

CHAPTER 10

The Basics of Capital Budgeting: Evaluating Cash Flows

*F*PL Group is a holding company that owns Florida Power & Light, electric generating plants across the country, the nation's largest fleet of wind turbines, and major solar power facilities. It takes up to 10 years to acquire property, obtain the necessary permits, design the plant, arrange the financing, and complete the construction of a large generating plant. Moreover, utilities like FPL are required by law to have electricity available when it is demanded—when people turn on the switch, the utility must have the energy its customers expect or suffer severe fines and other penalties. Thus, FPL must forecast power usage many years in advance and make plans for meeting that demand.

Making a 10-year forecast is always difficult, but the 2008–2009 recession increased this difficulty tremendously. The two most important sectors of Florida's economy are housing and tourism. In 2009 the state had a huge supply of unsold houses and was second only to California in foreclosures, which was driving home prices down and vacancies up. Also, the bad economy was hurting the tourism industry. No one could know when those two industries—and the retail businesses that depend on them—would start to improve. That means no one could accurately forecast electricity usage or, thus, the need for new generating capacity.

Before the economy started downhill, FPL had developed a detailed capital budget for 2009–2011. But as the economy began to decline, its managers had many long, hard meetings to consider modifications. On the one hand, FPL's managers wanted to keep construction on track—it's costly to start and stop large projects because large cancellation fees are imposed if contracts are canceled. Moreover, FPL wanted to move ahead with its wind and solar programs and thus provide more "green" energy. On the other hand, the capital markets were drying up, making it difficult and expensive to acquire the funds FPL needed to finance its capital budget. Even worse, if it charged ahead and completed plants for which there was no demand, then it was possible that interest, depreciation, and maintenance costs could literally drive the company to bankruptcy.

In the end, management compromised—they cut back on the projects that were easiest to defer but went ahead with those for which deferrals would be most costly. The 2009 capital budget was reduced from \$7.0 billion to \$5.3 billion. Of the \$1.7 billion reduction, \$1.3 billion was related to wind farms, solar, and other “green” projects. FPL’s actions, and similar ones by other utilities across the country, have had effects on the manufacturers of windmills, solar panels, and related products. Those firms have laid off workers, cut back R&D, and in some cases simply gone out of business.

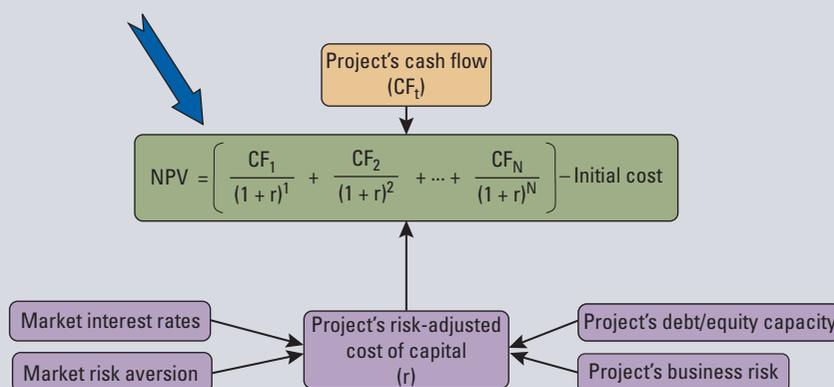
The FPL story is typical, and it illustrates that capital budgeting is critically important both to companies and to the economy. The principles set forth in this chapter will help you make the right choices regarding which projects to accept and which to reject.

Corporate Valuation and Capital Budgeting

You can calculate the cash flows (CF) for a project in much the same way as for a firm. When the project's cash flows are discounted at the appropriate risk-adjusted weighted average cost of capital ("r" for simplicity), the result is the project's value. Note that when valuing an entire firm we discount its free cash flows at the overall weighted average cost of capital, but when valuing a project we discount its cash flows at the project's own risk-adjusted cost of capital. Note also that the firm's free cash flows are the total of all the net cash flows from its past projects. Thus,

if a project is accepted and put into operation, it will provide cash flows that add to the firm's free cash flows and thus to the firm's value.

Subtracting the initial cost of the project from the discounted cash flows gives the project's net present value (NPV). A project that has a positive NPV adds value to the firm. In fact, the firm's Market Value Added (MVA) is the sum of all its projects' NPVs. The key point, though, is that the process of evaluating projects, or capital budgeting, is absolutely critical for a firm's success.



resource

The textbook's Web site contains an Excel file that will guide you through the chapter's calculations. The file for this chapter is **Ch10 Tool Kit.xls**, and we encourage you to open the file and follow along as you read the chapter.

In Chapter 10 and Chapter 11 we discuss *capital budgeting*. Here *capital* refers to long-term assets used in production, and a *budget* is a plan that outlines projected expenditures during a future period. Thus, *the capital budget* is a summary of planned investments of assets that will last for more than a year, and **capital budgeting** is the whole process of analyzing projects and deciding which ones to accept and thus include in the capital budget. Chapter 10 focuses on the basics of capital budgeting, especially the primary criteria used to evaluate projects, and it explains why one method—the net present value (NPV)—is the best single criterion. We use simplified examples in this chapter to explain the basic theory and then, in Chapter 11, we go on to discuss how cash flows are estimated, how risk is measured, and how capital budgeting decisions are actually made.

10.1 AN OVERVIEW OF CAPITAL BUDGETING

Capital budgeting is based on the same procedures that are used in security valuation, but with two major differences. First, stocks and bonds exist in the securities markets and investors choose from the available set. However, firms actually create capital budgeting projects, so capital budgeting involves project creation. Second, most investors have no influence over the cash flows produced by their investments, whereas corporations do have a major influence on their projects' results. If companies execute their plans well, then capital budgeting projects will be successful, but poor execution will lead to project failures. Still, in both security analysis and capital budgeting, we forecast

a set of cash flows, find the present value of those flows, and then make the investment if and only if the PV of the future expected cash flows 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 for new products, improvements in 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 division. 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 managers 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.

Analyzing capital expenditure proposals is not costless—benefits can be gained, but analysis does have a cost. For certain types of projects, an extremely detailed analysis may be warranted, whereas simpler procedures are adequate for other projects. Accordingly, firms generally categorize projects and analyze those in each category somewhat differently:

1. *Replacement needed to continue profitable operations.* An example would be an essential pump on a profitable offshore oil platform. The platform manager could make this investment without an elaborate review process.
2. *Replacement to reduce costs.* An example would be the replacement of serviceable but obsolete equipment in order to lower costs. A fairly detailed analysis would be needed, with more detail required for larger expenditures.
3. *Expansion of existing products or markets.* These decisions require a forecast of growth in demand, so a more detailed analysis is required. Go/no-go decisions are generally made at a higher level than are replacement decisions.
4. *Expansion into new products or markets.* These investments involve strategic decisions that could change the fundamental nature of the business. A detailed analysis is required, and the final decision is made by top officers, possibly with board approval.
5. *Contraction decisions.* Especially during bad recessions, companies often find themselves with more capacity than they are likely to need in the foreseeable future. Then, rather than continue to operate plants at, say, 50% of capacity and incur losses as a result of excessive fixed costs, they decide to downsize. That generally requires payments to laid off workers and additional costs for shutting down selected operations. These decisions are made at the board level.
6. *Safety and/or environmental projects.* Expenditures necessary to comply with environmental 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 and large ones requiring expenditures that might even cause the firm to abandon the line of business.

7. *Other*. This catch-all includes items such as office buildings, parking lots, and executive aircraft. How they are handled varies among companies.
8. *Mergers*. Buying a whole firm (or division) is different from buying a machine or building a new plant. Still, basic capital budgeting procedures are used when making merger decisions.

Relatively simple calculations, and only a few supporting documents, are required for most replacement decisions, especially maintenance investments in profitable plants. More detailed analyses are required as we move on to more complex expansion decisions, 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 simple payback 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.

If a firm has capable and imaginative executives and employees, and if its incentive system is working properly, then many ideas for capital investment will be forthcoming. Some ideas will be good and should be funded, but others should be killed. Therefore, the following procedures have been established for screening projects and deciding which to accept or reject:¹

1. Net Present Value (NPV)
2. Internal Rate of Return (IRR)
3. Modified Internal Rate of Return (MIRR)
4. Profitability Index (PI)
5. Regular Payback
6. Discounted Payback

As we shall see, the NPV is the best single criterion, primarily because it is directly related to the firm's central goal of maximizing the stock's intrinsic value. However, all of the methods provide some useful information, and all are used in practice.

Self-Test

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

What are some ways that firms generate ideas for capital projects?

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

List six procedures used for screening projects and deciding which to accept or reject.

10.2 NET PRESENT VALUE (NPV)

The **net present value (NPV)**, defined as the present value of a project's cash inflows minus the present value of its costs, tells us how much the project contributes to shareholder wealth—the larger the NPV, the more value the project adds and thus the higher the stock's price. NPV is generally regarded as the best single screening criterion. We use the data for Projects S and L shown in Figure 10-1 to illustrate the calculations for the NPV and the other criteria. 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 relatively soon; Project L has more total cash inflows, but most are realized in the later years.

¹One other rarely used criterion, the Accounting Rate of Return, is covered in the chapter's *Excel Tool Kit* model and *Web Extension 10A*.

FIGURE 10-1 Cash Flows (CF_t) and Selected Evaluation Criteria for Projects S and L

	A	B	C	D	E	F
23	Panel A: Project Cash Flows and Cost of Capital					
24						
25	Project cost of capital, r , for each project: 10%					
26						
27		Initial Cost	After-Tax, End of Year, Project Cash Flows, CF_t			
28		0	1	2	3	4
29	Project S	-\$10,000	\$5,000	\$4,000	\$3,000	\$1,000
30	Project L	-\$10,000	\$1,000	\$3,000	\$4,000	\$6,750
31						
32	Panel B: Summary of Selected Evaluation Criteria					
33						
34			Project S	Project L		
35		NPV	\$788.20	\$1,004.03		
36		IRR	14.49%	13.55%		
37		MIRR	12.11%	12.66%		
38		PI	1.08	1.10		
39		Payback	2.33	3.30		
40		Discounted Payback	2.95	3.78		



The projects are equally risky, and they both have a 10% cost of capital. Furthermore, the cash flows have been adjusted to incorporate the impact of depreciation, taxes, and salvage values.² The investment outlays are shown under Year 0, and they include investments in fixed assets and any necessary working capital. All subsequent cash flows occur at the end of the year. All of the calculations can be done easily with a financial calculator, but since capital budgeting in the real world is generally done using a spreadsheet, we show how problems would be set up in *Excel*.

We can find the NPVs as follows.

1. Calculate the present value of each cash flow discounted at the project's risk-adjusted cost of capital, which is $r = 10\%$ in our example.
2. The sum of the discounted cash flows is defined as the project's NPV.

The equation for the NPV, set up with input data for Project S, is

$$\begin{aligned}
 \text{NPV} &= CF_0 + \frac{CF_1}{(1+r)^1} + \frac{CF_2}{(1+r)^2} + \cdots + \frac{CF_N}{(1+r)^N} \\
 &= \sum_{t=0}^N \frac{CF_t}{(1+r)^t}
 \end{aligned}
 \tag{10-1}$$

²So that we can focus on the capital budgeting decision criteria, we provide the cash flows for each project in this chapter. However, the most difficult aspect of capital budgeting is estimating the “relevant” cash flows, which are defined as the cash flows generated by the project that are available for distribution to investors. In other words, they are the project's free cash flows. Cash flow estimation is simple conceptually but difficult in practice, so we defer its discussion to Chapter 11.

FIGURE 10-2 Finding the NPV for Projects S and L

	A	B	C	D	E	F	G
51	r = 10%						
52							
53	Year =	0 (r = 10%)	1	2	3	4	
54	Project S	-10,000.00	5,000	4,000	3,000	1,000	
55		4,545.45					
56		3,305.79					
57		2,253.94					
58		683.01					
59	NPV _S =	\$788.20	Long way: Sum the PVs of the CFs to find NPV				
60							
61	Year =	0 (r = 10%)	1	2	3	4	
62	Project L	-10,000.00	1,000	3,000	4,000	6,750	
63							
64	NPV _L =	\$1,004.03	Short way: use Excel's NPV function =NPV(B51,C62:F62)+B62				

Applying Equation 10-1 to Project S, we have

$$\begin{aligned}
 NPV_S &= -\$10,000 + \frac{\$5,000}{(1.10)^1} + \frac{\$4,000}{(1.10)^2} + \frac{\$3,000}{(1.10)^3} + \frac{\$1,000}{(1.10)^4} \\
 &= -\$10,000 + \$4,545.45 + \$3,305.79 + \$2,253.94 + \$683.01 \\
 &= \$788.20
 \end{aligned}$$

Here CF_t is the expected net cash flow at Time t , r is the project's risk-adjusted cost of capital (or WACC), and N is its life. Projects generally require an initial investment—for example, developing the product, buying the equipment needed to make it, building a factory, and stocking inventory. The initial investment is a negative cash flow. For Projects S and L, only CF_0 is negative, but for a large project such as an FPL power plant, outflows would occur for several years before cash inflows begin.

Figure 10-2 shows, on Row 59, the cash flow time line for project S as taken from Figure 10-1. The cost is $-\$10,000$, which is not discounted because it occurs at $t = 0$. The PV of each cash inflow, and the sum of the PVs, is shown in Column B. You could find the PVs of the cash flows with a calculator or with *Excel*, and the end result would be the numbers in Column B of the figure. When we sum the PVs of the inflows and subtract the cost, the result is $\$788.20$, which is NPV_S . The NPV for Project L, $\$1,004.03$, can be found similarly.

The step-by-step procedure shown for Project S is useful for illustrating how the NPV is calculated, but in practice (and on exams) it is far more efficient to use a financial calculator or *Excel*. Different calculators are set up somewhat differently, but (as we discussed in Chapter 4) they all have a “cash flow register” that can be used to evaluate uneven cash flows such as those for Projects S and L. Equation 10-1 is actually programmed into these calculators, and all we need to do is enter the cash flows (with the correct signs) along with $r = I/YR = 10$. Once the data have been entered, you can press the NPV key to get the answer, 788.20, on the screen.³

³The keystrokes for finding the NPV are shown for several calculators in the calculator tutorials we provide on the textbook's Web site.



If you are familiar with *Excel*, you can use it to find the NPVs for S and L:

$$\begin{aligned} \text{NPV}_S &= \$788.20 \\ \text{NPV}_L &= \$1,004.03 \end{aligned}$$

We provide the model used to obtain these values in the chapter's *Excel Tool Kit*. If you are familiar with *Excel* then you should look at the model, as this is how most people in the real world deal with capital budgeting problems.

Before using these NPVs in the decision process, we need to know whether Projects S and L are **independent** or **mutually exclusive**. Independent projects are those whose cash flows are not affected by other projects. If Wal-Mart were considering a new store in Boise and another in Atlanta, those projects would be independent, and if both had positive NPVs, Wal-Mart should accept both. Mutually exclusive projects, on the other hand, are two different ways of accomplishing the same result, so if one project is accepted then the other must be rejected. A conveyor-belt system to move goods in a warehouse and a fleet of forklifts for the same purpose would be mutually exclusive—accepting one implies rejecting the other.

What should the decision be if Projects S and L are independent? In this case, both should be accepted because both have positive NPVs and thus add value to the firm. However, if they are mutually exclusive, then Project L should be chosen because it has the higher NPV and thus adds more value than S. We can summarize these criteria with the following rules.

NPV Decision Rules

Independent projects: If NPV exceeds zero, accept the project. Since S and L both have positive NPVs, accept them both if they are independent.

Mutually exclusive projects: Accept the project with the highest positive NPV. If no project has a positive NPV, then reject them all. If S and L are mutually exclusive, the NPV criterion would select L.

Projects must be either independent or mutually exclusive, so one or the other of these rules applies to every project.⁴

Self-Test

Why is NPV the primary capital budgeting decision criterion?

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

Projects SS and LL have the following cash flows:

	End-of-Year Cash Flows			
	0	1	2	3
SS	-700	500	300	100
LL	-700	100	300	600

If the cost of capital is 10%, then what are the projects' NPVs?

(NPV_{SS} = \$77.61; NPV_{LL} = \$89.63)

What project or set of projects would be in your capital budget if SS and LL were

(a) independent or (b) mutually exclusive? **(Both; LL)**

⁴This is a simplification. For example, some projects can benefit others—these are “complementary” projects. Other projects harm others—these are called “cannibalizing” projects. These concepts are addressed in Chapter 11.

10.3 INTERNAL RATE OF RETURN (IRR)

In Chapter 5 we discussed the yield to maturity on a bond, and we explained that if you hold a bond to maturity then you will earn the yield to maturity on your investment. The YTM is found as the discount rate that forces the present value of the cash inflows to equal the price of the bond. This same concept is used in capital budgeting when we calculate a project's **internal rate of return**, or **IRR**:

A project's IRR is the discount rate that forces the PV of the inflows to equal the initial cost (or to equal the PVs of all the costs if costs are incurred over several years). This is equivalent to forcing the NPV to equal zero. The IRR is an estimate of the project's rate of return, and it is comparable to the YTM on a bond.

To calculate the IRR, we begin with Equation 10-1 for the NPV, replace r in the denominator with the term "IRR," and set the NPV equal to zero. This transforms Equation 10-1 into Equation 10-2, the one used to find the IRR. The rate that forces NPV to equal zero is the IRR.⁵

$$\begin{aligned} \text{NPV} &= \text{CF}_0 + \frac{\text{CF}_1}{(1 + \text{IRR})^1} + \frac{\text{CF}_2}{(1 + \text{IRR})^2} + \cdots + \frac{\text{CF}_N}{(1 + \text{IRR})^N} = 0 \\ &= \sum_{t=0}^N \frac{\text{CF}_t}{(1 + \text{IRR})^t} = 0 \end{aligned} \quad (10-2)$$



For Project S, we have

$$\text{NPV}_s = 0 = -\$10,000 + \frac{\$5,000}{(1 + \text{IRR})^1} + \frac{\$4,000}{(1 + \text{IRR})^2} + \frac{\$3,000}{(1 + \text{IRR})^3} + \frac{\$1,000}{(1 + \text{IRR})^4}$$

Figure 10-3 illustrates the process for finding the IRR of Project S.

FIGURE 10-3 Finding the IRR

	A	B	C	D	E	F
88	r = 14.49%					
89	Year =	0	1	2	3	4
90	Project S	-10,000.00	5,000	4,000	3,000	1,000
91		4,367.24				
92		3,051.64				
93		1,999.09				
94		582.03				
95	Sum of PVs =	\$0.00	= NPV at r = 14.489%. NPV = 0, so IRR = 14.489%.			
96						
97	IRR _s =	14.49%	= IRR(B90:F90) using IRR function			
98						
99	Year =	0	1	2	3	4
100	Project L	-10,000.00	1,000	3,000	4,000	6,750
101						
102	IRR _L =	13.55%	= IRR(B100:F100) using IRR function			

⁵For a large, complex project like an FPL power plant, costs are incurred for several years before cash inflows begin. That simply means that we have a number of negative cash flows before the positive cash flows begin.

Three procedures can be used to find the IRR:

1. *Trial-and-error.* We could use a trial-and-error procedure: try a discount rate, see if the equation solves to zero, and if it doesn't, try a different rate. We could then continue until we found the rate that forces the NPV to zero, and that rate would be the IRR. For Project S the IRR is 14.489%. Note, though, that the trial-and-error procedure is so time-consuming that—before computers and financial calculators were available—the IRR was almost never calculated. It's useful to think about the trial-and-error procedure, but it's far better to use either a calculator or *Excel* for the actual calculations.
2. *Calculator solution.* Enter the cash flows into the calculator's cash flow register just as we did to find the NPV, and then press the calculator key labeled "IRR." Instantly, you get the internal rate of return. Here are the values for Projects S and L:⁶

$$\text{IRR}_S = 14.489\%$$

$$\text{IRR}_L = 13.549\%$$

3. *Excel solution.* It is even easier to find IRRs using *Excel*, as we demonstrate in this chapter's *Tool Kit*.⁷

Why is the discount rate that causes a project's NPV to equal zero so special? The reason is that the IRR is an estimate of the project's rate of return. If this return exceeds the cost of the funds used to finance the project, then the difference is a bonus that goes to the firm's stockholders and causes the stock's price to rise. Project S has an estimated return of 14.489% versus a 10% cost of capital, so its bonus is 4.489%. On the other hand, if the IRR is less than the cost of capital then stockholders must make up the shortfall, which would hurt the stock price.

Note again that the IRR formula, Equation 10-2, is simply the NPV formula, Equation 10-1, solved for the particular discount rate that forces the NPV to zero. Thus, the same basic equation is used for both methods. The only difference is that 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 we find the interest rate that provides this equality.

If the IRR criterion is used to rank projects, then the decision rules are as follows.

Independent projects: If IRR exceeds the project's WACC, then the project should be accepted. If IRR is less than the project's WACC, reject it. Projects S and L both have positive IRRs, so they would both be accepted by the IRR method. Note that both projects were also accepted by the NPV criterion, so the NPV and IRR criteria provide the same result if the projects are independent.

Mutually exclusive projects. Accept the mutually exclusive project with the highest IRR, provided that the project's IRR is greater than its WACC. Reject any

⁶See our calculator tutorials on the textbook's Web site. Note that once the cash flows have been entered into the cash flow register, you can 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 easy to find the IRR. This is one reason most firms 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. The same is true with *Excel*: after estimating cash flows, it is easy to calculate both NPV and IRR.

⁷Note that to calculate the IRR with *Excel* the full data range is specified, because *Excel*'s IRR function assumes that the first cash flow (the negative \$10,000) occurs at $t = 0$. You can use the function wizard if you don't have the formula memorized.

Why NPV Is Better Than IRR

Buffett University recently hosted a seminar on business methods for managers. A finance professor covered capital budgeting, explaining how to calculate the NPV, and stated that it should be used to screen potential projects. In the Q-and-A session, Ed Wilson, treasurer of an electronics firm, said his firm used the IRR primarily because the CFO and the directors understood about selecting projects based on their rates of return but didn't understand the NPV. Ed had tried to explain why the NPV was better, but it simply confused his bosses, so the company stuck with the IRR. Now a meeting on the firm's capital budget is coming up, and Ed asked the professor for a simple, easy-to-understand explanation of why the NPV is better.

The professor recommended the following extreme example. A firm with adequate access to capital and a 10% WACC is choosing between two equally risky, mutually exclusive projects. Project Large calls for investing \$100,000 and then receiving \$50,000 per year for 10 years, while Project Small calls for investing \$1 and then receiving \$0.60 per year for 10 years. Here are the two project's NPVs and IRRs:

Project Large

NPV_L : \$207,228.36

IRR_L : 49.1%

Project Small

NPV_S : \$2.69

IRR_S : 59.4%

The IRR says choose S, but the NPV says accept L. Intuitively, it's obvious that the firm would be better off choosing the large project in spite of its lower IRR. With a cost of capital of only 10%, a 49% rate of return on a \$100,000 investment is much more profitable than a 59% return on a \$1 investment.

When Ed gave this example in his firm's executive meeting on the capital budget, the CFO argued that this example was extreme and unrealistic, and no one would choose S in spite of its higher IRR. Ed agreed, but he asked the CFO where the line should be drawn between realistic and unrealistic examples. When he received no answer, he went on to say that (1) it's hard to draw this line, and (2) the NPV is always better because it tells us how much each project will add to the firm's value. The president was listening, and he declared Ed the winner. The company switched from IRR to NPV, and Ed is now the CFO.

project whose best IRR does not exceed the firm's WACC. Since Project S has the higher IRR, it should be accepted (and L rejected) if the projects are mutually exclusive. However, recall that Project L had the larger NPV, so the NPV method ranked L over S and thus would choose L. Therefore, a conflict will exist between the NPV and the IRR criteria if the projects are mutually exclusive.

The IRR is logically appealing—it is useful to know the rates of return on proposed investments. However, as we see from Projects L and S, NPV and IRR can produce conflicting conclusions when one is choosing between mutually exclusive projects, and when conflicts occur the NPV criterion is generally better.

Self-Test

In what sense is a project's IRR similar to the YTM on a bond?

The cash flows for Projects SS and LL are as follows:

	End-of-Year Cash Flows			
	0	1	2	3
SS	-700	500	300	100
LL	-700	100	300	600

Assume that the firm's WACC = r = 10%. What are the two projects' IRRs?

(IRR_{SS} = 18.0%; IRR_{LL} = 15.6%)

Which project would the IRR method select if the firm has a 10% cost of capital and the projects are (a) independent or (b) mutually exclusive? (**Both; SS**)

10.4 MULTIPLE INTERNAL RATES OF RETURN⁸

One problem with the IRR is that, under certain conditions, a project may have more than one IRR. First, note that a project is said to have *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 started, meaning that the signs of the cash flows change *more than once*, then the project is said to have *nonnormal* cash flows. Here's an illustration of these concepts:

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

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

An example of a project with nonnormal flows would be a strip coal mine where the company first spends money to buy the property and prepare the site for mining, has positive inflows for several years, and then spends more money to return the land to its original condition. In this case, the project might have two IRRs—that is, **multiple IRRs**.⁹

To illustrate multiple IRRs, suppose a firm is considering a potential strip mine (Project M) that has a cost of \$1.6 million, will produce a cash flow of \$10 million at the end of Year 1; 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):

	Year 0	End of Year 1	End of Year 2
Cash flows	-\$1.6	+\$10	-\$10

We can substitute these values into Equation 10-2 and then solve for the IRR:

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

Here the NPV equals 0 when $IRR = 25\%$, but it also equals 0 when $IRR = 400\%$.¹⁰ Therefore, Project M has one IRR of 25% and another of 400%, and we don't know which one to use. This relationship is depicted graphically in Figure 10-4.¹¹ The graph is constructed by plotting the project's NPV at different discount rates.

Observe that no dilemma regarding Project M would arise if the NPV method were used; we would simply find the NPV at the appropriate cost of capital and use it to evaluate the project. We would see that if Project M's cost of capital were 10% then its NPV would be $-\$0.774$ million and the project should be rejected. If r were between 25% and 400% then the NPV would be positive, but any such number

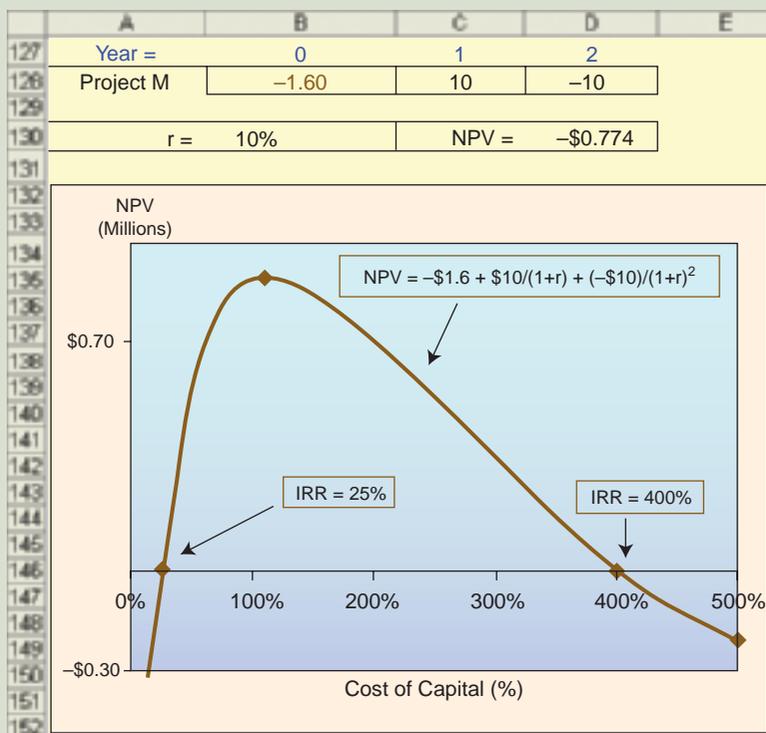
⁸This section is relatively technical, and some instructors may choose to omit it without loss of continuity.

⁹Equation 10-2 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, and hence of multiple IRRs, arises when negative net cash flows occur after the project has been placed in operation.

¹⁰If you attempt to find Project M's IRR with an HP calculator, you will get an error message, whereas 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 $r = I/YR$, constructing a graph with NPV on the vertical axis and cost of capital on the horizontal axis, and then visually determining approximately where $NPV = 0$. The intersection with the x-axis gives a rough idea of the IRRs' values. With some calculators and also with *Excel*, you can find both IRRs by entering guesses, as we explain in our calculator and *Excel* tutorials.

¹¹Figure 10-4 is called a *NPV profile*. Profiles are discussed in more detail in Section 10.7.



FIGURE 10-4 Graph for Multiple IRRs: Project M (Millions of Dollars)

Note: The data table shown below calculates Project M's NPV at the rates shown in the left column. These data are plotted to form the graph shown above. Notice that NPV = 0 at both 25% and 400%. Since the definition of the IRR is the rate at which the NPV = 0, we see that there are two IRRs.

r	NPV	
0%	-\$1.600	
10%	-\$0.774	
25%	\$0.000	= IRR #1 = 25%
110%	\$0.894	
400%	\$0.000	= IRR #2 = 400%
500%	-\$0.211	



would probably not be realistic or useful for anything. (At such a high cost of capital, the firm's typical projects would have negative NPVs.)

What condition regarding cash flows would cause more than one IRR to exist? Project MM has the following cash flows:

End-of-Year Cash Flows				
0	1	2	3	
-\$1,000	\$2,000	\$2,000	-\$3,350	

Calculate MM's NPV at discount rates of 0%, 10%, 12.2258%, 25%, 122.147%, and 150%. (**-\$350; -\$46; \$0; \$165; \$0; -\$94**) What are MM's IRRs? (**12.23% and 122.15%**) If the cost of capital were 10%, should the project be accepted or rejected? (**Reject because NPV < 0**)

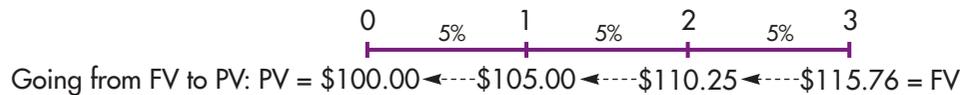
10.5 REINVESTMENT RATE ASSUMPTIONS¹²

The NPV calculation is based on the assumption that cash inflows can be reinvested at the project's risk-adjusted WACC, whereas the IRR calculation is based on the assumption that cash flows can be reinvested at the IRR itself. To see why this is so, think about the following diagram, first used in Chapter 4 to illustrate the future value of \$100 when the interest rate is 5%:



Observe that the FV calculation assumes that the interest earned during each year can itself be reinvested to earn the same 5% in each succeeding year.

Now recall that to find the PV we reversed the process, discounting rather than compounding at the 5% rate. The following diagram can be used to demonstrate this point:



We are thus led to the following conclusion: *When we calculate a present value, we are implicitly assuming that cash flows can be reinvested at a specified interest rate (5% in our example). This applies to Projects S and L: When we calculated their NPVs, we discounted at their WACC of 10%, which means that we assumed that their cash flows could be reinvested at 10%.*

Now consider the IRR. In Section 10.3 we presented a cash flow diagram set up to show the PVs of the cash flows when discounted at the IRR. We saw that the sum of the PVs is equal to the cost at a discount rate of 14.489%, so by definition 14.489% is the IRR. Now we can ask this question: What reinvestment rate is built into the IRR?

Because discounting at a given rate assumes that cash flows can be reinvested at that same rate, the IRR assumes that cash flows are reinvested at the IRR itself.

So the NPV assumes reinvestment at the WACC whereas the IRR assumes reinvestment at the IRR itself. Which assumption is more reasonable? For most firms, assuming reinvestment at the WACC is better, for the following reasons.

- If a firm has reasonably good access to the capital markets then it can raise all the capital it needs at the going rate, which in our example is 10%.
- Since the firm can obtain capital at 10%, if it has investment opportunities with positive NPVs then it should take them on, and it can finance them at a 10% cost.
- If we assume that the firm operates in a reasonably competitive industry, then its return on investment opportunities should be relatively close to its cost of capital; if it were much higher, then new firms would enter the market and drive prices (and thus returns) down to near the cost of capital.
- If the firm uses internally generated cash flows from past projects rather than external capital, this will simply save it the 10% cost of capital. Thus, 10% is the *opportunity cost* of the cash flows, and that is the effective return on reinvested funds.

¹²This section gives a theoretical explanation of the key difference between NPV and IRR. However, it is relatively technical, so if time is a constraint then professors may decide to have students skip it and just read the box "Why NPV Is Better Than IRR."

As an illustration, suppose a project's IRR is 50%, the firm's WACC is 10%, and it has good access to the capital markets and operates in a competitive industry. Thus, the firm can raise all the capital it needs at the 10% rate. Given the existence of competition, the 50% return would attract new entry, which would make it hard to find new projects with a similar high return, which is what the IRR assumes. Moreover, even if the firm does find such projects, it would take them on with external capital that costs 10%. The logical conclusion is that the original project's cash flows will simply save the 10% cost of the external capital and that 10%, not 50%, is the effective return on those flows.

If a firm does not have good access to external capital, and if it also has a lot of potential projects with high IRRs, then it might be reasonable to assume that a project's cash flows could be reinvested at rates close to their IRRs. However, that situation rarely occurs, since firms with good investment opportunities generally *do* have good access to debt and equity markets.

Our conclusion is that the assumption built into the IRR—that cash flows can be reinvested at the IRR, no matter how high it is—is flawed, whereas the assumption built into the NPV—that cash flows can be reinvested at the WACC—is generally correct. Moreover, if the true reinvestment rate is less than the IRR, then the true rate of return on the investment must be less than the calculated IRR; thus the IRR is misleading as a measure of a project's profitability. This point is discussed further in the next section.

Self-Test

Why is a reinvestment rate implicitly assumed whenever we find the present value of a future cash flow? Would it be possible to find the PV of a FV without specifying an implicit reinvestment rate?

What reinvestment rate is built into the NPV calculation? The IRR calculation?

For a firm that has adequate access to capital markets, is it more reasonable to assume reinvestment at the WACC or the IRR? Why?

10.6 MODIFIED INTERNAL RATE OF RETURN (MIRR)¹³

It is logical for managers to want to know the expected rate of return on investments, and this is what the IRR is supposed to tell us. However, the IRR is based on the assumption that projects' cash flows can be reinvested at the IRR itself, and this assumption is usually wrong: *The IRR overstates the expected return for accepted projects because cash flows cannot generally be reinvested at the IRR itself.* Therefore, the IRR for accepted projects is generally greater than the true expected rate of return. This imparts an upward bias on corporate projections based on IRRs. Given this fundamental flaw, is there a percentage evaluator that is better than the regular IRR? The answer is “yes”: *We can modify the IRR to make it a better measure of profitability.*

This new measure, the **Modified IRR (MIRR)**, is illustrated for Project S in Figure 10-5. It is similar to the regular IRR, except it is based on the assumption that cash flows are reinvested at the WACC (or some other explicit rate if that is a more reasonable assumption). Refer to Figure 10-5 as you read about the construction of this measure.

¹³This section is relatively technical, and some instructors may choose to omit it without loss of continuity.

FIGURE 10-5 Finding the MIRR for Projects S and L

	A	B	C	D	E	F	G	
206		r = 10%						
207								
208	Year =	0 (r=10%)	1	2	3	4		
209	Project S	-10,000	5,000	4,000	3,000	1,000		
210						\$3,300		
211						\$4,840		
212						\$6,655		
213		-10,000			Terminal Value (TV) =	\$15,795		
214								
215	Calculator:	N = 4, PV = -10000, PMT = 0, FV = 15795. Press I/YR to get:					MIRR _S =	12.11%
216	Excel Rate function--Easier:	= RATE(F208,0,B209,F213)					MIRR _S =	12.11%
217	Excel MIRR function--Easiest:	= MIRR(B209:F209,B206,B206)					MIRR _S =	12.11%
218								
219	Year =	0 (r = 10%)	1	2	3	4		
220	Project L	-10,000	1,000	3,000	4,000	6,750		
221								
222	For Project L, using the MIRR function:	=MIRR(B220:F220,B206,B206)=					MIRR _L =	12.66%

Notes:

- In this figure we find the rate that forces the present value of the terminal value to equal the project's cost. That rate is defined as the MIRR. We have $\$10,000 = TV/(1 + \text{MIRR})^N = \$15,795/(1 + \text{MIRR})^4$. We can find the MIRR with a calculator or *Excel*.
- If S and L are independent, then both should be accepted because both MIRRs exceed the cost of capital. If the projects are mutually exclusive, then L should be chosen because it has the higher MIRR.



- Project S has just one outflow, a negative \$10,000 at $t = 0$. Since it occurs at Time 0, it is not discounted, and its PV is $-\$10,000$. If the project had additional outflows, we would find the PV at $t = 0$ for each one and then sum them for use in the MIRR calculation.
- Next, we find the future value of each *inflow*, compounded at the WACC out to the “terminal year,” which is the year the last inflow is received. We assume that cash flows are reinvested at the WACC. For Project S, the first cash flow, \$5,000, is compounded at WACC = 10% for 3 years, and it grows to \$6,655.00. The second inflow, \$4,000, grows to \$4,840.00, and the third inflow, \$3,000, grows to \$3,300.00. The last inflow, \$1,000, is received at the end, so it is not compounded at all. The sum of the future values, \$15,795.00, is called the “terminal value,” or TV.
- We now have the cost at $t = 0$, $-\$10,000$, and the TV at Year 4, \$15,795.00. There is some discount rate that will cause the PV of the terminal value to equal the cost. *That interest rate is defined as the Modified Internal Rate of Return (MIRR)*. In a calculator, enter $N = 4$, $PV = -10000$, $PMT = 0$, and $FV = 15795.00$. Then pressing the I/YR key yields the MIRR, 12.11%.
- The MIRR can be found in a number of ways. Figure 10-5 illustrates exactly how the MIRR is calculated: We compound each cash inflow, sum them to determine the TV, and then find the rate that causes the PV of the TV to equal the cost. That rate in this example is 12.11%. However, *Excel* and some of the better calculators have a built-in MIRR function that streamlines the process. We explain how to use the

MIRR function in our calculator tutorials, and we explain how to find MIRR with *Excel* in this chapter's *Excel* model.¹⁴

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 (or some other explicit rate). Since reinvestment at the IRR is generally not correct, the MIRR is usually a better indicator of a project's true profitability. Second, the MIRR eliminates 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.

Our conclusion is that the MIRR is better than the regular IRR; however, this question remains: Is MIRR as good as the NPV? Here is our take on the situation.

- For *independent* projects, the NPV, IRR, and MIRR always reach the same accept–reject conclusion, so the three criteria are equally good when evaluating independent projects.
- However, if projects are *mutually exclusive* and if they differ in size, conflicts can arise. In such cases the NPV is best because it selects the project that maximizes value.¹⁵
- Our overall conclusions are that (1) the MIRR is superior to the regular IRR as an indicator of a project's “true” rate of return, but (2) NPV is better than either IRR or MIRR when choosing among competing projects. If managers want to know the expected rates of return on projects, it would be better to give them MIRRs rather than IRRs because MIRRs are more likely to be the rates that are actually earned.

Self-Test

What's the primary difference between the MIRR and the regular IRR?

Which provides a better estimate of a project's “true” rate of return, the MIRR or the regular IRR? Explain your answer.

Projects A and B have the following cash flows:

	0	1	2
A	-\$1,000	\$1,150	\$ 100
B	-\$1,000	\$ 100	\$1,300

The cost of capital is 10%. What are the projects' IRRs, MIRRs, and NPVs? (**IRR_A = 23.1%**, **IRR_B = 19.1%**; **MIRR_A = 16.8%**, **MIRR_B = 18.7%**; **NPV_A = \$128.10**, **NPV_B = \$165.29**) Which project would each method select? (**IRR: A; MIRR: B; NPV: B**)

¹⁴If we let COF_t and CIF_t denote cash outflows and inflows, respectively, then Equations 10-2a and 10-2b summarize the steps just described:

$$\sum_{t=0}^N \frac{COF_t}{(1+r)^t} = \frac{\sum_{t=0}^N CIF_t(1+r)^{N-t}}{(1+MIRR)^N} \quad (10-2a)$$

$$PV \text{ costs} = \frac{TV}{(1+MIRR)^N} \quad (10-2b)$$

Also, note that there are alternative definitions for the MIRR. One difference relates 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 more discussion, see David M. Shull, “Interpreting Rates of Return: A Modified Rate of Return Approach,” *Financial Practice and Education*, Fall 1993, pp. 67–71.

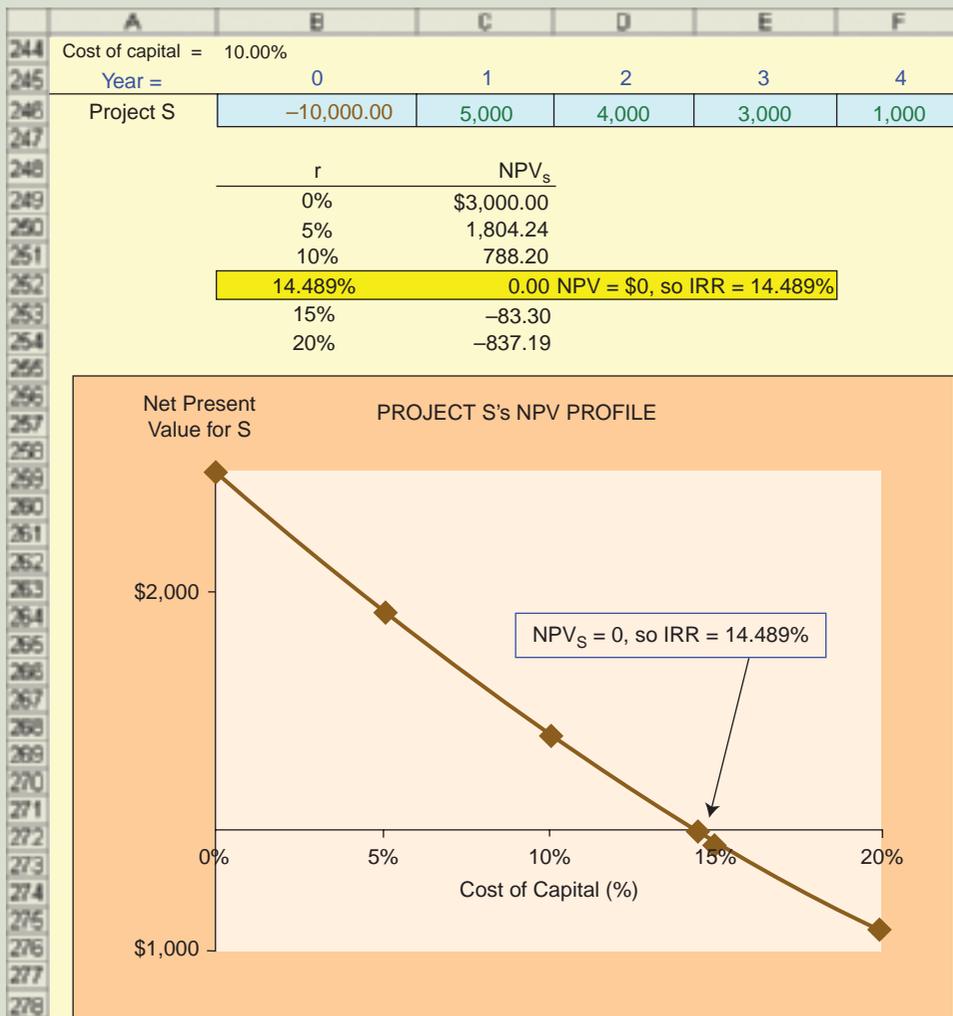
¹⁵For projects of equal size but different lives, the MIRR will always lead to the same decision as the NPV if the MIRRs are both calculated using as the terminal year the life of the longer project. (Just fill in zeros for the shorter project's missing cash flows.)

10.7 NPV PROFILES

Figure 10-6 shows the **net present value profile** for Project S. To make the profile, we find the project's NPV at a number of different discount rates and then plot those values to create a graph. Note that, at a zero cost of capital, the NPV is simply the net total of the undiscounted cash flows: $\$13,000 - \$10,000 = \$3,000$. 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, so the discount rate at which the profile line crosses the horizontal axis is the project's IRR. When we connect all the data points, we have the NPV profile.¹⁶

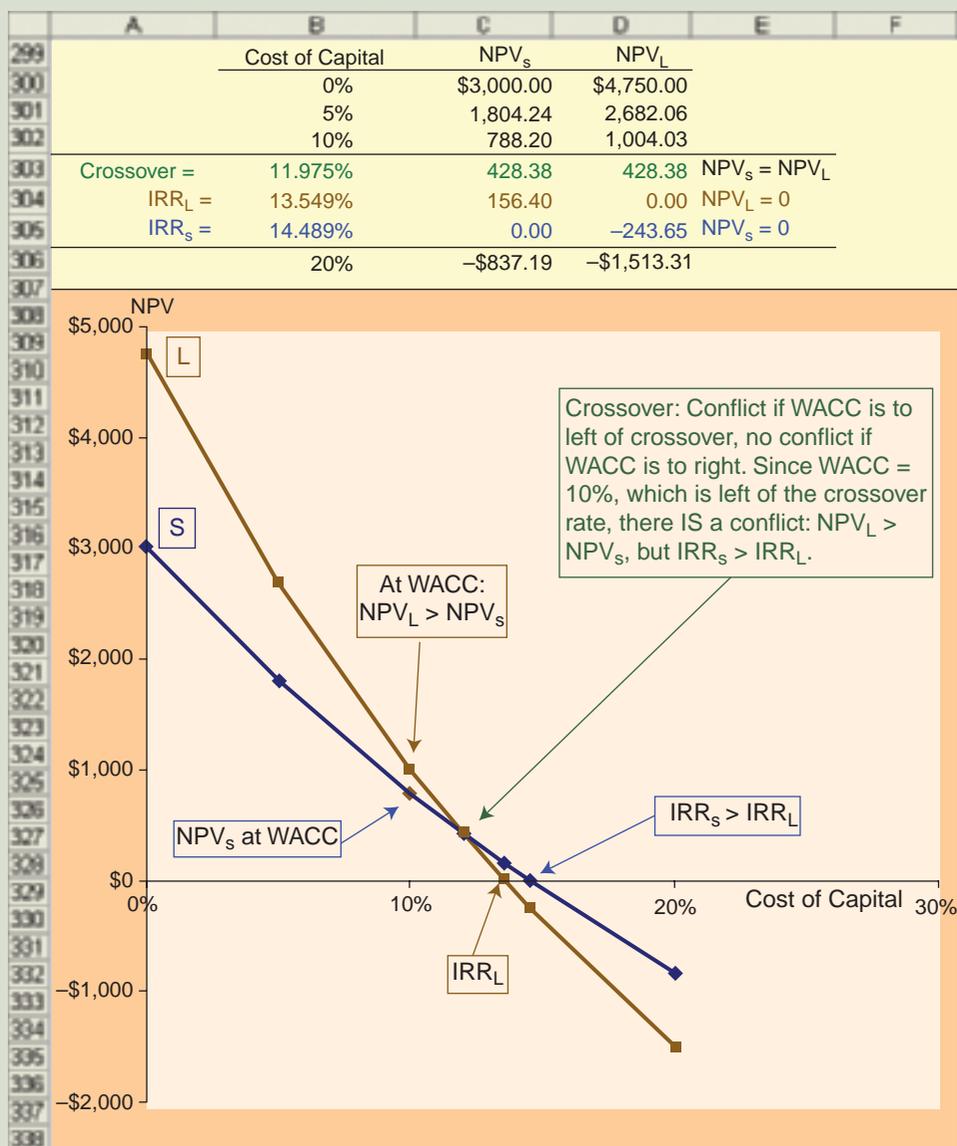


FIGURE 10-6 NPV Profile for Project S



¹⁶The NPV profile is curved—it is *not* a straight line. NPV approaches CF_0 , which is the $-\$10,000$ project cost, as the discount rate increases toward infinity. The reason is that, at an infinitely high cost of capital, the PVs of the inflows would all be zero, so NPV at $r = \infty$ must be CF_0 . We should also remark that under certain conditions the NPV profiles can cross the horizontal axis several times, or never cross it. This point was discussed in Section 10.4.

FIGURE 10-7 NPV Profiles for Projects S and L: Why Conflict Occurs



Now consider Figure 10-7, which shows two NPV profiles: the one for Project S, as developed in Figure 10-6, and a new one for L. Note the following points.

- The NPVs vary depending on the actual cost of capital—the higher the cost of capital, the lower the NPV. Observe also that L's NPV declines faster than does S's with increases in the cost of capital.
- However, the IRRs are fixed, and S has the higher IRR regardless of the cost of capital.
- The two NPV profile lines cross at a cost of capital of 11.975%, which is called the **crossover rate**. The crossover rate can be found by calculating the IRR of the differences in the projects' cash flows, as demonstrated below:

	0	1	2	3	4
Project S	-\$10,000	\$5,000	\$4,000	\$3,000	\$1,000
Project L	-10,000	1,000	3,000	4,000	6,750
$\Delta = CF_S - CF_L$	\$ 0	\$4,000	\$1,000	-\$1,000	-\$5,750

$$\text{IRR } \Delta = 11.975\%$$

- Project L has the higher NPV if the cost of capital is less than the crossover rate, but S has the higher NPV if the cost of capital is greater than that rate.

Notice that Project L has the steeper slope, indicating that a given increase in the cost of capital causes a larger decline in NPV_L than in NPV_S . To see why this is so, recall the equation for the NPV:

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

Now recognize (1) that L's cash flows come in later than those of S, with L's highest cash flows coming where N is large, and (2) that the impact of an increase in the discount rate is much greater on distant than on near-term cash flows. We demonstrate the second point below.

Effect of doubling r on a Year-1 cash flow

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

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

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

Effect of doubling r on a Year-20 cash flow

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

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

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

Thus, a doubling of the discount rate results in only a 4.5% decline in the PV of a Year-1 cash flow, but the same increase in discount rate causes the PV of a Year-20 cash flow to fall by more than 60%. Therefore, *a project like L, which has most of its cash flows coming in the later years, will suffer a sharp decline in its NPV if the cost of capital increases; but a project like S, whose cash flows come earlier, will not be severely penalized.* This is why Project L's NPV profile has the steeper slope.

As we have seen, Projects S and L have conflicting rankings when ranked by the NPV versus the IRR. Figure 10-7 can be used to see the conditions under which such conflicts can and cannot arise.

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 then IRR also says accept, and vice versa.* To see why this is so, look back at

Figure 10-6 and notice (1) that the IRR says accept Project S if the 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 must be positive. Thus, at any cost of capital less than 14.489%, Project S will be recommended by both the NPV and IRR criteria, but both methods reject the project if the cost of capital is greater than 14.489%. A similar graph could be created for Project L or any other normal project, and we would always reach the same conclusion: *For normal, independent projects, if the IRR says to accept it, then so will the NPV.*

Mutually Exclusive Projects. Now assume that Projects S and L are mutually exclusive rather than independent. Therefore, we can choose either S or L, or we can reject both, but we can't accept both. Now look at Figure 10-7 and note these points.

- As long as the cost of capital is *greater than* the crossover rate of 11.975%, both methods agree that Project S is better: $NPV_S > NPV_L$ and $IRR_S > IRR_L$. Therefore, if r is *greater* than the crossover rate, no conflict occurs.
- However, if the cost of capital is *less than* the crossover rate, a conflict arises: NPV ranks L higher, but IRR ranks S higher.

There are two basic conditions that cause NPV profiles to cross and thus lead to conflicts.¹⁷

1. *Timing differences.* If most of the cash flows from one project come in early while most of those from the other project come in later, then the NPV profiles may cross and result in a conflict. This is the reason for the conflict between our Projects S and L.
2. *Project size (or scale) differences.* If the amount invested in one project is larger than the other, this can also lead to profiles crossing and a resulting conflict. If you look back at the box titled “Why NPV is Better than IRR,” you will see an example of the size difference conflict.

When either size or timing differences occur, the firm will have different amounts of funds to invest in other projects in the various years, depending on which of the two mutually exclusive projects it chooses. If it chooses S, then it will have more funds to invest in Year 1 because S has a larger inflow that year. Similarly, if one project costs more than the other, then the firm will have more money to invest at $t = 0$ 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. We saw earlier that the NPV assumes reinvestment at the cost of capital, and that this is generally a more reasonable assumption. Therefore, whenever conflicts exist between mutually exclusive projects, use the NPV method.

Self-Test

Describe in words how an NPV profile is constructed. How does one determine the intercepts for the x-axis and the y-axis?

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?

¹⁷Also, if mutually exclusive projects have different lives (as opposed to different cash flow patterns over a common life), this introduces further complications; thus, for meaningful comparisons, some mutually exclusive projects must be evaluated over a common life. This point is discussed later in the chapter.

10.8 PROFITABILITY INDEX (PI)

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

$$PI = \frac{\text{PV of future cash flows}}{\text{Initial cost}} = \frac{\sum_{t=1}^N \frac{CF_t}{(1+r)^t}}{CF_0} \quad (10-3)$$

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. As we can see from Figure 10-8, the PI for Project S, based on a 10% cost of capital, is $\$10,788.20/\$10,000 = 1.0788$; the PI for Project L is 1.1004. Thus, Project S is expected to produce \$1.0788 of present value for each \$1 of investment whereas L should produce \$1.1004 for each dollar invested.

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 L would be ranked ahead of S if they were mutually exclusive.

Mathematically, the NPV, IRR, MIRR, and PI methods will always lead to the same accept/reject decisions for *normal, 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 if the projects differ in size or in the timing of cash flows. If the PI ranking conflicts with the NPV, then the NPV ranking should be used.



Explain how the PI is calculated. What does it measure?

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 is the PI? (1.32)

FIGURE 10-8 Profitability Index (PI)

	A	B	C	D	E
351	Project S :		$PI_S = \text{PV of future cash flows}$	÷	Initial cost
352			$PI_S = \$10,788.20$	÷	\$10,000
353			$PI_S = 1.0788$		
354					
355	Project L :		$PI_L = \text{PV of future cash flows}$	÷	Initial cost
356			$PI_L = \$11,004.03$	÷	\$10,000
357			$PI_L = 1.1004$		

Notes:

1. If Projects L and S are independent, then both should be accepted because both have PI greater than 1.0. However, if they are mutually exclusive then Project L should be chosen because it has the higher PI.
2. PI and NPV rankings will be consistent if the projects have the same cost, as is true for S and L. However, if they differ in size then conflicts can occur. In the event of a conflict, the NPV ranking should be used.

10.9 PAYBACK PERIOD

NPV and IRR are the most commonly used methods today, but historically the first selection criterion was the **payback period**, defined as the number of years required to recover the funds invested in a project from its operating cash flows. Equation 10-4 is used for the calculation, and the process is diagrammed in Figure 10-9. We start with the project's cost, a negative number, and 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 the prior year divided by the cash flow during the year when full recovery occurs:¹⁸

$$\text{Payback} = \text{Number of years prior to full recovery} + \frac{\text{Unrecovered cost at start of year}}{\text{Cash flow during full recovery year}} \quad (10-4)$$

The cash flows for Projects S and L, together with their paybacks, are shown in Figure 10-9.¹⁹ The shorter the payback, the better the project. Therefore, if the firm requires a payback of 3 years or less, then 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 regular payback has three flaws: (1) Dollars received in different years are all given the same weight—that is, the time value of money is ignored. (2) Cash flows beyond the payback year are given no consideration whatsoever, regardless of how large they might be. (3) Unlike the NPV or the IRR, which tell us how much wealth a project adds or how much a project's rate of return exceeds the cost of capital, the payback



FIGURE 10-9 Payback Period

	A	B	C	D	E	F	G
386		Years =	0	1	2	3	4
387	Project S	Cash flow	-10,000	5,000	4,000	3,000	1,000
388		Cumulative cash flow	-10,000	-5,000	-1,000	2,000	3,000
389		Intermediate calculation for payback	-	-	-	2.33	5.00
390						↑	
391						Intermediate calculation:	
392		Manual calculation fo Payback S = 2 + \$1,000/\$3,000 =	2.33			=IF(F388>0,E386+ABS(E388/F387),"-")	
393		Excel calculation of Payback S =	2.33			2.33	
394							
395		Years	0	1	2	3	4
396	Project L	Cash flow	-10,000	1,000	3,000	4,000	6,750
397		Cumulative cash flow	-10,000	-9,000	-6,000	-2,000	4,750
398							
399		Manual calculation of Payback L = 3 + \$2,000/\$6,750 =	3.30				
400		Alternative Excel calculation of Payback L =					
401		= PERCENTRANK(C397:G397,0,6)*G395 =	3.30				
402							Payback is between negative and positive cumulative cash flow.

¹⁸Equation 10-4 assumes that cash flows come in uniformly during the full recovery year.

¹⁹There is not an Excel function for payback. But if the cash flows are normal then the PERCENTRANK function can be used to find payback, as illustrated in Figures 10-9 and 10-10.

FIGURE 10-10 Discounted Payback

	A	B	C	D	E	F	G
414	WACC = 10%						
415		Years =	0	1	2	3	4
416	Project S	Cash flow	-10,000.00	5,000.00	4,000.00	3,000.00	1,000.00
417		Discounted Cash flow	-10,000.00	4,545.45	3,305.79	2,253.94	683.01
418		Cumulative discounted CF	-10,000.00	-5,454.55	-2,148.76	105.18	788.20
419							
420		Discounted Payback S = 2 + \$2,148.76/\$2,253.94 =		2.95			
421		Excel calculation of Discounted Payback S =					
422		= PERCENTRANK(C418:G418,0,6)*G415 =		2.95			
423							
424		Years	0	1	2	3	4
425	Project L	Cash flow	-10,000.00	1,000.00	3,000.00	4,000.00	6,750.00
426		Discounted Cash flow	-10,000.00	909.09	2,479.34	3,005.26	4,610.34
427		Cumulative discounted CF	-10,000.00	-9,090.91	-6,611.57	-3,606.31	1,004.03
428							
429		Discounted Payback L = 3 + \$3,606.31/\$4,610.34 =					
430		Excel calculation of Discounted Payback L =					
431		= PERCENTRANK(C427:G427,0,6)*G424 =					
432							



merely tells us how long it takes to recover our investment. There is no necessary relationship between a given payback period and investor wealth, so we don't know how to specify an acceptable payback. The firm might use 2 years, 3 years, or any other number as the minimum acceptable payback, but the choice is purely arbitrary.

To counter the first criticism, financial analysts developed the **discounted payback**, where cash flows are discounted at the WACC and then those discounted cash flows are used to find the payback. In Figure 10-10 we calculate the discounted paybacks for S and L, assuming both have a 10% cost of capital. Each 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 then those PVs are used to find the payback. Project S's discounted payback is 2.95 years and L's is 3.78 years.

Note that the payback is a "break-even" calculation in the sense that if cash flows come in at the expected rate, then the project will at least break even. However, since the regular payback doesn't consider the cost of capital, it doesn't specify the true break-even year. The discounted payback does consider capital costs, but it still disregards cash flows beyond the payback year, which is a serious flaw. Further, if mutually exclusive projects vary in size, both payback methods can conflict with the NPV, and that might lead to poor decisions. Finally, there is no way to determine how short the payback periods must be to justify accepting a project.

Although the payback methods have faults as ranking criteria, they do provide information about *liquidity* and *risk*. 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 period is also a risk indicator.

Self-Test

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

What three flaws does the regular payback method have? Does the discounted payback method correct all of those flaws? Explain.

Project P has a cost of \$1,000 and cash flows of \$300 per year for 3 years plus another \$1,000 in Year 4. The project's cost of capital is 15%. What are P's regular and discounted paybacks? (3.10, 3.55) If the company requires a payback of 3 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%)

10.10 CONCLUSIONS ON CAPITAL BUDGETING METHODS

We have discussed six capital budgeting decision criteria: NPV, IRR, MIRR, PI, 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, the NPV. However, virtually all capital budgeting decisions are analyzed by computer, so it is easy to calculate using all six methods. In making the accept–reject decision, large sophisticated firms such as FPL, GE, and Boeing generally calculate and consider all six measures, because each provides a somewhat different piece of information about the decision.

NPV is the single best criterion because it provides a direct measure of the value a project adds to shareholder wealth. IRR and MIRR measure profitability expressed as a percentage rate of return, which decision makers like to consider. The PI also measures profitability but in relation to the amount of the investment. Further, IRR, MIRR, and PI all contain information concerning a project's “safety margin.” To illustrate, consider a firm, whose WACC is 10%, that must choose between these two mutually exclusive projects: SS (for small) has a cost of \$10,000 and is expected to return \$16,500 at the end of one year; LL (for large) has a cost of \$100,000 and is expected to return \$115,550 at the end of one year. SS has a huge IRR, 65%, while LL's IRR is a more modest 15.6%. The NPV paints a somewhat different picture: at the 10% 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 indicates that it has a much larger margin for error: Even if its cash flow were 39% below 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% 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 would lose \$100,000 by accepting LL.

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

The PI tells a similar story to the IRR. Here PI_{LL} is only 1.05 while PI_{SS} is 1.50. As with the IRR, this indicates that Project SS's cash inflows could decline by 50% before it loses money, whereas a decline of only 5% in LL's cash flows would result in a loss.

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 a long time; hence the project is relatively illiquid. In addition, a long payback means that cash flows must be forecast far into the future, and that probably makes the project riskier than one with 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 risk is significantly influenced by its maturity. The same holds true for capital projects.

In summary, the different measures provide different types of useful information. It is easy to calculate all of them: Simply put the cost of capital and the cash flows into an *Excel* model like the one provided in this chapter's *Tool Kit* and the model

will instantly calculate all six criteria. Therefore, most sophisticated companies consider all six measures 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.

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 should 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. The existence of 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 cholesterol-reducing medicine) and Microsoft’s Vista 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 product features that cannot be patented. The bottom line is that managers should strive to develop nonreplicable sources of competitive advantage. 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. Should capital budgeting decisions be made solely on the basis of a project’s NPV, with no regard to the other criteria? Explain your answer.
What are some possible reasons that a project might have a high NPV?

TABLE 10-1 Capital Budgeting Methods Used in Practice

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

10.11 DECISION CRITERIA USED IN PRACTICE

Over the years, surveys have been designed and administered to find out which of the criteria managers actually use. Surveys prior to 1999 asked companies to indicate which method they gave the most weight, whereas the most recent one (taken in 1999) asked what method or methods managers actually calculated and used. A summary of all these surveys is shown in Table 10-1, and it 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 a survey were taken in 2009, NPV would be at the top of this list. Second, the IRR method was used slightly more than the NPV at the time of the last survey (1999), but its recent growth is much less dramatic than that of NPV; if a survey were taken today, we believe that the NPV would predominate. Third, payback was the most important criterion 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 provides some useful information, but it is rarely used as the primary criterion. Fourth, "other methods," primarily the profitability index and the accounting rate of return (the latter of which is explained in this chapter's *Tool Kit*), have been fading 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 and are easy to calculate. Hence all are used, along with judgment and common sense. We will have more to say about all this in the next chapter.

Self-Test

What trends in capital budgeting methodology can be seen from Table 10-1?

10.12 OTHER ISSUES IN CAPITAL BUDGETING

Three other issues in capital budgeting are discussed in this section: (1) how to deal with mutually exclusive projects whose lives differ; (2) the potential advantage of terminating a project before the end of its physical life; and (3) the optimal capital budget when the cost of capital rises as the size of the capital budget increases.

Mutually Exclusive Projects with Unequal Lives

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 is considering either a conveyor system (Project C) or a fleet of forklift trucks (Project F) for moving materials. The first two sections of Figure 10-11 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 12% cost of capital, has the higher NPV and thus appears to be the better project.

Although the NPVs shown in Figure 10-11 suggest 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 levels shown in Figure 10-11, then 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 in Figure 10-11 and discussed next.

Replacement Chains. The key to the *replacement chain*, or *common life, approach* is to analyze both projects over an equal life. In our example, Project C has a 6-year life, so we assume that Project F will be repeated after 3 years and then analyze it over the same 6-year period. We can then calculate the NPV of C and compare it to the extended-life NPV of Project F. The NPV for Project C, as shown in Figure 10-11, is already based on the 6-year common life. For Project F, however, we must add in a second project to extend the overall life to 6 years. The time line for this extended project, denoted as “All CFs for FF,” is shown in Figure 10-11. 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 12%.

The NPV of this extended Project F is \$8,824, and its IRR is 25.2%. (The IRR of two Project Fs is the same as the IRR for one Project F.) However, the \$8,824 extended NPV of Project F is greater than Project C's \$6,491 NPV, so Project F should be selected.



FIGURE 10-11 Analysis of Projects C and F ($r = 12\%$)

	A	B	C	D	E	F	G	H
467	Data on Project C, Conveyor System:							
468	Year (t)	0	1	2	3	4	5	6
469	CF _t for C	(\$40,000)	\$8,000	\$14,000	\$13,000	\$12,000	\$11,000	\$10,000
470		NPV _C = \$6,491		IRR _C = 17.5%				
471								
472	Data on Project F, Forklifts:							
473	Year (t)	0	1	2	3			
474	CF _t for F	(\$20,000)	\$7,000	\$13,000	\$12,000			
475		NPV _F = \$5,155		IRR _F = 25.2%				
476								
477	Common Life Approach with F Repeated (Project FF):							
478	Year (t)	0	1	2	3	4	5	6
479	CF _t for 1st F	(\$20,000)	\$7,000	\$13,000	\$12,000			
480	CF _t for 2nd F				(\$20,000)	\$7,000	\$13,000	\$12,000
481	All CFs for FF	(\$20,000)	\$7,000	\$13,000	(\$8,000)	\$7,000	\$13,000	\$12,000
482		NPV _{FF} = \$8,824		IRR _{FF} = 25.2%				

Alternatively, we could recognize that Project F has an NPV of \$5,155 at Time 0 and a second NPV of that same amount at Time 3, then find the PV of the second NPV at Time 0, and sum the two to find Project F's extended-life NPV of \$8,824.

Equivalent Annual Annuities (EAA). Electrical engineers designing power plants and distribution lines were the first to encounter the unequal life problem. They could install 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 into the indefinite future, so this was the issue: Which choice would result in a 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 simply find the constant payment streams that the projects' NPVs (\$6,491 for C and \$5,155 for F) would provide over their respective lives. Using a financial calculator for Project C, we enter $N = 6$, $I/YR = 12$, $PV = -6491$, and $FV = 0$. Then, when we press the PMT key, we find $EAA_C = \$1,579$. For Project F, we enter $N = 3$, $I/YR = 12$, $PV = -5155$, and $FV = 0$; solving for PMT, we find $EAA_F = \$2,146$. Project F would thus produce a higher cash flow stream over the 6 years, so it is the better project.

Conclusions about Unequal Lives. When should we worry about analysis of unequal lives? The unequal life issue (1) does not arise for independent projects but (2) 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 if and 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 occurs, then replacement equipment will have a higher price. Moreover, both sales prices and operating costs would 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 situations in practice where significant differences in project lives are encountered, we first use a computer spreadsheet to build expected inflation and/or possible efficiency gains directly into the cash flow estimates and then use the replacement chain approach. We prefer the replacement chain approach for two reasons. First, it is easier to explain to those who are responsible for approving capital budgets. Second, it is easier to build inflation and other modifications into a spreadsheet and then go on to make the replacement chain calculations.

Economic Life versus Physical Life

Projects are normally evaluated under the assumption that the firm will operate them over their full physical lives. However, this may not be the best plan—it may be better to terminate a project before the end of its potential life. For example, the cost of maintenance for trucks and machinery can become quite high if they are used for too many years, so it might be better to replace them before the end of their potential lives.

FIGURE 10-12 Economic Life versus Physical Life

	A	B	C	D	E	F	G
520					PVs of the Cash Flows		
521			Operating	Salvage	Operating	Salvage	
522		Year	Cash Flow	Value	Cash Flow	Value	
523		0	-\$4,800				
524		1	2,000	\$3,000	\$1,818.18	\$2,727.27	
525		2	2,000	1,650	1,652.89	1,363.64	
526		3	1,750	0	1,314.80	0.00	
527							
528	WACC: 10%						
529							
530	NPV at Different Operating Lives:		Initial Cost	+	PV of	+	PV of
531					Operating		Salvage
532					Cash Flows		Value
533	Operate for 3 Years:		-\$4,800.00	+	\$4,785.88	+	\$0.00
534	NPV ₃ :	-\$14.12					
535							
536	Operate for 2 Years:		-\$4,800.00	+	\$3,471.07	+	\$1,363.64
537	NPV ₂ :	\$34.71					
538							
539	Operate for 1 Year:		-\$4,800.00	+	\$1,818.18	+	\$2,727.27
540	NPV ₁ :	-\$254.55					

Note: The project is profitable if and only if it is operated for just 2 years.



Figure 10-12 provides data for an asset with a physical life of 3 years. However, the project can be terminated at the end of any year and the asset sold at the indicated salvage values. All of the cash flows are after taxes, and the firm's cost of capital is 10%. The undiscounted cash flows are shown in Columns C and D in the upper part of the figure, and the present values of these flows are shown in Columns E and F. We find the project's NPV under different assumptions about how long it will be operated. If the project is operated for its full 3-year life, it will have a negative NPV. The NPV will be positive if it is operated for 2 years and then the asset is sold for a relatively high salvage value; the NPV will be negative if the asset is disposed after only 1 year of operation. Therefore, the project's optimal life is 2 years.

This type of analysis is used to determine a project's **economic life**, which is the life that maximizes the NPV and thus shareholder wealth. For our project, 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.

The Optimal Capital Budget

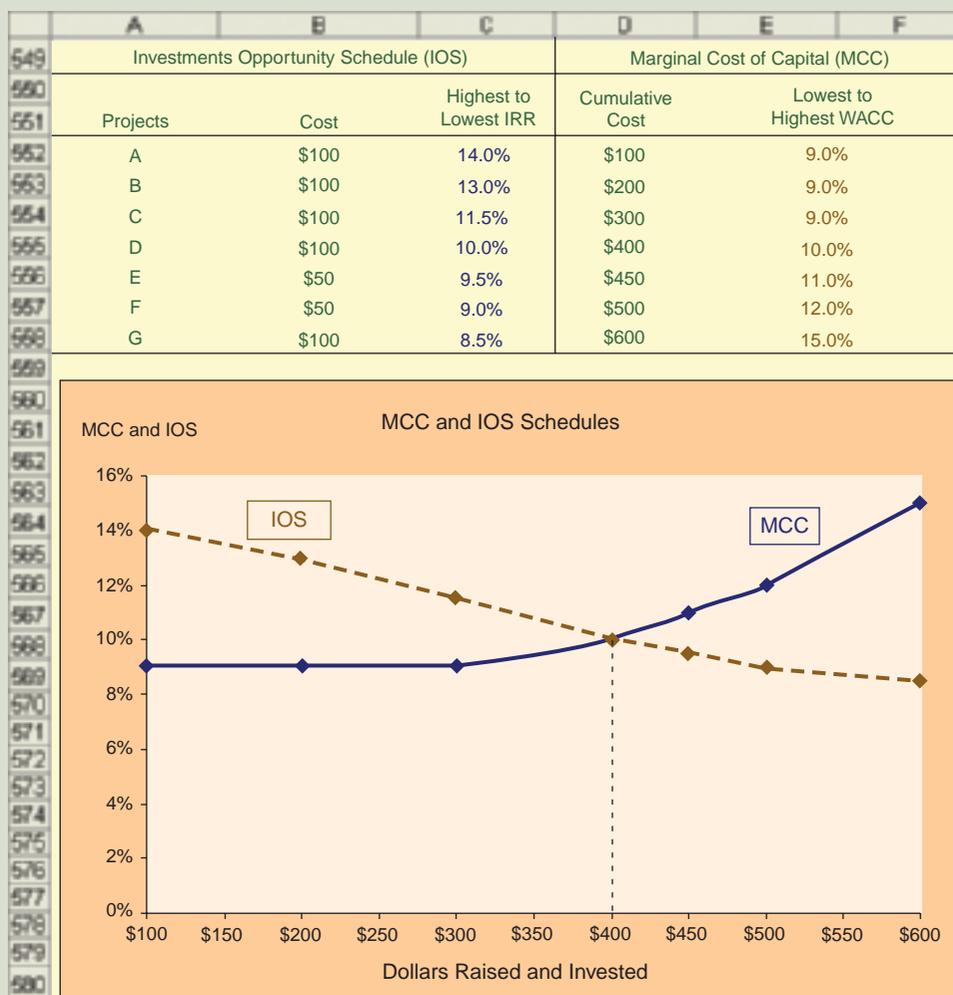
The **optimal capital budget** is defined as the set of projects that maximizes the value of the firm. Finance theory states that all independent projects with positive NPVs should be accepted, as should the mutually exclusive projects with the highest NPVs. Therefore, the optimal capital budget consists of that set of projects. However, two complications arise in practice: (1) The cost of capital might increase as the size of the capital budget increases, making it hard to know the proper discount rate to use when evaluating projects; and (2) sometimes firms set an upper limit on the size of their capital budgets, which is also known as *capital rationing*.

An Increasing Cost of Capital. The cost of capital may increase as the capital budget increases—this is called an *increasing marginal cost of capital*. As we discussed in Chapter 9, flotation costs associated with issuing new equity can be quite high. This means that the cost of capital will increase once a company has invested all of its internally generated cash and must sell new common stock. In addition, once a firm has used up its normal credit lines and must seek additional debt capital, it may encounter an increase in its cost of debt. This means that a project might have a positive NPV if it is part of a \$10 million capital budget but the same project might have a negative NPV if it is part of a \$20 million capital budget because the cost of capital might increase.

Fortunately, these problems rarely occur for most firms, especially those that are stable and well established. When a rising cost of capital is encountered, we would proceed as indicated below. You can look at Figure 10-13 as you read through our points.



FIGURE 10-13 IOS and MCC Schedules



Note: Use WACC = 10% as the base rate for finding base risk-adjusted project WACCs.

- Find the IRR (or MIRR) on all potential projects, arrange them in rank order (along with their initial costs), and then plot them on a graph with the IRR on the vertical axis and the cumulative costs on the horizontal axis. The firm's data are shown in Figure 10-13, and the IRRs are plotted in the graph. The line is called the Investment Opportunity Schedule (IOS), and it shows the marginal return on capital.
- Next, determine how much capital can be raised before it is necessary to issue new common stock or go to higher-cost sources of debt, and identify the amounts of higher-cost capital. Use this information to calculate the WACC that corresponds to the different amounts of capital raised. In this example, the firm can raise \$300 before the WACC rises, but the WACC increases as additional capital is raised. The increasing WACC represents the marginal cost of capital, and its graph is called the Marginal Cost of Capital (MCC) schedule.
- The intersection of the IOS and MCC schedules indicates the amount of capital the firm should raise and invest, and it is analogous to the familiar marginal cost versus marginal revenue schedule discussed in introductory economics courses. In our example, the firm should have a capital budget of \$400; if it uses a WACC of 10% then it will accept projects A, B, C, and D, which have a cumulative cost of \$400. The 10% WACC should be used for average-risk projects, but it should be scaled up or down for more or less risky projects as discussed in Chapter 9.

Our example illustrates the case of a firm that cannot raise all the money it needs at a constant WACC. Firms should not try to be too precise with this process—the data are not good enough for precision—but they should be aware of the concept and get at least a rough idea of how raising additional capital will affect the WACC.

Capital Rationing. Armbrister Pyrotechnics, a manufacturer of fireworks and lasers for light shows, has identified 40 potential independent projects, of which 15 have a positive NPV based on the firm's 12% cost of capital. The total investment required to implement these 15 projects would be \$75 million and so, according to finance theory, the optimal capital budget is \$75 million. Thus, Armbrister should accept the 15 projects with positive NPVs and invest \$75 million. However, Armbrister's management has imposed a limit of \$50 million for capital expenditures during the upcoming year. Because of 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 an amount less than would be 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, when combined with the limit on equity, this limits the amount of debt that can be added during any one year without raising the cost of that debt as well as the cost of equity. The result can be a serious constraint on the amount of funds available for investment in new projects.

The 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, companies might be better off explicitly incorporating the costs of raising external capital into their costs of capital along the lines shown in Figure 10-13. If there still are positive-NPV projects even with the higher cost of capital, then the company should go ahead and raise external equity and accept the projects.

2. *Constraints on nonmonetary resources.* Sometimes a firm simply doesn't have the necessary managerial, marketing, or engineering talent to immediately accept all positive-NPV projects. In other words, the potential projects may be independent from a demand standpoint but not from an internal standpoint, because accepting them all would raise the firm's costs. 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.

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, because 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

Briefly describe the replacement chain (common life) approach and differentiate it from the Equivalent Annual Annuity (EAA) approach.

Differentiate between a project's *physical* life and its *economic* life.

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 otherwise handle these situations?

Summary

This chapter has described six techniques that are used in capital budgeting analysis: NPV, IRR, MIRR, PI, payback, and discounted payback. 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 that 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 because such a project increases shareholders' value.

- 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.
- 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. In such cases, the NPV method should generally be relied upon.
- The NPV method assumes that cash flows will be reinvested at the firm's cost of capital, whereas 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, compounding them 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. Thus, the MIRR assumes reinvestment at the cost of capital, not at the IRR. If management wants to know the rate of return on projects, the MIRR is a better estimate than the regular IRR.
- The **profitability index (PI)** is calculated by dividing the present value of cash inflows by the initial cost, so it measures relative profitability—that is, the amount of the present value per dollar of investment.
- The regular **payback period** is defined as the number of years required to recover a project's cost. The regular payback method has three flaws: It ignores cash flows beyond the payback period, it does not consider the time value of money, and it doesn't give a precise acceptance rule. The payback does, however, provide an indication of a project's risk and liquidity, because it shows how long the invested capital will be tied up.
- The **discounted payback** is similar to the regular payback except that it discounts cash flows at the project's cost of capital. It considers the time value of money, but it still ignores cash flows beyond the payback period.
- The chapter's *Tool Kit Excel* model and *Web Extension 10A* describe another but seldom-used evaluation method, the **accounting rate of return**.
- 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 risk associated with unusually large expansion programs can cause the **marginal cost of capital** to increase 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

- (10–1) Define each of the following terms:
- Capital budgeting; regular payback period; discounted payback period
 - Independent projects; mutually exclusive projects
 - DCF techniques; net present value (NPV) method; internal rate of return (IRR) method; profitability index (PI)

- d. Modified internal rate of return (MIRR) method
 - e. NPV profile; crossover rate
 - f. Nonnormal cash flow projects; normal cash flow projects; multiple IRRs
 - g. Reinvestment rate assumption
 - h. Replacement chain; economic life; capital rationing; equivalent annual annuity (EAA)
- (10-2) What types of projects require the least detailed and the most detailed analysis in the capital budgeting process?
- (10-3) 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.
- (10-4) When two mutually exclusive projects are being compared, explain why the short-term project might be higher ranked under the NPV criterion if the cost of capital is high whereas 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?
- (10-5) 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?
- (10-6) 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 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), modified internal rate of return (MIRR), and profitability index (PI).
- 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

(10–1) 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.)

(10–2) IRR Refer to Problem 10-1. What is the project's IRR?

(10–3) MIRR Refer to Problem 10-1. What is the project's MIRR?

(10–4) Profitability Index Refer to Problem 10-1. What is the project's PI?

(10–5) Payback Refer to Problem 10-1. What is the project's payback period?

(10–6) Discounted Payback Refer to Problem 10-1. What is the project's discounted payback period?

(10–7) 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 5%? 10%? 15%?
- What are the two projects' IRRs at these same costs of capital?

INTERMEDIATE PROBLEMS

8–18

(10–8) 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.

(10-9)
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.

(10-10)
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, MIRR, 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?

(10-11)
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). Which project has the higher MIRR?

(10-12)
NPV and IRR Analysis

After discovering a new gold vein in the Colorado mountains, CTC Mining Corporation must decide whether to go ahead and develop the deposit. The most cost-effective method of mining gold is sulfuric acid extraction, a process that could result in environmental damage. Before proceeding 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 for 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.

- What are the project's NPV and IRR?
- Should this project be undertaken if environmental impacts were not a consideration?
- How should environmental effects be considered when evaluating this, or any other, project? How might these concepts affect the decision in part b?

(10-13)
NPV and IRR Analysis

Cummings Products is considering two mutually exclusive investments whose 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

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

(10-14)

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 million 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 million; under Plan B, cash flows will be \$1.75 million per year for 20 years.

- 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.)
- If the company accepts Plan A and 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?
- Suppose a firm's cost of capital is 10%. Is it logical to assume that the firm 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?
- Construct NPV profiles for Plans A and B, identify each project's IRR, and indicate the crossover rate.

(10-15)

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 that 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 that has an expected cash flow stream of \$3.4 million per year for 20 years. The firm's cost of capital is 10%.

- Calculate each project's NPV and IRR.
- 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 ?
- Graph the NPV profiles for Plan A, Plan B, and Project Δ .
- 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%.

(10-16)
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 only 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?

(10-17)
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?

(10-18)
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's cost of capital is 14%. Should the firm replace its old knitting machine? 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

(10-19)
Multiple Rates of
Return

The Ulmer Uranium Company is deciding whether or not it should open a strip mine whose net cost 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.

- Plot the project's NPV profile.
- Should the project be accepted if $r = 8\%$? If $r = 14\%$? 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 $r = 8\%$? At $r = 14\%$? Does the MIRR method lead to the same accept-reject decision as the NPV method?

(10–20)
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 following table:

Year	Expected Net Cost	
	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

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

(10–21)
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

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

(10–22)
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

- Should the firm operate the truck until the end of its 5-year physical life? If not, then what is its optimal economic life?
- 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

(10-23)

Build a Model: Capital Budgeting Tools

Start with the partial model in the file *Ch10 P23 Build a Model.xls* on the textbook's Web site. Gardial Fisheries is considering two mutually exclusive investments. The projects' expected net cash flows are as follows:



resource

Year	Expected Net Cash Flows	
	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

- If each project's cost of capital is 12%, which project should be selected? If the cost of capital is 18%, what project is the proper choice?
- Construct NPV profiles for Projects A and B.
- What is each project's IRR?
- What is the crossover rate, and what is its significance?
- 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.*)
- What is the regular payback period for these two projects?
- At a cost of capital of 12%, what is the discounted payback period for these two projects?
- What is the profitability index for each project if the cost of capital is 12%?

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 whereas 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):

Year	Expected Net Cash Flows	
	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. What does the profitability index (PI) measure? What are the PIs of Franchises S and L?
- i. (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?
- j. As a separate project (Project P), you are considering sponsorship of 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 single 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?
- k. In an unrelated analysis, you have the opportunity to choose between the following two mutually exclusive projects:

Year	Expected Net Cash Flows	
	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, Cengage 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)."