



CHAPTER 11

THE BASICS OF CAPITAL BUDGETING

Competition in the Aircraft Industry

In early 2005 Boeing was involved in a titanic struggle with European consortium Airbus SAS for dominance of the commercial aircraft industry.¹ Airbus first committed to spend \$16 billion to develop the A380, the largest plane ever built. Boeing countered by announcing that it would spend \$6 billion on a super efficient new plane, the 7E7 Dreamliner. Airbus then announced plans to spend another \$6 billion on the A350, a competitor to the 7E7. Many detailed calculations went into these multi-billion-dollar investment decisions—development costs were estimated, the cost of each plane was forecasted, a sales price per plane was established, and the number of planes that would be sold through 2025 was predicted.

Both companies projected negative cash flows for 5 or 6 years, then positive cash flows for the following 20 years. Given their forecasted cash flows, both managements decided that taking on the projects would increase their company's intrinsic value. Because the planes will compete with one another, either Boeing's or Airbus's forecast is probably incorrect. One will probably be a winner and the other a loser, and one set of stockholders is likely to be happy and the other unhappy.

Projects like the A350, A380, and 7E7 receive a lot of attention, but Boeing, Airbus, and other companies make a great many more routine investment

Airbus, Boeing

¹ Airbus SAS is owned by European Aeronautics Defense & Space Company (EADS), which, in turn, is owned by the French government and several large European companies. Airbus was formed because the Europeans wanted to create an organization large enough to raise the huge amounts of capital needed to compete with Boeing.

decisions every year, ranging from buying new trucks or machinery to spending millions on computer software to optimize inventory holdings. The techniques described in this chapter are required to analyze all types and sizes of projects.

Sources: Daniel Michaels, "EADS and BAE Systems Approve Launch of Airbus's A350 Plane," *The Wall Street Journal*, December 13, 2004, p. A6; and Carol Matlack, "Is Airbus Caught in a Down-draft?" *BusinessWeek*, December 27, 2004, p. 64.

Putting Things In Perspective

Capital Budgeting

The process of planning expenditures on assets whose cash flows are expected to extend beyond one year.

In the last chapter, we discussed the cost of capital. Now we turn to investment decisions involving fixed assets, or *capital budgeting*. Here *capital* refers to long-term assets used in production, while a *budget* is a plan that details projected expenditures during some future period. Thus, the *capital budget* is an outline of planned investments in long-term assets, and *capital budgeting* is the whole process of analyzing projects and deciding which ones to include in the capital budget. Boeing, Airbus, and other companies use the techniques in this chapter when deciding to accept or reject proposed capital expenditures.

11.1 GENERATING IDEAS FOR CAPITAL PROJECTS

The same general concepts that are used in security valuation are also used in capital budgeting, but there are two major differences. First, stocks and bonds exist in the security markets and investors select from the available set, whereas firms create capital budgeting projects. Second, most investors in the security markets have no influence on the cash flows produced by their investments, whereas corporations have a major influence on their projects' results. Still, in both security valuation and capital budgeting, we first forecast a set of cash flows, then find the present value of those flows, and make the investment only if the PV of the inflows exceeds the investment's cost.

A firm's growth, and even its ability to remain competitive and to survive, depends on a constant flow of ideas relating to new products, actions to improve existing products, and ways to operate more efficiently. Accordingly, well-managed firms go to great lengths to develop good capital budgeting proposals. For example, the executive vice president of one successful corporation told us that his company takes the following steps to generate projects:

Our R&D department constantly searches for new products and ways to improve existing products. In addition, our Executive Committee, which consists of senior executives in marketing, production, and finance, identifies the products and markets in which our company should compete, and the Committee sets long-run targets for each divi-

sion. These targets, which are spelled out in the corporation's **strategic business plan**, provide a general guide to the operating executives who must meet them. The operating executives then seek new products, set expansion plans for existing products, and look for ways to reduce production and distribution costs. Since bonuses and promotions are based on each unit's ability to meet or exceed its targets, these economic incentives encourage our operating executives to seek out profitable investment opportunities.

While our senior executives are judged and rewarded on the basis of how well their units perform, people further down the line are given bonuses and stock options for suggestions that lead to profitable investments. Additionally, a percentage of our corporate profit is set aside for distribution to nonexecutive employees, and we have an Employees' Stock Ownership Plan (ESOP) to provide further incentives. Our objective is to encourage employees at all levels to keep an eye out for good ideas, especially those that lead to capital investments.

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. Therefore, procedures must be established for screening projects, the primary topic of this chapter.



How is capital budgeting similar to security valuation? How is it different?

What are some ways firms generate ideas for capital projects?

Strategic Business Plan

A long-run plan that outlines in broad terms the firm's basic strategy for the next 5 to 10 years.

11.2 PROJECT CLASSIFICATIONS

Analyzing capital expenditure proposals is not a costless operation—benefits can be gained, but analysis does have a cost. For certain types of projects, a relatively detailed analysis may be warranted; for others, simpler procedures should be used. Accordingly, firms generally categorize projects and then analyze those in each category somewhat differently:

1. *Replacement: needed to continue current operations.* One category consists of expenditures to replace worn-out or damaged equipment required in the production of profitable products. The only questions here are should the operation be continued, and if so, should the firm continue to use the same production processes? If the answers are yes, then the project will be approved without going through an elaborate decision process.
2. *Replacement: cost reduction.* This category includes expenditures to replace serviceable but obsolete equipment and thereby lower costs. These decisions are discretionary, and a fairly detailed analysis is generally required.
3. *Expansion of existing products or markets.* These are expenditures to increase output of existing products or to expand retail outlets or distribution facilities in markets now being served. Expansion decisions are more complex because they require an explicit forecast of growth in demand, so a more detailed analysis is required. The go/no-go decision is generally made at a higher level within the firm.
4. *Expansion into new products or markets.* These investments relate to new products or geographic areas, and they involve strategic decisions that could change the fundamental nature of the business. Invariably, a detailed analysis is required, and the final decision is generally made at the very top level of management.

5. *Safety and/or environmental projects.* Expenditures necessary to comply with government orders, labor agreements, or insurance policy terms fall into this category. How these projects are handled depends on their size, with small ones being treated much like the Category 1 projects.
6. *Other.* This catch-all includes items such as office buildings, parking lots, and executive aircraft. How they are handled varies among companies.

In general, relatively simple calculations, and only a few supporting documents, are required for replacement decisions, especially maintenance investments in profitable plants. More detailed analyses are required for cost-reduction projects, for expansion of existing product lines, and especially for investments in new products or areas. Also, within each category projects are grouped by their dollar costs: Larger investments require increasingly detailed analysis and approval at higher levels. Thus, a plant manager might be authorized to approve maintenance expenditures up to \$10,000 using a relatively unsophisticated analysis, but the full board of directors might have to approve decisions that involve either amounts greater than \$1 million or expansions into new products or markets.

Note that the term “investments” encompasses more than buildings and equipment. Computer software used to manage inventories and costs related to major marketing programs are examples. These are “intangible” assets, but decisions to invest in them are analyzed in the same way as decisions related to buildings, equipment, and other tangible assets. In the following sections we examine the specific techniques used to evaluate proposed capital budgeting projects.



Identify the major project classification categories, and explain why and how they are used.

11.3 THE NET PRESENT VALUE (NPV) CRITERION

Net Present Value (NPV) Method

A method of ranking investment proposals using the NPV, which is equal to the present value of future net cash flows, discounted at the cost of capital.

The **net present value (NPV) method**, which estimates how much a potential project will contribute to shareholder wealth, is the primary capital budgeting decision criterion. In this section we use the cash flow data for Projects S and L as shown in Figure 11-1 to explain how the NPV is calculated. The S stands for *short* and the L for *long*: Project S is a short-term project in the sense that most of its cash inflows come in sooner than L's. We assume that the projects are equally risky and that the cash flows have been adjusted to reflect taxes, depreciation, and salvage values. Further, because many projects require an investment in both fixed assets and working capital, the investment outlays shown as CF_0 include any necessary investment in working capital.² Finally, we assume that all cash flows occur at the end of the year.

The NPV is a direct measure of the projects' contribution to shareholder wealth, and as such it is the primary criterion. It is found as follows:

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

²The most difficult aspect of capital budgeting is estimating the relevant cash flows. For simplicity, the net cash flows are treated as a given in this chapter, which allows us to focus on the capital budgeting decision rules. However, in Chapter 12 we will discuss cash flow estimation in detail. Also, note that *net operating working capital* is defined as the increase in current assets associated with the project minus the associated increases in payables and accruals. Thus, in capital budgeting, investment in working capital means the net amount that must be financed by investors.

FIGURE 11-1 Net Cash Flows for Projects S and L

EXPECTED AFTER-TAX NET CASH FLOWS, CF_t			
Year (t)	Project S	Project L	
0	-\$1,000	-\$1,000	(Initial cost in Year 1)
1	500	100	
2	400	300	
3	300	400	
4	100	675	

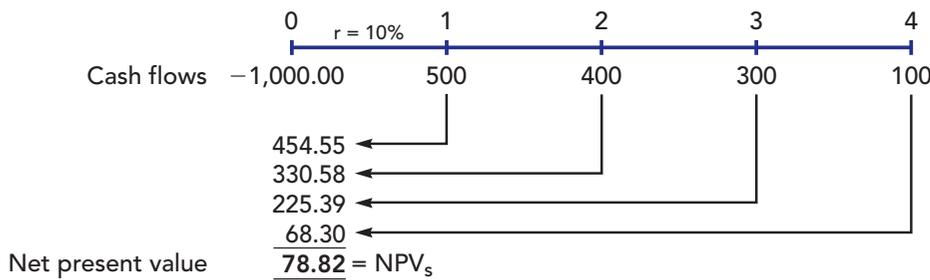
Project S	0	1	2	3	4
	----- ----- ----- ----- -----				
	-\$1,000	\$500	\$400	\$300	\$100
Project L	0	1	2	3	4
	----- ----- ----- ----- -----				
	-\$1,000	\$100	\$300	\$400	\$675

The equation for the NPV is as follows:

$$\begin{aligned}
 NPV &= CF_0 + \frac{CF_1}{(1+r)^1} + \frac{CF_2}{(1+r)^2} + \dots + \frac{CF_N}{(1+r)^N} \\
 &= \sum_{t=0}^N \frac{CF_t}{(1+r)^t} \tag{11-1}
 \end{aligned}$$

Here CF_t is the expected net cash flow at Time t , r is the project's cost of capital (or WACC), and N is its life. Cash outflows (for example, developing the product, buying production equipment, building a factory, and stocking inventory) are *negative* cash flows. For Projects S and L, only CF_0 is negative, but for large projects such as Boeing's 7E7, outflows occur for several years before cash inflows begin.

At a 10 percent cost of capital, Project S's NPV is \$78.82:



By a similar process, we find $NPV_L = \$100.40$.

If the projects were *mutually exclusive*, the one with the higher NPV should be accepted and the other rejected. L would be ranked over S and thus accepted because L 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

A set of projects where only one can be accepted.

Independent Projects

Projects whose cash flows are not affected by the acceptance or nonacceptance of other projects.

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 L should be chosen because it has the higher NPV.

It is not hard to calculate the NPV as shown in the time line by using Equation 11-1 and a regular calculator. However, it is more efficient to use a financial calculator. Different calculators are set up somewhat differently, but as we discussed in Chapter 2, they all have a “cash flow register” that can be used to evaluate uneven cash flows such as those in Projects S and L. Equation 11-1 is programmed into the calculators, and all you have to do is enter the cash flows (observe the correct signs), along with $r = I/YR$ (the cost of capital). Once the entries have been made using data for Project S, this equation is in the calculator:

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

There is one unknown, NPV, and when you press the NPV key the answer, 78.82, will appear on the screen.³

The rationale for the NPV method is straightforward: If NPV exceeds zero, then the project increases the firm’s value, and if it is negative, the project reduces shareholders’ wealth. In our example, Project L would increase shareholders’ wealth by \$100.40 and S would increase it by \$78.82:

$$NPV_L = \$100.40$$

$$NPV_S = \$78.82$$

Viewed in this manner, it is easy to see the logic of the NPV approach, and it is also easy to see why both projects should be accepted if they are independent and why L should be chosen if they are mutually exclusive.



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

What’s the difference between “independent” and “mutually exclusive” projects?

What are the NPVs of Projects SS and LL if both have a 10 percent cost of capital and the indicated cash flows? ($NPV_{SS} = \$77.61$; $NPV_{LL} = \$89.63$)

	END-OF-YEAR CASH FLOWS				WACC = $r = 10\%$
	0	1	2	3	
SS	-\$700	\$500	\$300	\$100	
LL	-700	100	300	600	

Which project or projects would you recommend if they are (a) independent or (b) mutually exclusive?

³ The keystrokes for finding the NPV are shown for several calculators in the calculator tutorials provided on the ThomsonNOW Web site. Since many projects last for more than four years and a number of calculations are required to develop their estimated cash flows, financial analysts often use spreadsheets when analyzing real world capital budgeting projects. We demonstrate this usage in Chapter 12.

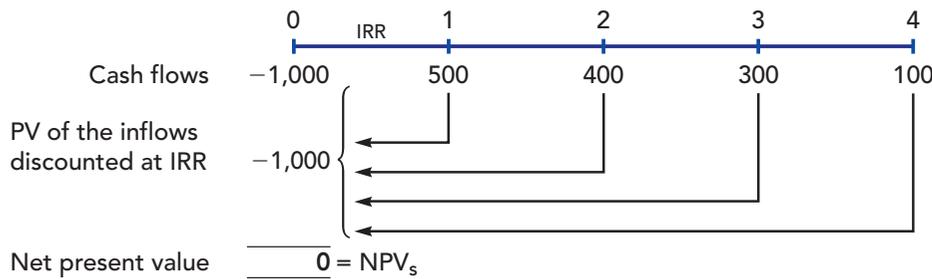
11.4 INTERNAL RATE OF RETURN (IRR)

When deciding on a potential investment, it is useful to know the investment's most likely rate of return. In Chapter 7 we discussed the yield to maturity on a bond—if you invest in a bond and hold it to maturity, you will earn the YTM on the money you invest. The YTM is defined as the discount rate that causes the PV of the cash inflows to equal the price paid for the bond. The same procedure is used in capital budgeting when we calculate the **internal rate of return**, or **IRR**. The IRR is defined as the discount rate that forces the project's NPV to equal zero. We simply take Equation 11-1 for the NPV and transform it to Equation 11-2 for the IRR by replacing r in the denominator with IRR and specifying that the NPV must equal zero. We then find the rate that forces NPV to equal zero, and that is the IRR:

$$\begin{aligned} \text{NPV} &= \text{CF}_0 + \frac{\text{CF}_1}{(1 + \text{IRR})^1} + \frac{\text{CF}_2}{(1 + \text{IRR})^2} + \cdots + \frac{\text{CF}_N}{(1 + \text{IRR})^N} = 0 \\ &= \sum_{t=0}^N \frac{\text{CF}_t}{(1 + \text{IRR})^t} = 0 \end{aligned} \quad (11-2)$$

Note that for a project like Boeing's 7E7 jetliner, costs are incurred for several years before cash inflows begin, but that does not invalidate the equation. That simply means that we have more than one negative cash flow.

For our Project S, here's a picture of the process:



We have an equation with one unknown, IRR, and we can solve it to find the IRR. Without a calculator, we would have to solve Equation 11-2 by trial-and-error—try some discount rate, see if the equation solves to zero, if it does not, try a different discount rate, and continue until we find the rate that forces the equation to equal zero. That rate is the IRR. For a project with a fairly long life, the trial-and-error calculations would be time-consuming, but with a financial calculator we can find IRR quickly. Simply enter the cash flows into the calculator's cash flow register as we did to find the NPV and then press the button labeled "IRR." Here are the IRRs for Projects S and L:⁴

$$\text{IRR}_S = 14.49\%$$

$$\text{IRR}_L = 13.55\%$$

Why is the discount rate that equates a project's cost to the present value of its inflows so special? The reason is straightforward: The IRR is the project's expected rate of return. If this return exceeds the cost of the funds used to

Internal Rate of Return (IRR)

The discount rate that forces a project's NPV to equal zero.

⁴ See our calculator tutorial on the ThomsonNOW Web site. Note that once the cash flows have been entered in the cash flow register, you can immediately find both the NPV and the IRR. To find the NPV, enter the interest rate (I/YR) and then press the NPV key. Then, with no further entries, press the IRR key to find the IRR. Thus, once you set up the calculator to find the NPV, it is trivially easy to find the IRR. This is one reason most companies calculate both the NPV and the IRR—if you calculate one, it is easy to also calculate the other, and both provide information that decision makers find useful.

finance the project, then the excess goes to the firm's stockholders. On the other hand, if the internal rate of return were less than the cost of capital, then stockholders would have to make up the shortfall, which would cause the stock price to decline. It is this "breakeven" characteristic that makes the IRR useful.

Again, note 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 zero. Thus, the same basic equation is used for both methods, but with the NPV method the discount rate is given and we find the NPV, whereas with the IRR method the NPV is set equal to zero and the interest rate that produces this equality is calculated.



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

The cash flows for projects SS and LL are shown below. What are the projects' IRRs, and which one would the IRR method select if the firm has a 10 percent cost of capital and the projects are (a) independent or (b) mutually exclusive? ($IRR_{SS} = 18.0\%$; $IRR_{LL} = 15.6\%$)

	END-OF-YEAR CASH FLOWS				WACC = $r = 10\%$
	0	1	2	3	
SS	-\$700	\$500	\$300	\$100	
LL	-700	100	300	600	

11.5 COMPARISON OF THE NPV AND IRR METHODS

In many respects the NPV method is better than IRR, so it is tempting to simply explain NPV, state that it should be used to select projects, and go on to the next topic. However, the IRR is familiar to many corporate executives, it is widely entrenched in industry, and it is useful to know the rate of return a project is likely to produce. Also, the NPV and IRR methods can provide conflicting recommendations when used to evaluate mutually exclusive projects. Therefore, it is important that you understand the IRR method, know how it is related to the NPV, and know why it is sometimes better to choose a project with a relatively low IRR over a mutually exclusive alternative with a higher IRR.

NPV Profiles

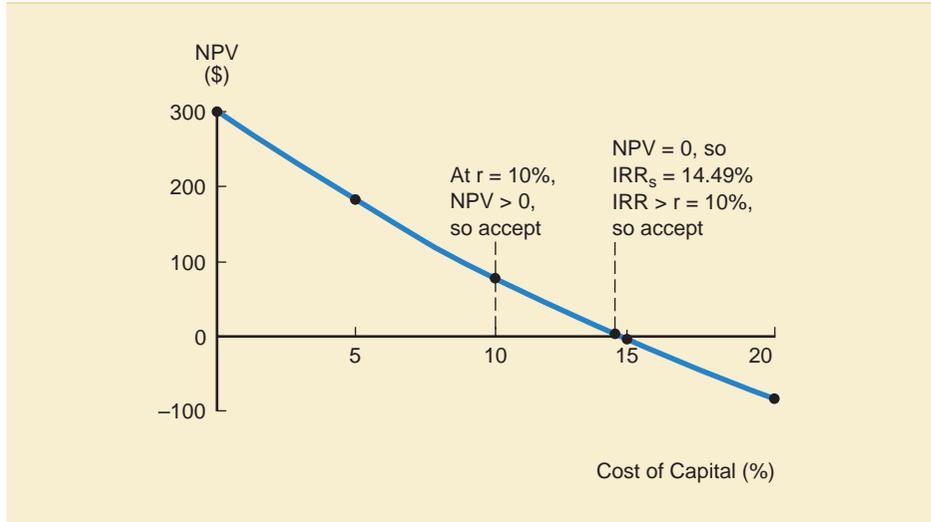
A graph that plots a project's NPV against the discount rates used to calculate the NPV is defined as the project's **net present value profile**, and the profile for Project S is shown in Figure 11-2. To construct the profile, we used the data on Project S in Figure 11-1, calculated NPVs at the discount rates shown in the data below the graph, and then plotted those values on the graph. Note that at a zero cost of capital the NPV is simply the total of the undiscounted cash flows, or \$300. This value is plotted as the vertical axis intercept. Also, recall that the IRR is the discount rate that causes the NPV to equal zero. Therefore, the discount rate at which the profile line crosses the horizontal axis is the project's IRR. When we connect the data points, we have the net present value profile.⁵ These profiles are quite useful, and we refer to them often in the remainder of the chapter.

Net Present Value Profile

A graph showing the relationship between a project's NPV and the firm's cost of capital.

⁵ Notice that the NPV profiles are curved—they are *not* straight lines. NPV approaches CF_0 , that is, the cost of the project, as the discount rate increases without limit. The reason is that, at an infinitely

FIGURE 11-2 NPV Profile for Project S



Cost of Capital	NPV _S
0%	\$300.00
5	180.42
10	78.82
IRR _S = 14.49	0.00
15	-8.33
20	-83.72

NPV Rankings Depend on the Cost of Capital

Now consider Figure 11-3, which shows the NPV profiles for both S and L. Notice that the IRRs are fixed and that S has the higher IRR regardless of the level of the cost of capital. However, the NPV varies depending on the level of the cost of capital, and the project with the higher NPV depends on the actual cost of capital. Specifically, L has the higher NPV if the cost of capital is below 11.97 percent, but S has the higher NPV if the cost of capital is above that rate. The discount rate at which the profile lines cross, 11.97 percent, is called the **crossover rate**.⁶

Notice also that L's profile has the steeper slope, indicating that increases in the cost of capital lead to larger declines in its NPV. To see why L has the greater sensitivity, recall first that L's cash flows come in later than those of S. Therefore,

Crossover Rate

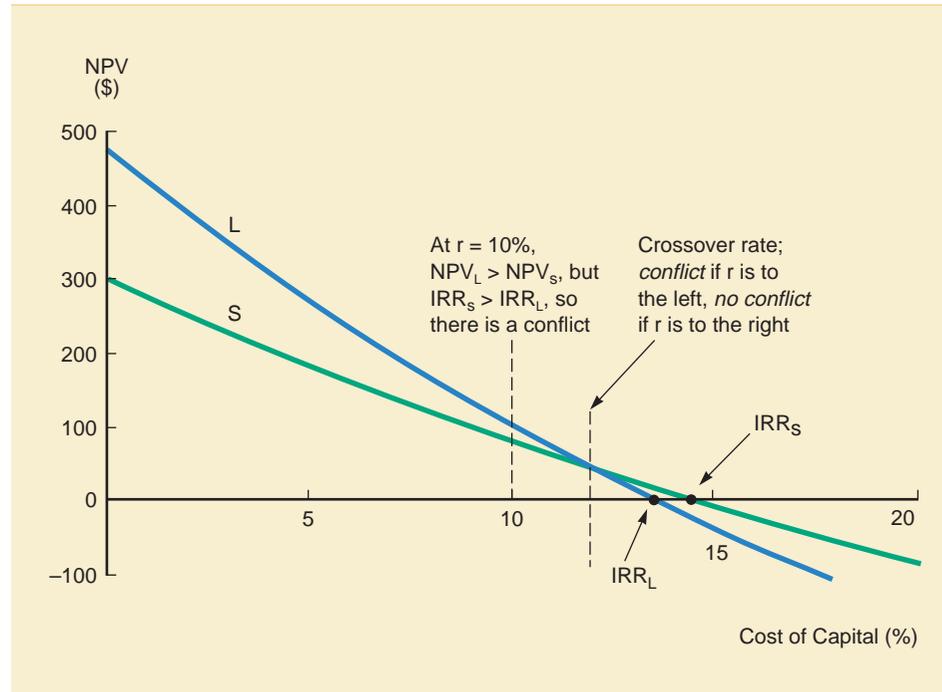
The cost of capital at which the NPV profiles of two projects cross and, thus, at which the projects' NPVs are equal.

(Footnote 5 continued)

high cost of capital, the PVs of the inflows would all be zero, so NPV at $r = \infty$ is simply CF_0 , which in our example is $-\$1,000$. We should also note that under certain conditions the NPV profiles can cross the horizontal axis several times, or never cross it. This point is discussed later in Section 11.6.

⁶ For an explanation of how to calculate the crossover rate, see Eugene F. Brigham and Phillip R. Daves, *Intermediate Financial Management*, 8th edition (Mason, OH: Thomson/South-Western, 2004), footnote 6, p. 385.

FIGURE 11-3 NPV Profiles for Projects S and L



Cost of Capital	NPV _S	NPV _L
0 %	\$300.00	\$475.00
5	180.42	268.21
10	78.82	100.40
Crossover = 11.97	42.84	42.84
IRR _L = 13.55	15.64	0.00
IRR _S = 14.49	0.00	-24.37
15	-8.33	-37.26
20	-83.72	-151.33

L is a long-term project, while S is a short-term project. Next, recall the equation for the NPV:

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

The impact of an increase in the cost of capital is much greater on distant than on near-term cash flows as is demonstrated in the following examples:

$$\text{PV of \$100 due in 1 year @ } r = 5\%: \frac{\$100}{(1.05)^1} = \$95.24$$

$$\text{PV of \$100 due in 1 year @ } r = 10\%: \frac{\$100}{(1.10)^1} = \$90.91$$

$$\text{Percentage decline due to higher } r = \frac{\$95.24 - \$90.91}{\$95.24} = 4.5\%$$

$$\text{PV of \$100 due in 20 years @ } r = 5\%: \frac{\$100}{(1.05)^{20}} = \$37.69$$

$$\text{PV of \$100 due in 20 years @ } r = 10\%: \frac{\$100}{(1.10)^{20}} = \$14.86$$

$$\text{Percentage decline due to higher } r = \frac{\$37.69 - \$14.86}{\$37.69} = 60.6\%$$

Thus, a doubling of the discount rate causes only a 4.5 percent decline in the PV of a Year 1 cash flow, but the same discount rate doubling causes the PV of a Year 20 cash flow to fall by more than 60 percent. Therefore, 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. Most of Project L's cash flows come in the later years, so L is hurt badly if the cost of capital is high, but S is not affected as much by high capital costs. Therefore, Project L's NPV profile has the steeper slope.

Independent Projects

If an *independent* project with normal cash flows is 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, look back at Figure 11-2 and notice (1) that the IRR criterion for acceptance is that the project's cost of capital is less than (or to the left of) the IRR and (2) that if the cost of capital is less than the IRR, then the NPV will be positive. Thus, at any cost of capital less than 14.49 percent, Project S will be acceptable by both the NPV and the IRR criteria, while both methods reject the project if the cost of capital is greater than 14.49 percent. A similar graph could be used for Project L or any other normal project, and we would reach the same conclusion. *Thus, for normal projects it always turns out that if the IRR says accept, then so will the NPV.*

Mutually Exclusive Projects⁷

Now assume that Projects S and L are *mutually exclusive* rather than independent. That is, we can choose either S or L, or we can reject both, but we can't accept both. Now look at Figure 11-3 and note that as long as the cost of capital is *greater than* the crossover rate of 11.97 percent, both methods recommend Project S: $\text{NPV}_S > \text{NPV}_L$ and $\text{IRR}_S > \text{IRR}_L$. Therefore, if r is *greater* than the crossover rate, no conflict occurs because both methods choose S. However, if the cost of capital is *less than* the crossover rate, a conflict arises: NPV ranks L higher but IRR chooses S.

Two basic conditions cause NPV profiles to cross and thus lead to conflicts:⁸

1. *Timing differences* exist, where most of the cash flows from one project come in early while most of those from the other project come in later, as occurred with our Projects S and L.

⁷ This section is relatively technical and can be omitted without loss of continuity.

⁸ Of course, mutually exclusive projects can differ with respect to both scale and timing. Also, if mutually exclusive projects have different lives (as opposed to different cash flow patterns over a common life), this introduces further complications, and for meaningful comparisons, some mutually exclusive projects must be evaluated over a common life. This point is discussed later in the text or on the ThomsonNOW Web site.

2. *Project size (or scale) differences* exist, where the amount invested in one project is larger than the other.

When either size or timing differences occur, 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 the firm chooses Project S, then it will have more funds to invest in Year 1 because S has a higher cash flow in that year than L. Similarly, 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. *Given this situation, the rate of return at which differential cash flows can be reinvested is a critical issue.*

The key to resolving conflicts between mutually exclusive projects is this: At what rate of return can the firm invest the differential cash flows it would receive if it chooses the shorter or smaller project; that is, at what rate can they be reinvested? *The NPV method implicitly assumes that the reinvestment rate is the cost of capital, whereas the IRR method assumes that the reinvestment rate is the IRR itself.* To see why this is so, think back to Chapter 2, where we discussed the time value of money. There we started with \$100 and assumed that it would be invested at the rate $I\%$ for N years. We also assumed that the interest earned during each year would itself earn $I\%$ in the following years. Thus, we were assuming that earnings would be reinvested and would earn $I\%$, and we then compounded by $(1 + I)$ to find the future value. Then, when we found present values, we reversed the process, discounting at the rate $I\%$ to find the present value of a given future value. That leads to this conclusion: *When we calculate present values, we are implicitly assuming that cash flows can be reinvested and that they will earn the specified interest rate, $I\%$.*⁹

That leads to another very important conclusion: *When we find the NPV, we use the WACC as the discount rate, which means that the NPV method automatically assumes that cash flows can be reinvested at the WACC. However, when we find the IRR, we are discounting at the rate that causes the NPV to be zero, which means that the IRR method assumes that cash flows can be reinvested at the IRR itself.*

Which assumption is more realistic? For most firms, reinvestment at the WACC is more realistic because, if a firm has access to the capital markets, it can raise additional capital at the going rate, which in our examples is 10 percent. Since it can obtain capital at 10 percent, if it has investment opportunities that return more than 10 percent, it can take them on using external capital at a 10 percent cost. If it chooses to use internally generated cash flows from past projects rather than external capital, it will save the 10 percent cost of capital, which implies reinvestment at the 10 percent cost of capital.¹⁰

If the firm does not have good access to external capital and also has a lot of projects with high IRRs, then it would be reasonable to assume that project cash flows would be reinvested at rates close to their IRRs. However, this situation rarely exists because firms with good investment opportunities generally do have access to debt and equity markets. *Therefore, the fundamental assumption built into the NPV method is generally more valid than the assumption built into the IRR method.*

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 size or timing, the NPV method is generally superior.*

⁹ It's not critical that cash flows actually be reinvested at the specified interest rate. What's critical is that cash flows *could* be reinvested at that rate.

¹⁰ The 10 percent is also called the *opportunity cost rate*, which is the return on the next best alternative. The opportunity cost for reinvested cash flows for firms with access to capital markets is the cost of capital.

Reinvestment Rate Assumption

The assumption that cash flows from a project can be reinvested (1) at the cost of capital, if using the NPV method, or (2) at the internal rate of return, if using the IRR method.



Describe in words how a project's NPV profile is constructed. What is the Y-axis intercept equal to?

Do the NPV and IRR criteria lead to conflicting recommendations for normal independent projects? For mutually exclusive projects?

What is the "crossover rate," and how does it interact with the cost of capital to determine whether or not a conflict exists between NPV and IRR?

What two characteristics can lead to conflicts between the NPV and the IRR when evaluating mutually exclusive projects?

What reinvestment rate assumptions are built into the NPV and IRR? Which assumption is better for firms (a) with good access to external capital or (b) with no access to external capital?

11.6 MULTIPLE IRRs¹¹

A project has *normal* cash flows if it has one or more cash outflows (costs) followed by a series of cash inflows. If, however, a cash *outflow* occurs sometime after the inflows have commenced, meaning that the signs of the cash flows change more than once, then the project is said to have *nonnormal* cash flows.

Examples:

Normal: - + + + + + or - - - + + + + +
 Nonnormal: - + + + + - or - + + + - + + +

If a project has nonnormal cash flows, it can have two or more IRRs, that is, **multiple IRRs**. This occurs because, when we solve Equation 11-2 to find the IRR for such a project, it is possible to obtain more than one solution value for IRR.¹²

To illustrate this problem, suppose a firm is considering the development of a strip mine (Project M). The mine will cost \$1.6 million, then it will produce a cash flow of \$10 million at the end of Year 1, and then, at the end of Year 2, the firm must spend \$10 million to restore the land to its original condition. Therefore, the project's expected net cash flows are as follows (in millions):

EXPECTED NET CASH FLOWS		
Year 0	End of Year 1	End of Year 2
-\$1.6	+\$10	-\$10

We can substitute these values into Equation 11-2 and then solve for the IRR:

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

¹¹ This section is relatively technical and can be omitted without loss of continuity.

¹² Equation 11-2 is a polynomial of degree n , so it has n different roots, or solutions. All except one of the roots is an imaginary number 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 negative net cash flows occur during some year after the project has been placed in operation.

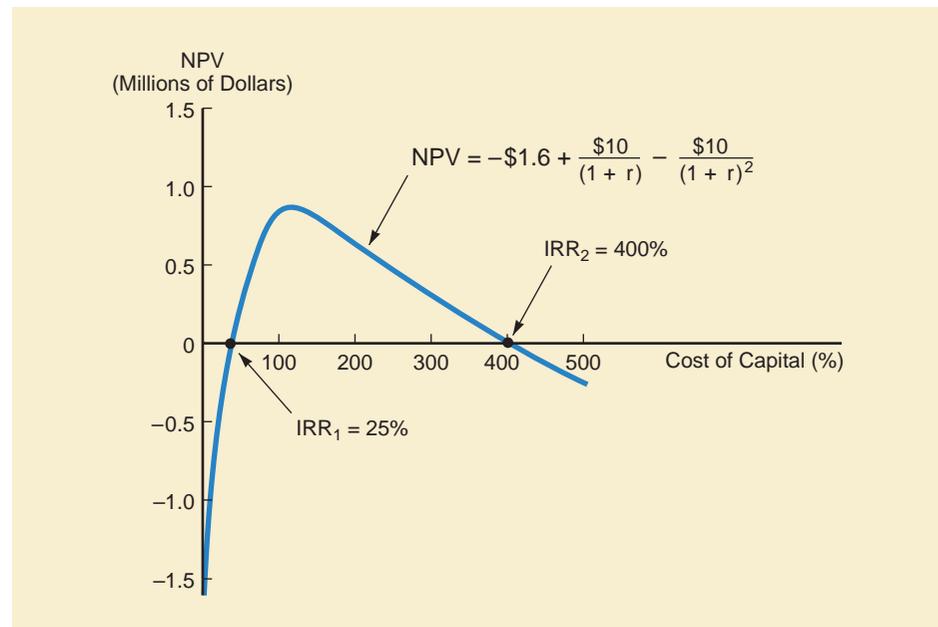
Multiple IRRs

The situation where a project has two or more IRRs.

NPV equals 0 when $IRR = 25\%$ and also when $IRR = 400\%$.¹³ Therefore, Project M has an IRR of 25 percent and another of 400 percent, and we don't know which one to use. This relationship is depicted graphically in the NPV profile shown in Figure 11-4.¹⁴ The graph is constructed by plotting the project's NPV at different discount rates. Note that no dilemma would arise if the NPV method were used; we would simply use Equation 11-1, find the NPV, and use this to evaluate the project. If Project M's cost of capital were 10 percent, then its NPV would be $-\$0.77$ million, and the project should be rejected. If r were between 25 and 400 percent, NPV would be positive.

Another example of multiple internal rates of return occurred when a major California bank borrowed funds from an insurance company and then used these funds (plus an initial investment of its own) to buy a number of jet engines, which it then leased to a major airline. The bank expected to receive

FIGURE 11-4 NPV Profile for Project M



¹³ If you attempt to find Project M's IRR with an HP calculator, you will get an error message, while TI calculators give only the IRR that's closest to zero. When you encounter either situation, you can find the approximate IRRs by first calculating NPVs using several different values for $r = I/YR$ and then plotting the NPV profile. The intersections with the X-axis give a rough idea of the IRR values. With an HP calculator, you can actually find both IRRs by entering guesses as we explain in the tutorial. We are not aware of a corresponding feature for TI calculators.

¹⁴ Does Figure 11-4 suggest that the firm should try to *raise* its cost of capital to about 100 percent in order to maximize the NPV of the project? Certainly not. The firm should seek to *minimize* its cost of capital; this will cause its stock price to be maximized. Actions taken to raise the cost of capital might make this particular project look good, but those actions would be terribly harmful to the firm's more numerous projects with normal cash flows. Only if the firm's cost of capital is high in spite of efforts to keep it down will the illustrative project have a positive NPV.

positive net cash flows (lease payments minus interest on the insurance company loan) for a number of years, then several large negative cash flows as it repaid the insurance company loan, and, finally, a large inflow from the sale of the engines when the lease expired. The bank discovered two IRRs and wondered which was correct. It could not ignore the IRR and just use the NPV method because the bank's senior loan committee, as well as Federal Reserve bank examiners, wanted to know the return on the lease. The bank's solution called for calculating and then using the "modified internal rate of return," which is discussed in the next section.



What characteristic must a project's cash flow stream have for more than one IRR to exist?

Project MM has the cash flows shown below. Calculate MM's NPV at discount rates of 0, 10, 12.2258, 25, 122.1470, and 150 percent. What are MM's IRRs? If the cost of capital were 10 percent, should the project be accepted or rejected? (NPVs range from $-\$350$ to $+\$164$ and back to $-\$94$; the IRRs are 12.23 and 122.15 percent)

END-OF-YEAR CASH FLOWS			
0	1	2	3
$-\$1,000$	$\$2,000$	$\$2,000$	$-\$3,350$

11.7 MODIFIED INTERNAL RATE OF RETURN (MIRR)¹⁵

Managers like to know the rates of return projects are expected to provide. The regular IRR assumes that cash flows will be reinvested at the IRR, but that may not be correct. In addition, projects can have more than one IRR. Given these problems, can we find a percentage evaluator that is better than the regular IRR? The answer is yes—we can modify the IRR and make it both a better indicator of relative profitability and also free of the multiple IRR problem. The new measure is called the **modified IRR**, or **MIRR**, and it is defined as follows:

$$\begin{aligned}
 \text{PV costs} &= \text{PV terminal value} \\
 \sum_{t=0}^N \frac{\text{COF}_t}{(1+r)^t} &= \frac{\sum_{t=0}^N \text{CIF}_t (1+r)^{N-t}}{(1+\text{MIRR})^N} \\
 \text{PV costs} &= \frac{\text{TV}}{(1+\text{MIRR})^N} \quad (11-2a)
 \end{aligned}$$

Here COF refers to cash outflows (negative numbers, or costs associated with the project) and CIF refers to cash inflows (positive numbers). The left term is simply the PV of the investment outlays when discounted at the cost of capital, and the numerator of the right term is the compounded value of the inflows, assuming that the cash inflows are reinvested at the cost of capital. The compounded value of the cash inflows is also called the *terminal value*, or *TV*. The discount

Modified IRR (MIRR)

The discount rate at which the present value of a project's cost is equal to the present value of its terminal value, where the terminal value is found as the sum of the future values of the cash inflows, compounded at the firm's cost of capital.

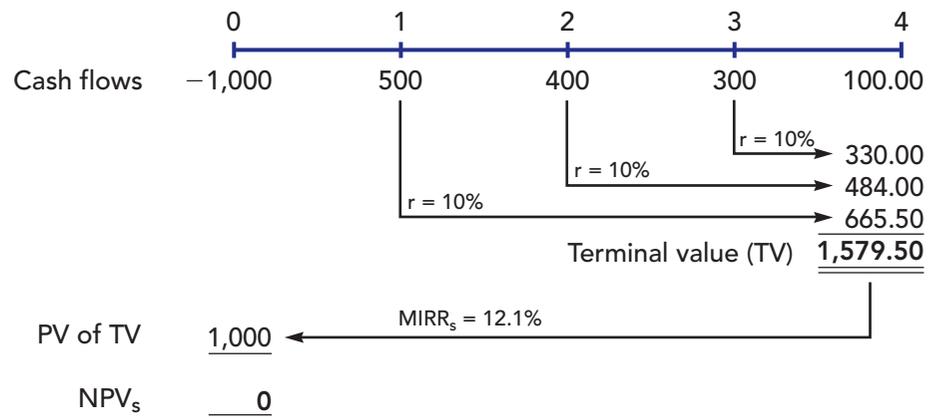
¹⁵ Again, this section is relatively technical, but it can be omitted without loss of continuity.

rate that forces the PV of the TV to equal the PV of the costs is defined as the MIRR.¹⁶

If the investment costs are all incurred at $t = 0$, and if the first operating inflow occurs at $t = 1$, as is true for our illustrative Projects S and L as presented in Figure 11-1, then this equation can be used:

$$\text{Cost} = \frac{\text{TV}}{(1 + \text{MIRR})^N} = \frac{\sum_{t=1}^N \text{CIF}_t(1 + r)^{N-t}}{(1 + \text{MIRR})^N} \quad (11-2b)$$

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 percent cost of capital. Then enter $N = 4$, $PV = -1000$, $PMT = 0$, $FV = 1579.5$, and then press the I/YR button to find $\text{MIRR}_S = 12.1\%$. Similarly, we find $\text{MIRR}_L = 12.7\%$.¹⁷

The MIRR has two significant advantages over the regular IRR. First, whereas the regular IRR assumes that the cash flows from each project are reinvested at the IRR itself, the MIRR assumes that cash flows are reinvested at the cost of capital.¹⁸ As we discussed earlier, reinvestment at the cost of capital is generally more correct, so the MIRR is a better indicator of a project's true profitability than the IRR. Also, the MIRR solves the multiple IRR problem—there can never be more than one MIRR, and it can be compared with the cost of capital when deciding to accept or reject projects.

Is MIRR as good as NPV for choosing between mutually exclusive projects? In general, the answer is no. If projects differ in size or length of life, conflicts

¹⁶ There are several alternative definitions for the MIRR. The differences relate to whether negative cash flows after the 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.

¹⁷ It is easy to calculate the MIRR in practice. Some calculators, including the HP-17B and the TI BAII+ Professional, can do the MIRR calculations, and *Excel* has a MIRR function that makes the calculation trivially easy.

¹⁸ This statement is not completely true. With *Excel*, the reinvestment rate can be specified to be a rate other than either the IRR or the WACC if the most likely reinvestment rate is known.

can arise, and in such cases the NPV is better because it leads to the choice that maximizes value.

Our conclusion is that the MIRR is superior to the regular IRR as an indicator of a project's "true" rate of return. However, NPV is still best for choosing among competing projects because it provides the best indication of how much each project will add to the value of the firm.



What is the primary difference between the MIRR and the regular IRR?

What advantages does the MIRR have over the regular IRR?

What conditions can cause MIRR and NPV to produce conflicting rankings?

Projects S and L have the following cash flows, and their cost of capital is 10 percent. What are the projects' IRRs, MIRRs, and NPVs? Which project would each method select? ($IRR_S = 23.1\%$, $IRR_L = 19.1\%$, $MIRR_S = 16.8\%$, $MIRR_L = 18.7\%$, $NPV_S = \$128.10$, $NPV_L = \$165.29$)

	0	1	2
S	-\$1,000	\$1,150	\$ 100
L	-1,000	100	1,300

11.8 PAYBACK PERIOD

The NPV and IRR are the most used methods today, but the earliest selection criterion was the **payback period**, defined as the number of years required to recover a project's cost from operating cash flows. Equation 11-3 is used for the calculation, and the process is diagrammed in Figure 11-5. We start with the project's cost, then add the cash inflow for each year until the cumulative cash flow turns positive. The payback year is the year prior to full recovery plus a fraction equal to the shortfall at the end of that year divided by the cash flow during the full recovery year:¹⁹

$$\text{Payback} = \text{Number of years prior to full recovery} + \frac{\text{Unrecovered cost at start of year}}{\text{Cash flow during full recovery year}} \quad (11-3)$$

The shorter the payback, the better. Therefore, if the firm requires a payback of three years or less, S would be accepted but L would be rejected. If the projects were mutually exclusive, S would be ranked over L because of its 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 whatever, regardless of how large they might be. (3) Unlike the NPV, which tells us by how much the project should increase shareholder wealth, and

Payback Period

The length of time required for an investment's net revenues to cover its cost.

¹⁹ Equation 11-3 assumes that cash flows come in uniformly during the year and the cash flow during the full recovery year is positive.

FIGURE 11-5 Payback Calculations

Project S	Years	0	1	2	3	4
Cash flow		-1,000	500	400	300	100
Cumulative cash flow		-1,000	-500	-100	200	300
Payback S = 2 + 100/300 =		2.33				
Project L	Years	0	1	2	3	4
Cash flow		-1,000	100	300	400	675
Cumulative cash flow		-1,000	-900	-600	-200	475
Payback L = 3 + 200/675 =		3.30				

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. The two years, three years, or whatever is used as the cutoff is essentially arbitrary.

To counter the first criticism, analysts developed the **discounted payback**, where cash flows are first discounted at the WACC and then used to find the payback year. Thus, the discounted payback period is defined as the number of years required to recover the investment's cost from *discounted* cash flows. Figure 11-6 calculates the discounted paybacks for S and L, assuming both have a 10 percent cost of capital. 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, and those PVs are used to find the payback. Project S's discounted payback is just under three years, while L's is almost four years.

Note that the payback is a "breakeven" calculation in the sense that if cash flows come in at the expected rate until the payback year, then the project will break even. However, since the regular payback doesn't consider the cost of capital, it doesn't really specify the breakeven year. The discounted payback does consider capital costs, but it still disregards cash flows beyond the payback year, which is a serious flaw. Further, there is no way of telling how low the paybacks must be to maximize shareholder wealth.

Although both payback methods have faults as ranking criteria, they do provide information on how long funds will be tied up in a project. The shorter the payback, other things held constant, the greater the project's *liquidity*. This factor is often important for smaller firms that don't have ready access to the capital markets. Also, cash flows expected in the distant future are generally riskier than near-term cash flows, so the payback can be used as a risk indicator.

Discounted Payback

The length of time required for an investment's cash flows, discounted at the investment's cost of capital, to cover its cost.



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

FIGURE 11-6 Discounted Payback Calculations at 10% Cost of Capital

Project S	Years	0	1	2	3	4
	Cash flow	-1,000	500	400	300	100
	Discounted cash flow	-1,000	455	331	225	68
	Cumulative discounted CF	-1,000	-545	-215	11	79
Discounted payback S = 2 + 215/225 =		2.95				
Project L	Years	0	1	2	3	4
	Cash flow	-1,000	100	300	400	675
	Discounted cash flow	-1,000	91	248	301	461
	Cumulative discounted CF	-1,000	-909	-661	-361	100
Discounted payback L = 3 + 361/461 =		3.78				

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

Project P has a cost of \$1,000 and cash flows of \$300 per year for three years plus another \$1,000 in Year 4. The project's cost of capital is 15 percent. What are P's regular and discounted paybacks? (3.10, 3.55) If the company requires a payback of three years or less, would the project be accepted? Would this be a good accept/reject decision, considering the NPV and/or the IRR? (NPV = \$256.72, IRR = 24.78%)

11.9 CONCLUSIONS ON CAPITAL BUDGETING METHODS

We have discussed five capital budgeting decision criteria—NPV, IRR, MIRR, payback, and discounted payback. We compared these methods with one another and highlighted their strengths and weaknesses. In the process, we may have 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 all five of the decision criteria. In making the accept/reject decision, large, sophisticated firms such as GE, Boeing, and Airbus generally calculate and consider all five measures, because each provides a somewhat different piece of information.

NPV is important because it gives a direct measure of the dollar benefit of the project to shareholders, so we regard it as the best measure of profitability. IRR and MIRR also measure profitability, but expressed as a percentage rate of return, which is interesting to decision makers. Further, IRR and MIRR contain information concerning a project's “safety margin.” To illustrate, consider two

projects, Project SS (for small), which costs \$10,000 and is expected to return \$16,500 at the end of one year, and Project LL (for large), which costs \$100,000 and has an expected payoff of \$115,550 after one year. SS has a huge IRR and MIRR, 65 percent, while LL's IRR and MIRR are a more modest 15.6 percent. The NPV paints a somewhat different picture—at a 10 percent cost of capital, SS's NPV is \$5,000 while LL's is \$5,045. By the NPV rule we would choose LL. However, SS's IRR and MIRR indicate that it has a much larger margin for error: Even if its realized cash flow fell by 39 percent from the \$16,500 forecast, the firm would still recover its \$10,000 investment. On the other hand, if LL's inflows fell by only 13.5 percent from its forecasted \$115,550, the firm would not recover its investment. Further, if neither project generated any cash flows at all, the firm would lose only \$10,000 on SS but \$100,000 if it took on LL.

The modified IRR has all the virtues of the IRR, but it incorporates a better reinvestment rate assumption, and it also avoids the multiple rate of return problem. Thus, if decision makers want to know projects' rates of return, the MIRR is a better indicator than the regular IRR.

Payback and discounted payback provide indications of a project's *liquidity* and *risk*. A long payback means that investment dollars will be locked up for many years, hence the project is relatively illiquid, and also that cash flows must be forecasted far out into the future, hence the project is probably riskier than if it had a shorter payback. A good analogy for this is bond valuation. An investor should never compare the yields to maturity on two bonds without also considering their terms to maturity because a bond's riskiness is significantly influenced by its maturity. The same holds true for capital projects.

In summary, the different measures provide different types of information. Since it is easy to calculate all of them, all should be considered when making capital budgeting decisions. For most decisions, the greatest weight should be given to the NPV, but it would be foolish to ignore the information provided by the other criteria.



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

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

11.10 DECISION CRITERIA USED IN PRACTICE

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

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	<u>100%</u>	<u>100%</u>	<u>100%</u>	

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. R. Block, "A Survey of Multinational Capital Budgeting," *The Financial Review*, March 1984, pp. 36–51.

1980. Companies still use payback because it is easy to calculate and it does provide some information, 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. We will have more to say about all this when we discuss cash flow.



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

11.11 USING CAPITAL BUDGETING TECHNIQUES IN OTHER CONTEXTS

The techniques developed in this chapter are also used to help managers make other types of decisions. One example is the analysis relating to a corporate merger. Companies frequently decide to acquire other firms to obtain low-cost production facilities, to increase capacity, or to expand into new markets, and the analysis related to such mergers is similar to that used in capital budgeting. Thus, when the bank that is now Bank of America began to expand out of its North Carolina base, it often had the choice of building new facilities from the

ground up or acquiring existing banks. It frequently chose to acquire other banks, and its managers used the same techniques we employ in capital budgeting when making this choice.

Managers also use similar techniques when deciding whether to downsize operations or to sell off particular assets or divisions. Like capital budgeting, such an analysis requires an assessment of how the action will affect the firm's cash flows. In a downsizing, companies typically spend money (that is, invest) in severance payments to employees who will be laid off, but the companies then receive benefits in the form of lower future wage costs. Regarding asset sales, the pattern of cash flows is reversed from those in a typical capital budgeting decision—positive cash flows are realized at the outset, but the firm is sacrificing future cash flows that it would have received if it had continued to use the asset. So, when deciding whether it makes sense to shed assets, managers compare the cash received with the present value of the lost inflows. If the net present value is positive, selling the asset would increase shareholder value.



Give some examples of other types of decisions that can be analyzed with the capital budgeting techniques developed in this chapter.

11.12 THE POST-AUDIT

Post-Audit

A comparison of actual versus expected results for a given capital project.

An important aspect of the capital budgeting process is the **post-audit**, which involves (1) comparing actual results with those predicted by the project's sponsors and (2) explaining why any differences occurred. For example, many firms require that the operating divisions send a monthly report for the first six months after a project goes into operation, and a quarterly report thereafter, until the project's results are up to expectations. From then on, reports on the operation are reviewed on a regular basis like those of other operations.

The post-audit has two main purposes:

1. *Improve forecasts.* When decision makers are forced to compare their projections with actual outcomes, there is a tendency for estimates to improve. Conscious or unconscious biases are observed and eliminated; new forecasting methods are sought as the need for them becomes apparent; and people simply tend to do everything better, including forecasting, if they know that their actions are being monitored. How hard and how effectively would you study if you never had to take a test?
2. *Improve operations.* Businesses are run by people, and people can perform at higher or lower levels of efficiency. When a divisional team has made a forecast about an investment, the team members are, in a sense, putting their reputations on the line. Accordingly, if costs are above predicted levels, sales are below expectations, and so on, then executives in production, marketing, and other areas will strive to improve operations and to bring results into line with forecasts. In a discussion related to this point, one executive made this statement: "You academicians only worry about making good decisions. In business, we also worry about making decisions good."

The post-audit is not a simple process, and a number of factors can cause complications. First, we must recognize that each element of the cash flow forecast is subject to uncertainty, so a percentage of all projects undertaken by any

reasonably aggressive firm will necessarily go awry. This fact must be considered when appraising the performances of the operating executives who submit capital expenditure requests. Second, projects sometimes fail to meet expectations for reasons beyond the control of the operating executives and for reasons that no one could realistically be expected to anticipate. For example, the unanticipated run-up in oil prices in 2005 adversely affected many projects. Third, it is often difficult to separate the operating results of one investment from those of a larger system. Although some projects stand alone and permit ready identification of costs and revenues, the cost savings that result from assets like new computers may be very hard to measure. Fourth, it is often hard to hand out blame or praise because the executives who were responsible for launching a given investment have moved on by the time the results are known.

Because of these difficulties, some firms tend to play down the importance of the post-audit. However, observations of both businesses and governmental units suggest that the best-run and most successful organizations are the ones that put the greatest emphasis on post-audits. Accordingly, we regard the post-audit as an important element in a good capital budgeting system.



What is done in the post-audit?

Identify several benefits of the post-audit.

What are some factors that complicate the post-audit process?

Tying It All Together

In this chapter we described five techniques—NPV, IRR, MIRR, payback, and discounted payback—that are used to evaluate proposed capital budgeting projects. The NPV is the best single measure and is gaining in usage. However, the other approaches provide useful information, and in this age of computers, it is easy to calculate all of them. Therefore, managers generally look at all five criteria when deciding to accept or reject projects and when choosing among mutually exclusive projects.

We simplified things greatly in this chapter. In particular, you were given a set of cash flows and a risk-adjusted cost of capital, and you were then asked to evaluate the projects. The hardest part of capital budgeting, however, is estimating the cash flows and risk. We address these issues later when we discuss cash flow.

SELF-TEST QUESTIONS AND PROBLEMS (Solutions Appear in Appendix A)

- ST-1 Key terms** Define each of the following terms:
- Capital budget; capital budgeting; strategic business plan
 - Net present value (NPV) method
 - Internal rate of return (IRR)
 - NPV profile; crossover rate
 - Reinvestment rate assumption
 - Mutually exclusive projects; independent projects
 - Nonnormal cash flows; normal cash flows; multiple IRRs
 - Modified internal rate of return (MIRR)
 - Payback period; discounted payback
 - Post-audit

- ST-2 Capital budgeting criteria** You must analyze two projects, X and Y. Each project costs \$10,000, and the firm's WACC is 12 percent. The expected net cash flows are

	0	1	2	3	4
Project X	−\$10,000	\$6,500	\$3,000	\$3,000	\$1,000
Project Y	−\$10,000	\$3,500	\$3,500	\$3,500	\$3,500

- Calculate each project's NPV, IRR, MIRR, payback, and discounted payback.
- Which project(s) should be accepted if they are independent?
- Which project should be accepted if they are mutually exclusive?
- How might a change in the WACC produce a conflict between the NPV and IRR rankings of these two projects? Would there be a conflict if WACC were 5 percent? (Hint: Plot the NPV profiles. The crossover rate is 6.21875 percent.)
- Why does the conflict exist?

QUESTIONS

- 11-1** How are project classifications used in the capital budgeting process?
- 11-2** What are three potential flaws with the regular payback method? Does the discounted payback method correct all three flaws?
- 11-3** Why is the NPV of a relatively long-term project (one for which a high percentage of its cash flows occur in the distant future) more sensitive to changes in the WACC than that of a short-term project?
- 11-4** What is a mutually exclusive project? How should managers rank mutually exclusive projects?
- 11-5** If two mutually exclusive projects were being compared, would a high cost of capital favor the longer-term or the shorter-term project? Why? If the cost of capital declined, would that lead firms to invest more in longer-term projects or shorter-term projects? Would a decline (or an increase) in the WACC cause changes in the IRR ranking of mutually exclusive projects?
- 11-6** Discuss the following statement: "If a firm has only independent projects, a constant WACC, and projects with normal cash flows, then the NPV and IRR methods will always lead to identical capital budgeting decisions." What does this imply about the choice between IRR and NPV? If each of the assumptions above were changed (one by one), how would your answer change?
- 11-7** Why might it be rational for a small firm that does not have access to the capital markets to use the payback method rather than the NPV method?

- 11-8** Project X is very risky and has an NPV of \$3 million. Project Y is very safe and has an NPV of \$2.5 million. They are mutually exclusive, and project risk has been properly considered in the NPV analyses. Which project should be chosen? Explain.
- 11-9** What reinvestment rate assumptions are built into the NPV, IRR, and MIRR methods? Give an explanation (other than “because the text says so”) for your answer.
- 11-10** A firm has a \$100 million capital budget. It is considering two projects that each cost \$100 million. Project A has an IRR of 20 percent, an NPV of \$9 million, and will be terminated after 1 year at a profit of \$20 million, resulting in an immediate increase in EPS. Project B, which cannot be postponed, has an IRR of 30 percent and an NPV of \$50 million. However, the firm’s short-run EPS will be reduced if it accepts Project B, because no revenues will be generated for several years.
- Should the short-run effects on EPS influence the choice between the two projects?
 - How might situations like this influence a firm’s decision to use payback?

PROBLEMS

Easy Problems 1–6

- 11-1** **NPV** Project K costs \$52,125, its expected net cash inflows are \$12,000 per year for 8 years, and its WACC is 12 percent. What is the project’s NPV?
- 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** **Payback period** Refer to problem 11-1. What is the project’s payback?
- 11-5** **Discounted payback** Refer to problem 11-1. What is the project’s discounted payback?
- 11-6** **NPV** Your division is considering two projects with the following net cash flows (in millions):

	0	1	2	3
	----- ----- ----- -----			
Project A	−\$25	\$5	\$10	\$17
Project B	−\$20	\$10	\$9	\$6

- What are the projects’ NPVs, assuming the WACC is 5 percent? 10 percent? 15 percent?
- What are the projects’ IRRs at each of these WACCs?
- If the WACC were 5 percent and A and B were mutually exclusive, which would you choose? What if the WACC were 10 percent? 15 percent? (Hint: The crossover rate is 7.81 percent.)

Intermediate Problems 7–13

- 11-7** **Capital budgeting criteria** A firm with a 14 percent WACC is evaluating two projects for this year’s capital budget. After-tax cash flows, including depreciation, are as follows:

	0	1	2	3	4	5
	----- ----- ----- ----- ----- -----					
Project A	−\$6,000	\$2,000	\$2,000	\$2,000	\$2,000	\$2,000
Project B	−\$18,000	\$5,600	\$5,600	\$5,600	\$5,600	\$5,600

- Calculate NPV, IRR, MIRR, payback, and discounted payback for each project.
 - Assuming the projects are independent, which one or ones would you recommend?
 - If the projects are mutually exclusive, which would you recommend?
 - Notice that the projects have the same cash flow timing pattern. Why is there a conflict between NPV and IRR?
- 11-8** **Capital budgeting criteria: ethical considerations** A mining company is considering a new project. It has received a permit, so the mine would be legal, but it would cause significant harm to a nearby river. The firm could spend an additional \$10 million at Year 0 to mitigate the environmental problem, but it would not be required to do so.

Developing the mine (without mitigation) would cost \$60 million, and the expected net cash inflows would be \$20 million per year for 5 years. If the firm does invest in mitigation, the annual inflows would be \$21 million. The risk-adjusted WACC is 12 percent.

- Calculate the NPV and IRR with and without mitigation.
- How should the environmental effects be dealt with when evaluating this project?
- Should this project be undertaken? If so, should the firm do the mitigation?

11-9 Capital budgeting criteria: ethical considerations An electric utility is considering a new power plant in northern Arizona. Power from the plant would be sold in the Phoenix area, where it is badly needed. The firm has received a permit, so the plant would be legal, but it would cause some air pollution near the plant. The company could spend an additional \$40 million at Year 0 to mitigate the environmental problem, but it would not be required to do so. The plant without mitigation would cost \$240 million, and the expected net cash inflows would be \$80 million per year for 5 years. If the firm does invest in mitigation, the annual inflows would be \$84 million. Unemployment in the area where the plant would be built is high, and the plant would provide about 350 good jobs. The risk-adjusted WACC is 17 percent.

- Calculate the NPV and IRR with and without mitigation.
- How should the environmental effects be dealt with when evaluating this project?
- Should this project be undertaken? If so, should the firm do the mitigation?

11-10 Capital budgeting criteria: mutually exclusive projects A firm with a WACC of 10 percent is considering the following mutually exclusive projects:

	0	1	2	3	4	5
Project A	-\$400	\$55	\$55	\$55	\$225	\$225
Project B	-\$600	\$300	\$300	\$50	\$50	\$49

Which project would you recommend? Explain.

11-11 Capital budgeting criteria: mutually exclusive projects Project S costs \$15,000, and its expected cash flows would be \$4,500 per year for 5 years. Mutually exclusive Project L costs \$37,500, and its expected cash flows would be \$11,100 per year for 5 years. If both projects have a WACC of 14 percent, which project would you recommend? Explain.

11-12 IRR and NPV A company is analyzing two mutually exclusive projects, S and L, with the following cash flows:

	0	1	2	3	4
Project S	-\$1,000	\$900	\$250	\$10	\$10
Project L	-\$1,000	\$0	\$250	\$400	\$800

The company's WACC is 10 percent. What is the IRR of the *better* project? (Hint: Note that the better project may or may not be the one with the higher IRR.)

11-13 MIRR A firm is considering two mutually exclusive projects, X and Y, with the following cash flows:

	0	1	2	3	4
Project X	-\$1,000	\$100	\$300	\$400	\$700
Project Y	-\$1,000	\$1,000	\$100	\$50	\$50

The projects are equally risky, and their WACC is 12 percent. What is the MIRR of the better project?

Challenging
Problems 14–22

- 11-14 Choosing mandatory projects on the basis of least cost** K. Kim Inc. must install a new air conditioning unit in its main plant. Kim absolutely must install one or the other of the units because otherwise the highly profitable plant would have to shut down. Two units are available, HCC and LCC (for high and low capital costs). HCC has a high capital cost but relatively low operating costs, while LCC has a low capital cost but higher operating costs because it uses more electricity. The units' costs are shown below. Kim's WACC is 7 percent.

	0	1	2	3	4	5
HCC	-\$600,000	-\$50,000	-\$50,000	-\$50,000	-\$50,000	-\$50,000
LCC	-\$100,000	-\$175,000	-\$175,000	-\$175,000	-\$175,000	-\$175,000

- a. Which unit would you recommend? Explain.
 - b. If Kim's controller wanted to know the IRRs of the two projects, what would you tell him?
 - c. If the WACC rose to 15 percent would this affect your recommendation? Explain your answer and why this result occurred.
- 11-15 NPV profiles: timing differences** An oil drilling company must choose between two mutually exclusive extraction projects, and each costs \$12 million. Under Plan A, all the oil would be extracted in 1 year, producing a cash flow at $t = 1$ of \$14.4 million. Under Plan B, cash flows would be \$2.1 million per year for 20 years. The firm's WACC is 12 percent.
- a. Construct NPV profiles for Plans A and B, identify each project's IRR, and show the approximate crossover rate.
 - b. Is it logical to assume that the firm would take on all available independent, average-risk projects with returns greater than 12 percent? If all available projects with returns greater than 12 percent have been undertaken, would this mean that cash flows from past investments would have an opportunity cost of only 12 percent, because all it could do with these cash flows would be to replace money that has a cost of 12 percent? Does this imply that the WACC is the correct reinvestment rate assumption for a project's cash flows?
- 11-16 NPV profiles: scale differences** A company is considering two mutually exclusive expansion plans. Plan A requires a \$40 million expenditure on a large-scale, integrated plant that would provide expected cash flows of \$6.4 million per year for 20 years. Plan B requires a \$12 million expenditure to build a somewhat less efficient, more labor-intensive plant with an expected cash flow of \$2.72 million per year for 20 years. The firm's WACC is 10 percent.
- a. Calculate each project's NPV and IRR.
 - b. Graph the NPV profiles for Plan A and Plan B and approximate the crossover rate.
 - c. Why is NPV better than IRR for making capital budgeting decisions that add to shareholder value?
- 11-17 Capital budgeting criteria** A company has a 12 percent WACC and is considering two mutually exclusive investments with the following net cash flows:

	0	1	2	3	4	5	6	7
Project A	-\$300	-\$387	-\$193	-\$100	\$600	\$600	\$850	-\$180
Project B	-\$405	\$134	\$134	\$134	\$134	\$134	\$134	\$0

- a. What is each project's NPV?
 - b. What is each project's IRR?
 - c. What is each project's MIRR? (Hint: Consider Period 7 as the end of Project B's life.)
 - d. From your answers to parts a, b, and c, which project would be selected? If the WACC were 18 percent, which project would be selected?
 - e. Construct NPV profiles for Projects A and B.
 - f. What is each project's MIRR at a WACC of 18 percent?
- 11-18 NPV and IRR** A store has 5 years remaining on its lease in a mall. Rent is \$2,000 per month, 60 payments remain, and the next payment is due in 1 month. The mall's owner

plans to sell the property in a year and wants rent at that time to be high so the property will appear more valuable. Therefore, the store has been offered a “great deal” (owner’s words) on a new 5-year lease. The new lease calls for no rent for 9 months, then payments of \$2,600 per month for the next 51 months. The lease cannot be broken, and the store’s WACC is 12 percent (or 1 percent per month).

- Should the new lease be accepted? (Hint: Be sure to use 1 percent per month.)
- If the storeowner decided to bargain with the mall’s owner over the new lease payment, what new lease payment would make the storeowner indifferent between the new and the old leases? (Hint: Find FV of the old lease’s original cost at $t = 9$, then treat this as the PV of a 51-period annuity whose payments represent the rent during months 10 to 60.)
- The storeowner is not sure of the 12 percent WACC—it could be higher or lower. At what *nominal* WACC would the storeowner be indifferent between the two leases? (Hint: Calculate the differences between the two payment streams, and then find its IRR.)

11-19 Multiple IRRs and MIRR A mining company is deciding whether to open a strip mine, which costs \$2 million. Net cash inflows of \$13 million would occur at the end of Year 1. The land must be returned to its natural state at a cost of \$12 million, payable at the end of Year 2.

- Plot the project’s NPV profile.
- Should the project be accepted if $WACC = 10\%$? If $WACC = 20\%$? Explain your reasoning.
- Can you think of some other capital budgeting situations in which negative cash flows during or at the end of the project’s life might lead to multiple IRRs?
- What is the project’s MIRR at $WACC = 10\%$? At $WACC = 20\%$? Does MIRR lead to the same accept/reject decision for this project as the NPV method? Does the MIRR method *always* lead to the same accept/reject decision as NPV? (Hint: Consider mutually exclusive projects that differ in size.)

11-20 NPV A project has annual cash flows of \$7,500 for the next 10 years and then \$10,000 each year for the following 10 years. The IRR of this 20-year project is 10.98 percent. If the firm’s WACC is 9 percent, what is the project’s NPV?

11-21 MIRR Project X costs \$1,000, and its cash flows are the same in Years 1 through 10. Its IRR is 12 percent, and its WACC is 10 percent. What is the project’s MIRR?

11-22 MIRR A project has the following cash flows:



This project requires two outflows at Years 0 and 2, but the remaining cash flows are positive. Its WACC is 10 percent, and its MIRR is 14.14 percent. What is the Year 2 cash outflow?

COMPREHENSIVE/SPREADSHEET PROBLEM

11-23 Capital budgeting criteria Your division is considering two projects. Its WACC is 10 percent, and the projects’ after-tax cash flows (in millions of dollars) would be:

	0	1	2	3	4
Project A	-\$30	\$5	\$10	\$15	\$20
Project B	-\$30	\$20	\$10	\$8	\$6

- Calculate the projects' NPVs, IRRs, MIRRs, regular paybacks, and discounted paybacks.
- If the two projects are independent, which project(s) should be chosen?
- If the two projects are mutually exclusive and the WACC is 10 percent, which project should be chosen?
- Plot NPV profiles for the two projects. Identify the projects' IRRs on the graph.
- If the WACC were 5 percent, would this change your recommendation if the projects were mutually exclusive? If the WACC were 15 percent, would this change your recommendation? Explain your answers.
- The "crossover rate" is 13.5252 percent. Explain in words what this rate is and how it affects the choice between mutually exclusive projects.
- Is it possible for conflicts to exist between the NPV and the IRR when *independent* projects are being evaluated? Explain your answer.
- Now, just look at the regular and discounted paybacks. Which project looks better when judged by the paybacks?
- If the payback were the only method a firm used to accept or reject projects, what payback should it choose as the cutoff point, that is, reject projects if their payouts are not below the chosen cutoff? Is your selected cutoff based on some economic criteria or is it more or less arbitrary? Are the cutoff criteria equally arbitrary when firms use the NPV and/or the IRR as the criteria?
- Define the MIRR. What's the difference between the IRR and the MIRR, and which generally gives a better idea of the rate of return on the investment in a project?
- Why do most academics and financial executives regard the NPV as being the single best criterion, and better than the IRR? Why do companies still calculate IRRs?

Integrated Case

Allied Components Company

11-24 Basics of capital budgeting You recently went to work for Allied Components Company, a supplier of auto repair parts used in the after-market with products from DaimlerChrysler, Ford, and other auto makers. Your boss, the chief financial officer (CFO), has just handed you the estimated cash flows for two proposed projects. Project L involves adding a new item to the firm's ignition system line; it would take some time to build up the market for this product, so the cash inflows would increase over time. Project S involves an add-on to an existing line, and its cash flows would decrease over time. Both projects have 3-year lives, because Allied is planning to introduce entirely new models after 3 years.

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

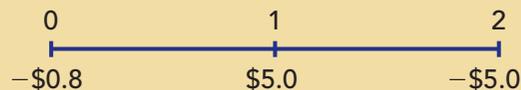
	0	1	2	3
Project L	−\$100	\$10	\$60	\$80
Project S	−\$100	\$70	\$50	\$20

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

The CFO also made subjective risk assessments of each project, and he concluded that both projects have risk characteristics that are similar to the firm's average project. Allied's WACC is 10 percent. You must now determine whether one or both of the projects should be accepted.

- What is capital budgeting? Are there any similarities between a firm's capital budgeting decisions and an individual's investment decisions?
- What is the difference between independent and mutually exclusive projects? Between projects with normal and nonnormal cash flows?

- c. (1) Define the term *net present value (NPV)*. What is each project's NPV?
 (2) What is the rationale behind the NPV method? According to NPV, which project or projects should be accepted if they are independent? Mutually exclusive?
 (3) Would the NPVs change if the WACC changed?
- d. (1) Define the term *internal rate of return (IRR)*. What is each project'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 projects should be accepted if they are independent? Mutually exclusive?
 (4) Would the projects' IRRs change if the WACC changed?
- e. (1) Draw NPV profiles for Projects 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 project or projects should be accepted if they are independent? Mutually exclusive? Explain. Are your answers correct at any WACC less than 23.6 percent?
- 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 Projects L and S.
 (2) What are the MIRR's advantages and disadvantages vis-à-vis the NPV?
- h. (1) What is the payback period? Find the paybacks for Projects L and S.
 (2) What is the rationale for the payback method? According to the payback criterion, which project or projects should be accepted if the firm's maximum acceptable payback is 2 years, and if Projects L and S are independent? If they are mutually exclusive?
 (3) What is the difference between the regular and discounted payback methods?
 (4) What are the two main disadvantages of discounted payback? Is the payback method of any real usefulness in capital budgeting decisions?
- i. As a separate project (Project P), the firm is 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):



The project is estimated to be of average risk, so its WACC is 10 percent.

- (1) What is Project P's NPV? What is its IRR? Its MIRR?
 (2) Draw Project P's NPV profile. Does Project P have normal or nonnormal cash flows? Should this project be accepted? Explain.



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