
      |-----+-----+-----+-----+-----+-----|
   $5,391              $5,391
```

Ignoring rounding differences, the present value of these two cash flows, when discounted at 11.5%, is again $9,281.

simply find the constant payment that has the same NPV as the project's traditional NPV. Using a financial calculator to find Project C's EAA, we enter N = 3, I/YR = 11.5, PV = −7165, and FV = 0; solving for PMT, we find an EAA of $1,718. For Project F, we enter N = 3, I/YR = 11.5, PV = −5391, and FV = 0; solving for PMT, we find an EAA of $2,225. Project F has the higher EAA, so it is the better project.

Conclusions about Unequal Lives When should we worry about unequal life analysis? The unequal life issue (1) does not arise for independent projects, but (2) it can arise if mutually exclusive projects with significantly different lives are being compared. However, even for mutually exclusive projects, it is not always appropriate to extend the analysis to a common life. This should be done only if there is a high probability that the projects will actually be repeated at the end of their initial lives.

We should note several potentially serious weaknesses inherent in this type of analysis: (1) If inflation is expected, then replacement equipment will have a higher price. Moreover, both sales prices and operating costs will probably change. Thus, the static conditions built into the analysis would be invalid. (2) Replacements that occur down the road would probably employ new technology, which in turn might change the cash flows. (3) It is difficult enough to estimate the lives of most projects, and even more so to estimate the lives of a series of projects.

In view of these problems, no experienced financial analyst would be too concerned about comparing mutually exclusive projects with lives of, say, 8 years and 10 years. Given all the uncertainties in the estimation process, such projects would, for all practical purposes, be assumed to have the same life. Still, it is important to recognize that a problem exists if mutually exclusive projects have substantially different lives. When we encounter such problems in practice, we use a computer spreadsheet and build expected inflation and/or possible efficiency gains directly into the cash flow estimates, and then use the replacement chain approach. The cash flow estimation is a bit more complicated, but the concepts involved are exactly the same as in our example.

Economic Life versus Physical Life

Projects are normally analyzed under the assumption that the firm will operate the asset over its full physical life. However, this may not be the best course of action—it may be best to terminate a project before the end of its potential life, and this possibility can materially affect the project's estimated profitability. The situation in Table 11-2 can be used to illustrate this concept and its effects on capital budgeting. The salvage values listed in the third column are after taxes, and they have been estimated for each year of Project A's life.

Using a 10% cost of capital, the expected NPV based on 3 years of operating cash flows and the zero abandonment (salvage) value is −$14.12:

```
0       10%      1            2            3
|_____|_____|_____|
($4,800)         $2,000       $2,000       $1,750
                                                0
                                           _____
                                           $1,750
```
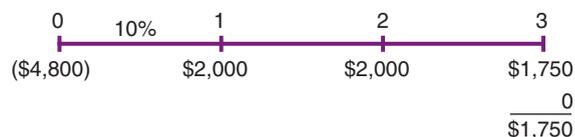
$$NPV = -\$4,800 + \$2,000/(1.10)^1 + \$2,000/(1.10)^2 + \$1,750/(1.10)^3$$
$$= -\$14.12.$$

Table 11-2

Project A: Investment, Operating, and Salvage Cash Flows

Year (t)	Initial (Year 0) Investment and After-Tax Operating Cash Flows	Net Salvage Value at End of Year t
0	($4,800)	$4,800
1	2,000	3,000
2	2,000	1,650
3	1,750	0

Thus, Project A would not be accepted if we assume that it will be operated over its full 3-year life. However, what would its NPV be if the project were terminated after 2 years? In this case, we would receive operating cash flows in Years 1 and 2, plus the salvage value at the end of Year 2, and the project's NPV would be $34.71:

```
        0            1            2
        ├────────────┼────────────┤
    ($4,800)      $2,000       $2,000
                               1,650
                              ──────
                              $3,650
```

$$\text{NPV} = -\$4,800 + \$2,000/(1.10)^1 + \$3,650/(1.10)^2$$
$$= \$34.71.$$

Thus, Project A would be profitable if we operate it for 2 years and then dispose of it. To complete the analysis, note that if the project were terminated after 1 year, its NPV would be −$254.55. Thus, the optimal life for this project is 2 years.

This type of analysis can be used to determine a project's **economic life,** which is the life that maximizes the NPV and thus maximizes shareholder wealth. For Project A, the economic life is 2 years versus the 3-year **physical,** or **engineering, life.** Note that this analysis was based on the expected cash flows and the expected salvage values, and it should always be conducted as a part of the capital budgeting evaluation if salvage values are relatively high.

SELF-TEST

Briefly describe the replacement chain (common life) approach.

Define the economic life of a project (as opposed to its physical life).

11.12 The Optimal Capital Budget

The **optimal capital budget** is the set of projects that maximizes the value of the firm. Finance theory states that all projects with positive NPVs should be accepted, and the optimal capital budget consists of these positive NPV projects. However, two complications arise in practice: (1) an increasing marginal cost of capital and (2) capital rationing.

An Increasing Marginal Cost of Capital

The cost of capital may depend on the size of the capital budget. As we discussed in Chapter 10, the flotation costs associated with issuing new equity or public debt can be quite high. This means that the cost of capital jumps upward after a company invests all of its internally generated cash and must sell new common stock. In addition, investors often perceive extremely large capital investments to be riskier, which may also drive up the cost of capital as the size of the capital budget increases. As a result, a project might have a positive NPV if it is part of a "normal size" capital budget, but the same project might have a negative NPV if it is part of an unusually large capital budget. Fortunately, this problem occurs very rarely for most firms, and it is unusual for an established firm to require new outside equity. Still, *Web Extension 11B* contains a more detailed discussion of this problem and shows how to deal with the existence of an increasing marginal cost of capital.

Capital Rationing

Armbrister Pyrotechnics, a manufacturer of fireworks and lasers for light shows, has identified 40 potential independent projects, with 15 having a positive NPV based on the firm's 12% cost of capital. The total cost of implementing these 15 projects is $75 million. Based on finance theory, the optimal capital budget is $75 million, and Armbrister should accept the 15 projects with positive NPVs. However, Armbrister's management has imposed a limit of $50 million for capital expenditures during the upcoming year. Due to this restriction, the company must forgo a number of value-adding projects. This is an example of **capital rationing,** defined as a situation in which a firm limits its capital expenditures to less than the amount required to fund the optimal capital budget. Despite being at odds with finance theory, this practice is quite common.

Why would any company forgo value-adding projects? Here are some potential explanations, along with some suggestions for better ways to handle these situations:

1. *Reluctance to issue new stock*. Many firms are extremely reluctant to issue new stock, so all of their capital expenditures must be funded out of debt and internally generated cash. Also, most firms try to stay near their target capital structure, and, combined with the limit on equity, this limits the amount of debt that can be added during any one year. The result can be a serious constraint on the amount of funds available for investment in new projects.

   This reluctance to issue new stock could be based on some sound reasons: (a) flotation costs can be very expensive; (b) investors might perceive new stock offerings as a signal that the company's equity is overvalued; and (c) the company might have to reveal sensitive strategic information to investors, thereby reducing some of its competitive advantages. To avoid these costs, many companies simply limit their capital expenditures.

   However, rather than placing a somewhat artificial limit on capital expenditures, a company might be better off explicitly incorporating the costs of raising external capital into its cost of capital. If there still are positive NPV projects even using this higher cost of capital, then the company should go ahead and raise external equity and accept the projects. See *Web Extension 11B* for more details concerning an increasing marginal cost of capital.

2. *Constraints on nonmonetary resources*. Sometimes a firm simply does not have the necessary managerial, marketing, or engineering talent to immediately accept

all positive NPV projects. In other words, the potential projects are not really independent, because the firm cannot accept them all. To avoid potential problems due to spreading existing talent too thinly, many firms simply limit the capital budget to a size that can be accommodated by their current personnel.

A better solution might be to employ a technique called **linear programming.** Each potential project has an expected NPV, and each potential project requires a certain level of support by different types of employees. A linear program can identify the set of projects that maximizes NPV, subject to the constraint that the total amount of support required for these projects does not exceed the available resources.[12]

3. *Controlling estimation bias*. Many managers become overly optimistic when estimating the cash flows for a project. Some firms try to control this estimation bias by requiring managers to use an unrealistically high cost of capital. Others try to control the bias by limiting the size of the capital budget. Neither solution is generally effective since managers quickly learn the rules of the game and then increase their own estimates of project cash flows, which might have been biased upward to begin with.

A better solution is to implement a post-audit program and to link the accuracy of forecasts to the compensation of the managers who initiated the projects.

SELF-TEST

What factors can lead to an increasing marginal cost of capital? How might this affect capital budgeting?

What is capital rationing?

What are three explanations for capital rationing? How might firms handle these situations?

Summary

This chapter has described six techniques (NPV, IRR, MIRR, PI, payback, and discounted payback,) that are used in capital budgeting analysis. Each approach provides a different piece of information, so in this age of computers, managers often look at all of them when evaluating projects. However, NPV is the best single measure, and almost all firms now use NPV. The key concepts covered in this chapter are listed below:

- **Capital budgeting** is the process of analyzing potential projects. Capital budgeting decisions are probably the most important ones managers must make.
- The **net present value (NPV) method** discounts all cash flows at the project's cost of capital and then sums those cash flows. The project should be accepted if the NPV is positive.
- The **internal rate of return (IRR)** is defined as the discount rate that forces a project's NPV to equal zero. The project should be accepted if the IRR is greater than the cost of capital.

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[12]See Stephen P. Bradley and Sherwood C. Frey, Jr., "Equivalent Mathematical Programming Models of Pure Capital Rationing," *Journal of Financial and Quantitative Analysis*, June 1978, pp. 345–361.

- The NPV and IRR methods make the same accept/reject decisions for **independent projects,** but if projects are **mutually exclusive,** then ranking conflicts can arise. If conflicts arise, the NPV method should be used. The NPV and IRR methods are both superior to the payback, but NPV is superior to IRR.
- The NPV method assumes that cash flows will be reinvested at the firm's cost of capital, while the IRR method assumes reinvestment at the project's IRR. **Reinvestment at the cost of capital is generally a better assumption** because it is closer to reality.
- The **modified IRR (MIRR) method** corrects some of the problems with the regular IRR. MIRR involves finding the **terminal value (TV)** of the cash inflows, compounded at the firm's cost of capital, and then determining the discount rate that forces the present value of the TV to equal the present value of the outflows.
- The **profitability index (PI)** shows the dollars of present value divided by the initial cost, so it measures relative profitability.
- The **payback period** is defined as the number of years required to recover a project's cost. The regular payback method ignores cash flows beyond the payback period, and it does not consider the time value of money. The payback does, however, provide an indication of a project's risk and liquidity, because it shows how long the invested capital will be "at risk."
- The **discounted payback method** is similar to the regular payback method except that it discounts cash flows at the project's cost of capital. It considers the time value of money, but it ignores cash flows beyond the payback period.
- If mutually exclusive projects have **unequal lives,** it may be necessary to adjust the analysis to put the projects on an equal-life basis. This can be done using the **replacement chain (common life) approach** or the **equivalent annual annuity (EAA) approach.**
- A project's true value may be greater than the NPV based on its **physical life** if it can be **terminated** at the end of its **economic life.**
- Flotation costs and increased riskiness associated with unusually large expansion programs can cause the **marginal cost of capital** to rise as the size of the capital budget increases.
- **Capital rationing** occurs when management places a constraint on the size of the firm's capital budget during a particular period.

Questions

(11-1) Define each of the following terms:
   a. Capital budgeting; regular payback period; discounted payback period
   b. Independent projects; mutually exclusive projects
   c. DCF techniques; net present value (NPV) method; internal rate of return (IRR) method
   d. Modified internal rate of return (MIRR) method; profitability index
   e. NPV profile; crossover rate
   f. Nonnormal cash flow projects; normal cash flow projects; multiple IRRs
   g. Hurdle rate; reinvestment rate assumption
   h. Replacement chain; economic life; capital rationing

(11-2) What types of projects require more detailed analysis in the capital budgeting process?

(11-3) Explain why the NPV of a relatively long-term project, defined as one for which a high percentage of its cash flows are expected in the distant future, is more sensitive to changes in the cost of capital than is the NPV of a short-term project.

(11-4) Explain why, if two mutually exclusive projects are being compared, the short-term project might have the higher ranking under the NPV criterion if the cost of capital is high, but the long-term project might be deemed better if the cost of capital is low. Would changes in the cost of capital ever cause a change in the IRR ranking of two such projects?

(11-5) In what sense is a reinvestment rate assumption embodied in the NPV, IRR, and MIRR methods? What is the assumed reinvestment rate of each method?

(11-6) Suppose a firm is considering two mutually exclusive projects. One has a life of 6 years and the other a life of 10 years. Would the failure to employ some type of replacement chain analysis bias an NPV analysis against one of the projects? Explain.

Self-Test Problem   Solution Appears in Appendix A

(ST-1)
Project Analysis

You are a financial analyst for the Hittle Company. The director of capital budgeting has asked you to analyze two proposed capital investments, Projects X and Y. Each project has a cost of $10,000, and the cost of capital for each project is 12%. The projects' expected net cash flows are as follows:

Expected Net Cash Flows

Year	Project X	Project Y
0	($10,000)	($10,000)
1	6,500	3,500
2	3,000	3,500
3	3,000	3,500
4	1,000	3,500

a. Calculate each project's payback period, net present value (NPV), internal rate of return (IRR), and modified internal rate of return (MIRR).
b. Which project or projects should be accepted if they are independent?
c. Which project should be accepted if they are mutually exclusive?
d. How might a change in the cost of capital produce a conflict between the NPV and IRR rankings of these two projects? Would this conflict exist if r were 5%? (Hint: Plot the NPV profiles.)
e. Why does the conflict exist?

Problems   Answers Appear in Appendix B

Easy Problems 1–7

(11-1)
NPV

A project has an initial cost of $52,125, expected net cash inflows of $12,000 per year for 8 years, and a cost of capital of 12%. What is the project's NPV? (Hint: Begin by constructing a time line.)

(11-2)
IRR

Refer to Problem 11-1. What is the project's IRR?

(11-3)
MIRR

Refer to Problem 11-1. What is the project's MIRR?

(11-4)
Profitability Index

Refer to Problem 11-1. What is the project's PI?

(11-5)
Payback

Refer to Problem 11-1. What is the project's payback period?

(11-6)
Discounted Payback

Refer to Problem 11-1. What is the project's discounted payback period?

(11-7)
NPV

Your division is considering two investment projects, each of which requires an up-front expenditure of $15 million. You estimate that the investments will produce the following net cash flows:

Year	Project A	Project B
1	$ 5,000,000	$20,000,000
2	10,000,000	10,000,000
3	20,000,000	6,000,000

What are the two projects' net present values, assuming the cost of capital is 10%? 5%? 15%?

Intermediate Problems 8–18

(11-8)
NPVs, IRRs, and MIRRs for Independent Projects

Edelman Engineering is considering including two pieces of equipment, a truck and an overhead pulley system, in this year's capital budget. The projects are independent. The cash outlay for the truck is $17,100, and that for the pulley system is $22,430. The firm's cost of capital is 14%. After-tax cash flows, including depreciation, are as follows:

Year	Truck	Pulley
1	$5,100	$7,500
2	5,100	7,500
3	5,100	7,500
4	5,100	7,500
5	5,100	7,500

Calculate the IRR, the NPV, and the MIRR for each project, and indicate the correct accept/reject decision for each.

(11-9)
NPVs and IRRs for
Mutually Exclusive
Projects

Davis Industries must choose between a gas-powered and an electric-powered forklift truck for moving materials in its factory. Since both forklifts perform the same function, the firm will choose only one. (They are mutually exclusive investments.) The electric-powered truck will cost more, but it will be less expensive to operate; it will cost $22,000, whereas the gas-powered truck will cost $17,500. The cost of capital that applies to both investments is 12%. The life for both types of truck is estimated to be 6 years, during which time the net cash flows for the electric-powered truck will be $6,290 per year and those for the gas-powered truck will be $5,000 per year. Annual net cash flows include depreciation expenses. Calculate the NPV and IRR for each type of truck, and decide which to recommend.

(11-10)
Capital Budgeting
Methods

Project S has a cost of $10,000 and is expected to produce benefits (cash flows) of $3,000 per year for 5 years. Project L costs $25,000 and is expected to produce cash flows of $7,400 per year for 5 years. Calculate the two projects' NPVs, IRRs, MIRRs, and PIs, assuming a cost of capital of 12%. Which project would be selected, assuming they are mutually exclusive, using each ranking method? Which should actually be selected?

(11-11)
MIRR and NPV

Your company is considering two mutually exclusive projects, X and Y, whose costs and cash flows are shown below:

Year	X	Y
0	($1,000)	($1,000)
1	100	1,000
2	300	100
3	400	50
4	700	50

The projects are equally risky, and their cost of capital is 12%. You must make a recommendation, and you must base it on the modified IRR (MIRR). What is the MIRR of the better project?

(11-12)
NPV and IRR
Analysis

After discovering a new gold vein in the Colorado mountains, CTC Mining Corporation must decide whether to mine the deposit. The most cost-effective method of mining gold is sulfuric acid extraction, a process that results in environmental damage. To go ahead with the extraction, CTC must spend $900,000 for new mining equipment and pay $165,000 for its installation. The gold mined will net the firm an estimated $350,000 each year over the 5-year life of the vein. CTC's cost of capital is 14%. For the purposes of this problem, assume that the cash inflows occur at the end of the year.
a. What are the NPV and IRR of this project?
b. Should this project be undertaken, ignoring environmental concerns?
c. How should environmental effects be considered when evaluating this, or any other, project? How might these effects change your decision in part b?

(11-13)
NPV and IRR
Analysis

Cummings Products Company is considering two mutually exclusive investments. The projects' expected net cash flows are as follows:

	Expected Net Cash Flows	
Year	**Project A**	**Project B**
0	($300)	($405)
1	(387)	134
2	(193)	134
3	(100)	134
4	600	134
5	600	134
6	850	134
7	(180)	0

a. Construct NPV profiles for Projects A and B.
b. What is each project's IRR?
c. If you were told that each project's cost of capital was 10%, which project should be selected? If the cost of capital was 17%, what would be the proper choice?
d. What is each project's MIRR at a cost of capital of 10%? At 17%? (Hint: Consider Period 7 as the end of Project B's life.)
e. What is the crossover rate, and what is its significance?

(11-14)
Timing Differences

The Ewert Exploration Company is considering two mutually exclusive plans for extracting oil on property for which it has mineral rights. Both plans call for the expenditure of $10,000,000 to drill development wells. Under Plan A, all the oil will be extracted in 1 year, producing a cash flow at t = 1 of $12,000,000, while under Plan B, cash flows will be $1,750,000 per year for 20 years.
a. What are the annual incremental cash flows that will be available to Ewert Exploration if it undertakes Plan B rather than Plan A? (Hint: Subtract Plan A's flows from B's.)
b. If the firm accepts Plan A, then invests the extra cash generated at the end of Year 1, what rate of return (reinvestment rate) would cause the cash flows from reinvestment to equal the cash flows from Plan B?
c. Suppose a company has a cost of capital of 10%. Is it logical to assume that it would take on all available independent projects (of average risk) with returns greater than 10%? Further, if all available projects with returns greater than 10% have been taken, would this mean that cash flows from past investments would have an opportunity cost of only 10%, because all the firm could do with these cash flows would be to replace money that has a cost of 10%? Finally, does this imply that the cost of capital is the correct rate to assume for the reinvestment of a project's cash flows?
d. Construct NPV profiles for Plans A and B, identify each project's IRR, and indicate the crossover rate of return.

(11-15)
Scale Differences

The Pinkerton Publishing Company is considering two mutually exclusive expansion plans. Plan A calls for the expenditure of $50 million on a large-scale, integrated plant which will provide an expected cash flow stream of $8 million per year for 20 years. Plan B calls for the expenditure of $15 million to build a somewhat less efficient, more labor-intensive plant which has an expected cash flow stream of $3.4 million per year for 20 years. The firm's cost of capital is 10%.

a. Calculate each project's NPV and IRR.
b. Set up a Project Δ by showing the cash flows that will exist if the firm goes with the large plant rather than the smaller plant. What are the NPV and the IRR for this Project Δ?
c. Graph the NPV profiles for Plan A, Plan B, and Project Δ.
d. Give a logical explanation, based on reinvestment rates and opportunity costs, as to why the NPV method is better than the IRR method when the firm's cost of capital is constant at some value such as 10%.

(11-16)
Unequal Lives

Shao Airlines is considering two alternative planes. Plane A has an expected life of 5 years, will cost $100 million, and will produce net cash flows of $30 million per year. Plane B has a life of 10 years, will cost $132 million, and will produce net cash flows of $25 million per year. Shao plans to serve the route for 10 years. Inflation in operating costs, airplane costs, and fares is expected to be zero, and the company's cost of capital is 12%. By how much would the value of the company increase if it accepted the better project (plane)? What is the equivalent annual annuity for each plane?

(11-17)
Unequal Lives

The Perez Company has the opportunity to invest in one of two mutually exclusive machines that will produce a product it will need for the foreseeable future. Machine A costs $10 million but realizes after-tax inflows of $4 million per year for 4 years. After 4 years, the machine must be replaced. Machine B costs $15 million and realizes after-tax inflows of $3.5 million per year for 8 years, after which it must be replaced. Assume that machine prices are not expected to rise because inflation will be offset by cheaper components used in the machines. The cost of capital is 10%. By how much would the value of the company increase if it accepted the better machine? What is the equivalent annual annuity for each machine?

(11-18)
Unequal Lives

Filkins Fabric Company is considering the replacement of its old, fully depreciated knitting machine. Two new models are available: Machine 190-3, which has a cost of $190,000, a 3-year expected life, and after-tax cash flows (labor savings and depreciation) of $87,000 per year; and Machine 360-6, which has a cost of $360,000, a 6-year life, and after-tax cash flows of $98,300 per year. Knitting machine prices are not expected to rise, because inflation will be offset by cheaper components (microprocessors) used in the machines. Assume that Filkins' cost of capital is 14%. Should the firm replace its old knitting machine, and, if so, which new machine should it use? By how much would the value of the company increase if it accepted the better machine? What is the equivalent annual annuity for each machine?

Challenging Problems 19–22

(11-19)
Multiple Rates of Return

The Ulmer Uranium Company is deciding whether or not it should open a strip mine, the net cost of which is $4.4 million. Net cash inflows are expected to be $27.7 million, all coming at the end of Year 1. The land must be returned to its natural state at a cost of $25 million, payable at the end of Year 2.
a. Plot the project's NPV profile.
b. Should the project be accepted if r = 8%? If r = 14%? Explain your reasoning.
c. Can you think of some other capital budgeting situations where negative cash flows during or at the end of the project's life might lead to multiple IRRs?

d.   What is the project's MIRR at r = 8%? At r = 14%? Does the MIRR method lead to the same accept/reject decision as the NPV method?

(11-20)
Present Value
of Costs

The Aubey Coffee Company is evaluating the within-plant distribution system for its new roasting, grinding, and packing plant. The two alternatives are (1) a conveyor system with a high initial cost, but low annual operating costs, and (2) several forklift trucks, which cost less, but have considerably higher operating costs. The decision to construct the plant has already been made, and the choice here will have no effect on the overall revenues of the project. The cost of capital for the plant is 8%, and the projects' expected net costs are listed in the table:

	Expected Net Cost	
Year	Conveyor	Forklift
0	($500,000)	($200,000)
1	(120,000)	(160,000)
2	(120,000)	(160,000)
3	(120,000)	(160,000)
4	(120,000)	(160,000)
5	(20,000)	(160,000)

a.   What is the IRR of each alternative?
b.   What is the present value of costs of each alternative? Which method should be chosen?

(11-21)
Payback, NPV,
and MIRR

Your division is considering two investment projects, each of which requires an up-front expenditure of $25 million. You estimate that the cost of capital is 10% and that the investments will produce the following after-tax cash flows (in millions of dollars):

Year	Project A	Project B
1	5	20
2	10	10
3	15	8
4	20	6

a.   What is the regular payback period for each of the projects?
b.   What is the discounted payback period for each of the projects?
c.   If the two projects are independent and the cost of capital is 10%, which project or projects should the firm undertake?
d.   If the two projects are mutually exclusive and the cost of capital is 5%, which project should the firm undertake?
e.   If the two projects are mutually exclusive and the cost of capital is 15%, which project should the firm undertake?
f.   What is the crossover rate?
g.   If the cost of capital is 10%, what is the modified IRR (MIRR) of each project?

(11-22)
Economic Life

The Scampini Supplies Company recently purchased a new delivery truck. The new truck cost $22,500, and it is expected to generate net after-tax operating cash flows, including depreciation, of $6,250 per year. The truck has a 5-year expected life. The expected salvage values after tax adjustments for the truck are given below. The company's cost of capital is 10%.

Year	Annual Operating Cash Flow	Salvage Value
0	($22,500)	$22,500
1	6,250	17,500
2	6,250	14,000
3	6,250	11,000
4	6,250	5,000
5	6,250	0

a. Should the firm operate the truck until the end of its 5-year physical life, or, if not, what is its optimal economic life?
b. Would the introduction of salvage values, in addition to operating cash flows, ever *reduce* the expected NPV and/or IRR of a project?

Spreadsheet Problem

(11-23)
Build a Model: Capital
Budgeting Tools

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Start with the partial model in the file *FM12 Ch 11 P23 Build a Model.xls* from the textbook's Web site. Gardial Fisheries is considering two mutually exclusive investments. The projects' expected net cash flows are as follows:

Expected Net Cash Flows

Year	Project A	Project B
0	($375)	($575)
1	(300)	190
2	(200)	190
3	(100)	190
4	600	190
5	600	190
6	926	190
7	(200)	0

a. If you were told that each project's cost of capital was 12%, which project should be selected? If the cost of capital was 18%, what would be the proper choice?
b. Construct NPV profiles for Projects A and B.
c. What is each project's IRR?
d. What is the crossover rate, and what is its significance?
e. What is each project's MIRR at a cost of capital of 12%? At r = 18%? (Hint: Consider Period 7 as the end of Project B's life.)
f. What is the regular payback period for these two projects?
g. At a cost of capital of 12%, what is the discounted payback period for these two projects?
h. What is the profitability index for each project if the cost of capital is 12%?

Cyberproblem

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Please go to the textbook's Web site to access any Cyberproblems.

Mini Case

You have just graduated from the MBA program of a large university, and one of your favorite courses was "Today's Entrepreneurs." In fact, you enjoyed it so much you have decided you want to "be your own boss." While you were in the master's program, your grandfather died and left you $1 million to do with as you please. You are not an inventor, and you do not have a trade skill that you can market; however, you have decided that you would like to purchase at least one established franchise in the fast-foods area, maybe two (if profitable). The problem is that you have never been one to stay with any project for too long, so you figure that your time frame is 3 years. After 3 years you will go on to something else.

You have narrowed your selection down to two choices: (1) Franchise L, Lisa's Soups, Salads, & Stuff, and (2) Franchise S, Sam's Fabulous Fried Chicken. The net cash flows shown below include the price you would receive for selling the franchise in Year 3 and the forecast of how each franchise will do over the 3-year period. Franchise L's cash flows will start off slowly but will increase rather quickly as people become more health conscious, while Franchise S's cash flows will start off high but will trail off as other chicken competitors enter the marketplace and as people become more health conscious and avoid fried foods. Franchise L serves breakfast and lunch, while Franchise S serves only dinner, so it is possible for you to invest in both franchises. You see these franchises as perfect complements to one another: You could attract both the lunch and dinner crowds and the health conscious and not so health conscious crowds without the franchises directly competing against one another.

Here are the net cash flows (in thousands of dollars):

	Expected Net Cash Flow	
Year	Franchise L	Franchise S
0	($100)	($100)
1	10	70
2	60	50
3	80	20

Depreciation, salvage values, net working capital requirements, and tax effects are all included in these cash flows.

You also have made subjective risk assessments of each franchise and concluded that both franchises have risk characteristics that require a return of 10%. You must now determine whether one or both of the franchises should be accepted.

a. What is capital budgeting?
b. What is the difference between independent and mutually exclusive projects?
c. (1) Define the term *net present value (NPV)*. What is each franchise's NPV?
    (2) What is the rationale behind the NPV method? According to NPV, which franchise or franchises should be accepted if they are independent? Mutually exclusive?
    (3) Would the NPVs change if the cost of capital changed?
d. (1) Define the term *internal rate of return (IRR)*. What is each franchise's IRR?
    (2) How is the IRR on a project related to the YTM on a bond?
    (3) What is the logic behind the IRR method? According to IRR, which franchises should be accepted if they are independent? Mutually exclusive?
    (4) Would the franchises' IRRs change if the cost of capital changed?

e. (1) Draw NPV profiles for Franchises L and S. At what discount rate do the profiles cross?
   (2) Look at your NPV profile graph without referring to the actual NPVs and IRRs. Which franchise or franchises should be accepted if they are independent? Mutually exclusive? Explain. Are your answers correct at any cost of capital less than 23.6%?

f. (1) What is the underlying cause of ranking conflicts between NPV and IRR?
   (2) What is the "reinvestment rate assumption," and how does it affect the NPV versus IRR conflict?
   (3) Which method is the best? Why?

g. (1) Define the term *modified IRR (MIRR)*. Find the MIRRs for Franchises L and S.
   (2) What are the MIRR's advantages and disadvantages vis-à-vis the regular IRR? What are the MIRR's advantages and disadvantages vis-à-vis the NPV?

h. As a separate project (Project P), you are considering sponsoring a pavilion at the upcoming World's Fair. The pavilion would cost $800,000, and it is expected to result in $5 million of incremental cash inflows during its 1 year of operation. However, it would then take another year, and $5 million of costs, to demolish the site and return it to its original condition. Thus, Project P's expected net cash flows look like this (in millions of dollars):

Year	Net Cash Flows
0	($0.8)
1	5.0
2	(5.0)

The project is estimated to be of average risk, so its cost of capital is 10%.
   (1) What are normal and nonnormal cash flows?
   (2) What is Project P's NPV? What is its IRR? Its MIRR?
   (3) Draw Project P's NPV profile. Does Project P have normal or nonnormal cash flows? Should this project be accepted?

i. What does the profitability index (PI) measure? What are the PI's of Franchises S and L?

j. (1) What is the payback period? Find the paybacks for Franchises L and S.
   (2) What is the rationale for the payback method? According to the payback criterion, which franchise or franchises should be accepted if the firm's maximum acceptable payback is 2 years, and if Franchises L and S are independent? If they are mutually exclusive?
   (3) What is the difference between the regular and discounted payback periods?
   (4) What is the main disadvantage of discounted payback? Is the payback method of any real usefulness in capital budgeting decisions?

k. In an unrelated analysis, you have the opportunity to choose between the following two mutually exclusive projects:

Expected Net Cash Flow

Year	Project S	Project L
0	($100,000)	($100,000)
1	60,000	33,500
2	60,000	33,500
3	—	33,500
4	—	33,500

The projects provide a necessary service, so whichever one is selected is expected to be repeated into the foreseeable future. Both projects have a 10% cost of capital.

(1) What is each project's initial NPV without replication?

(2) What is each project's equivalent annual annuity?

(3) Now apply the replacement chain approach to determine the projects' extended NPVs. Which project should be chosen?

(4) Now assume that the cost to replicate Project S in 2 years will increase to $105,000 because of inflationary pressures. How should the analysis be handled now, and which project should be chosen?

l. You are also considering another project that has a physical life of 3 years; that is, the machinery will be totally worn out after 3 years. However, if the project were terminated prior to the end of 3 years, the machinery would have a positive salvage value. Here are the project's estimated cash flows:

Year	Initial Investment and Operating Cash Flows	End-of-Year Net Salvage Value
0	($5,000)	$5,000
1	2,100	3,100
2	2,000	2,000
3	1,750	0

Using the 10% cost of capital, what is the project's NPV if it is operated for the full 3 years? Would the NPV change if the company planned to terminate the project at the end of Year 2? At the end of Year 1? What is the project's optimal (economic) life?

m. After examining all the potential projects, you discover that there are many more projects this year with positive NPVs than in a normal year. What two problems might this extra large capital budget cause?

Selected Additional Cases

The following cases from Textchoice, *Thomson Learning's online library, cover many of the concepts discussed in this chapter and are available at* **http://www.textchoice2.com.**

Klein-Brigham Series:
Case 11, "Chicago Valve Company."

Brigham-Buzzard Series:
Case 6, "Powerline Network Corporation (Basics of Capital Budgeting)."