CHAPTER 10

The Fundamentals of Capital Budgeting

In this Chapter:

An Introduction to Capital Budgeting
Net Present Value
The Payback Period
The Accounting Rate of Return
Internal Rate of Return
Capital Budgeting in Practice

LEARNING OBJECTIVES

1. Discuss why capital budgeting decisions are the most important investment decisions made by a firm's management.
2. Explain the benefits of using the net present value (NPV) method to analyse capital expenditure decisions and be able to calculate the NPV for a capital project.
3. Describe the strengths and weaknesses of the payback period as a capital expenditure decision-making tool and be able to compute the payback period for a capital project.
4. Explain why the accounting rate of return (ARR) is not recommended for use as a capital expenditure decision-making tool.
5. Be able to compute the internal rate of return (IRR) for a capital project and discuss the conditions under which the IRR technique and the NPV technique produce different results.
6. Explain the benefits of a post-audit review of a capital project.

In 1996, Airbus formed its Large Aircraft Division to design and build a super-large passenger aircraft, an idea it had been working on from 1988 and discussing with major international carriers since 1991. In December 2000, Airbus revealed the A380, the world's first twin-deck, twin-aisle 555 seat passenger superjumbo airliner. The manufacture of the various components (engines, fuselage and wings) began in 2002 and the first delivery to Singapore Airlines took place in October 2007, with further deliveries taking place thereafter as Airbus geared up to produce the 200 plus aircraft for which it had firm orders. It needs about twice that number to break even on the project.

The superjumbo project has not been without its problems. The first was finance – the need for the company to invest heavily in development and start-up costs. Airbus invested about €13 billion to develop the airliner that has a list price of $300 million apiece.[1] To put the project into perspective, in 2008 Airbus delivered 483 aircraft of all types – but only 13 A380s – and had total revenues of €27.5 billion and EBIT of €1.8 billion. During the development of the new airliner, the company also had to compete with its arch rival Boeing, the Seattle-based airline manufacturer, which was also considering a similar aircraft. In the end, Boeing opted to develop a smaller aircraft, the Dreamliner, based on its analysis of the way air travel is likely to evolve.

The development of the A380 illustrates not only the large amount of cash involved in a major capital project, but also the strategic importance such an investment can have. If Airbus is successful, it will be the only producer of superjumbo airliners and will have the market to itself. The A380 project involves considerable downside risk for Airbus and its parent company EADS. For example, if the demand for superjumbos proves to be less than expected, the project could be a significant drain on future earnings. In addition, there are technical risks with the design, and forecasting passenger demand and the demands of airlines in the future is fraught with uncertainties. In 2009, as a result of the global credit crunch and a downturn in airline travel, some airlines which had ordered A380s were seeking to delay deliveries and hence payment. If these problems persist, the financial consequences for Airbus could be severe.

It is clear that investment decisions of this magnitude must be carefully scrutinised and their costs and benefits carefully weighed. How do firms make capital budgeting decisions that involve large amounts of money? In this chapter, we examine the decision-making process and introduce some of the financial models that aid in the process.

CHAPTER PREVIEW

This chapter is about capital budgeting, a topic we first visited in Chapter 1. Capital budgeting – or investment appraisal – is the process of deciding which capital investments the firm should make.

We begin the chapter with a discussion of the types of capital projects that firms undertake and how the capital budgeting process is managed within the firm. When making capital investment decisions, management's goal is to select projects that will increase the value of the firm.

Next we examine some of the techniques used to evaluate capital budgeting decisions. We first discuss the net present value (NPV) method, which is the capital budgeting approach recommended in this book. The NPV method takes into account the time value of money and provides a direct measure of how much a capital project will increase the value of the firm.

We then examine the payback method and the accounting rate of return. As methods of selecting capital projects, both have some serious deficiencies. Finally, we discuss the internal rate of return (IRR), which is the expected rate of return for a capital project. Like the NPV, the IRR involves discounting a project's future cash flows. It is a popular and important alternative to the NPV technique. However, in certain circumstances, the IRR can lead to incorrect decisions. We close by discussing evidence on techniques financial managers actually use when making capital budgeting decisions.

AN INTRODUCTION TO CAPITAL BUDGETING

Learning Objective 1

Discuss why capital budgeting decisions are the most important investment decisions made by a firm's management.

We begin with an overview of capital budgeting, followed by a discussion of some important concepts you will need to understand in this and later chapters.

The Importance of Capital Budgeting

Capital budgeting decisions are the most important investment decisions made by management. The objective of these decisions is to select investments in real assets that will increase the value of the firm. These investments *create value* when they are worth more than they cost. Capital investments are important because they can involve substantial cash outlays and, once made, are not easily reversed. They also define what the company is all about – the firm's lines of business and its inherent business risk. For better or worse, capital investments produce most of a typical firm's revenues for years to come.

Capital budgeting

the process of choosing the real assets in which the firm will invest

Capital budgeting *techniques* help management systematically analyse potential business opportunities in order to decide which are worth undertaking. As you will see, not all capital budgeting techniques are equal. The best techniques are those that determine the value of a capital project by discounting all of the cash flows generated by the project, and thus account for the time value of money. We focus on these techniques in this chapter.

In the final analysis, capital budgeting is really about management's search for the best capital projects – those that add the greatest value to the firm. Over the long term, the most successful firms are those whose managements consistently search for and find capital investment opportunities that increase firm value.

WEB

You can read about real-world examples of how capital budgeting techniques are used at: http://www.acq.osd.mil/dpap/cpf/docs/contract_pricing_finance_guide/vol2_ch9.pdf and http://www.hmrc.gov.uk/ebu/npv-and-example.pdf.

The Capital Budgeting Process

The capital budgeting process starts with a firm's strategic plan, which spells out its strategy for the next three to five years. Division managers then convert the firm's strategic objectives into business plans. These plans have a one-year to two-year time horizon, provide a detailed description of what each division should accomplish during the period covered by the plan and have quantifiable targets that each division is expected to achieve. Behind each division's business plan is a capital budget that details the resources management believes it needs to get the job done.

The capital budget is generally prepared jointly by the CFO's staff and financial staff at the divisional and lower levels and reflects, in large part, the activities outlined in the divisional business plans. Many of these proposed expenditures are routine in nature, such as the repair or purchase of new equipment at existing facilities. Less frequently, firms face broader strategic decisions, such as whether to launch a new product, build a new plant, enter a new market or buy a business. Exhibit 10.1 identifies some reasons that firms initiate capital projects.

Capital budgeting decisions are the most important investment decisions made by management. Many of these decisions are routine in nature but, from time to time, managers face broader strategic decisions that call for significant capital investments.

Sources of Information

Where does a firm get all of the information it needs to make capital budgeting decisions? Most of the information is generated within the firm and, for expansion decisions, it often starts with sales representatives and marketing managers who are in the marketplace talking to potential and current customers on a day-to-day basis. For example, a sales manager with a new product idea might present the idea to management and the marketing research group. If the product looks promising, the marketing research group will estimate the size of the market and a market price. If the product requires new technology, the firm's research and development group must decide whether to develop the technology or to buy it. Next, cost accountants and production engineers determine the cost of producing the product and any capital expenditures necessary to manufacture it. Finally, the CFO's staff take the data and estimate the cost of the project and the cash flows it will generate over time. The project is a viable candidate for the capital budget if the present value of the cash benefits exceeds the project's cost.

EXHIBIT 10.1
KEY REASONS FOR MAKING CAPITAL EXPENDITURES

Reason	Description
Renewal:	Over time, equipment must be repaired, overhauled, rebuilt or retrofitted with new technology to keep the firm's manufacturing or service operations going. For example, a company that has a fleet of delivery trucks may decide to overhaul the trucks and their engines rather than purchase new trucks. Renewal decisions typically do not require an elaborate analysis and are made on a routine basis.
Replacement:	At some point, an asset will have to be replaced rather than repaired or overhauled. This typically happens when the asset is worn out or damaged. The major decision is whether to replace the asset with a similar piece of equipment or purchase equipment that would require a change in the production process. Sometimes, replacement decisions involve equipment that is operating satisfactorily but has become obsolete. The new or retrofitted equipment may provide cost savings with respect to labour or material usage and/or may improve product quality. These decisions typically originate at the plant level.
Expansion:	Strategically, the most important motive for capital expenditures is to expand the level of operating output. One type of expansion decision involves increasing the output of existing products. This may mean new equipment to produce more products or expansion of the firm's distribution system. These types of decisions typically require a more complex analysis than a renewal or replacement decision. Another type of expansion decision involves producing a new product or entering a new market. This type of expansion often involves large sums of money and significant business risk, and requires the approval of the firm's board of directors.
Regulatory:	Some capital expenditures are required by government regulations. These mandatory expenditures usually involve meeting workplace safety standards and environmental standards.
Other:	This category includes items such as parking facilities, office buildings and executive aircraft. Many of these capital expenditures are hard to analyse because it is difficult to estimate their cash inflows. Ultimately, the decisions can be more subjective than analytical.

Classification of Investment Projects

Potential capital budgeting projects can be classified into three types: (1) **independent projects,** (2) **mutually exclusive projects** and (3) **contingent projects.**

Mutually exclusive projects

projects for which acceptance of one precludes acceptance of the other

Independent projects

projects whose cash flows are unrelated

Contingent projects

projects whose acceptance depends on the acceptance of another project

Independent Projects

Projects are independent when their cash flows are unrelated. With independent projects, accepting or rejecting one project does not eliminate the other projects from consideration (assuming the firm has unlimited funds to invest). For example, suppose a firm has unlimited funding and management wants to: (1) build a new parking ramp at its headquarters; (2) acquire a small competitor; and (3) add manufacturing capacity to one of its plants. Since the cash flows for each project are unrelated, accepting or rejecting one of the projects will have no effect on the others.

Mutually Exclusive Projects

When projects are mutually exclusive, acceptance of one project precludes acceptance of the others. Typically, mutually exclusive projects perform the same function and, thus, only one project needs to be accepted. For example, when BMW decided to manufacture automobiles in the United States, it considered three possible manufacturing sites (or capital projects). Once BMW management had selected the Spartanburg, South Carolina, site, the other two possible locations were out of the running.

Contingent Projects

With contingent projects, the acceptance of one project is contingent on the acceptance of another. There are two types of contingency situations. In the first type of situation, the contingent product is *mandatory*. For example, when a public utility company (such as your local electric company) builds a power plant, it must also invest in suitable pollution control equipment to meet environmental standards. The pollution control investment is a mandatory contingent project. When faced with mandatory contingent projects, it is best to treat all of the projects as a single investment for the purpose of evaluation. This provides management with the best measure of the value created by these projects.

In the second type of situation, the contingent project is *optional*. For example, in the Airbus situation above, consider the adaptation of the A380 to carry cargo. The cargo version of the superjumbo is a contingent project and is optional. In these situations, the optional contingent project should be evaluated *independently* and should be accepted or rejected on its own merits.

Basic Capital Budgeting Terms

In this section we briefly introduce two terms that you will need to be familiar with – *cost of capital* and *capital rationing*.

Cost of Capital

The **cost of capital** is the rate of return that a capital project must earn to be accepted by management. The cost of capital can be thought of as an opportunity cost. Recall from Chapter 8 that an *opportunity cost* is the value of the most valuable alternative given up if a particular investment is made.

> **Cost of capital**
>
> the required rate of return for a capital investment

> **Opportunity cost of capital**
>
> the return an investor gives up when his or her money is invested in one asset rather than the best alternative asset

Let us consider the opportunity cost concept in the context of capital budgeting decisions. When investors buy shares in a company or loan money to a company, they are giving management money to invest on their behalf. Thus, when a firm's management makes capital investments, they are really investing shareholders' and creditors' money in *real assets* – plant and equipment. Since shareholders and creditors

BUILDING INTUITION

Investment Decisions have Opportunity Costs

When any investment is made, the opportunity to earn a return from an alternative investment is lost. The lost return can be viewed as a cost that arises from a lost opportunity. For this reason, it is called an *opportunity cost*. The opportunity cost of capital is the return an investor gives up when his or her money is invested in one asset rather than the best alternative asset. For example, suppose that a firm invests in a piece of equipment rather than returning money to shareholders. If shareholders could have earned an annual return of 12% on shares with cash flows that are as risky as the cash flows the equipment will produce, then this is the opportunity cost of capital associated with the investment in the piece of equipment.

could have invested their money in *financial assets*, the minimum rate of return they are willing to accept on an investment in a real asset is the rate they could have earned investing in financial assets that have similar risk. The rate of return that investors can earn on financial assets with similar risk is an *opportunity cost* because investors lose the opportunity to earn that rate if the money is invested in a real asset instead. It is therefore the rate of return that investors will require for an investment in a capital project. In other words, this rate is the cost of capital. It is also known as the **opportunity cost of capital**. Chapter 13 discusses how we estimate the opportunity cost of capital in practice.

Capital Rationing

When a firm has all the money it needs to invest in all the capital projects that meet its capital selection criteria, the firm is said to be operating without a *funding constraint* or *resource constraint*. Firms are rarely in this position, especially growth firms. Typically, a firm has a fixed amount of money available for capital expenditures and the number of qualified projects that need funding exceeds the funds that are available. Therefore, the firm must allocate its funds to the subset of projects that will provide the largest overall increase in shareholder value. The process of limiting, or rationing, capital expenditures in this way is called **capital rationing**. Capital rationing and its implications for capital budgeting are discussed in Chapter 12.

Capital rationing

a situation where a firm does not have enough capital to invest in all attractive projects and must therefore ration capital

Before You Go On

1. Why are capital investments the most important decisions made by a firm's management?
2. What are the differences between capital projects that are independent, mutually exclusive and contingent?

NET PRESENT VALUE

Learning Objective 2

Explain the benefits of using the net present value (NPV) method to analyse capital expenditure decisions and be able to calculate the NPV for a capital project.

In this section we discuss a capital budgeting method that is consistent with this goal of financial management – to maximise the wealth of the firm's owners. It is called the **net present value** (**NPV**) **method**, and is one of the most basic concepts underlying corporate finance. The NPV method tells us the amount by which the benefits from a capital expenditure exceed its costs. It is the capital budgeting technique recommended in this book.

Net present value (NPV) method

a method of evaluating a capital investment project which measures the difference between its cost and the present value of its expected cash flows

WEB

CCH Business Owner's toolkit is a valuable Web source for information about running a business, including capital budget analysis. Go to www.toolkit.cch.com/text/p06_6500.asp.

Valuation of Real Assets

Throughout this book, we have emphasised that the value of any asset is the present value of its future cash flows. In Chapters 8 and 9, we developed valuation models for financial assets, such as bonds, preference and ordinary shares. We now extend our discussion of valuation models from financial to real assets. The steps used in valuing an asset are the same whether the asset is real or financial:

1. Estimate the future cash flows.
2. Determine the required rate of return, or discount rate, which depends on the riskiness of the future cash flows.
3. Compute the present value of the future cash flows to determine what the asset is worth.

The valuation of real assets, however, is less straightforward than the valuation of financial assets, for several reasons.

First, in many cases, cash flows for financial assets are well documented in a legal contract. If they are not, we are at least able to make some reasonable assumptions about what they are. For real assets, much less information exists. Specialists within the firm, usually from the finance, marketing and production groups, often prepare estimates of future cash flows for capital projects with only limited information.

Second, many financial securities are traded in public markets and these markets are reasonably efficient. Thus, market data on rates of return are accessible. For real assets, no such markets exist. As a result, we must estimate required rates of return on real assets (opportunity costs) from market data on financial assets: this can be difficult to do.

NPV – The Basic Concept

The NPV of a project is the difference between the present value of the project's future cash flows and the present value of its cost. The NPV can be expressed as follows:

$$\begin{aligned} \text{NPV} = {} & \text{PV(Project's future cash flows)} \\ & - \text{PV(Cost of the project)} \end{aligned}$$

If a capital project has a positive NPV, the value of the cash flows the project is expected to generate exceeds the project's cost. Thus, a positive NPV project increases the value of the firm and, hence, shareholders' wealth. If a capital project has a negative NPV, the value of the cash flows from the project is less than its cost. If accepted, a negative NPV project will reduce the value of the firm and shareholders' wealth.

To illustrate these important points, consider an example. Suppose a firm is considering building a new marina for pleasure boats. The firm has a genie that can tell the future with perfect certainty. The finance staff estimate that the marina will cost €3.50 million. The genie volunteers that the market value of the marina is €4.25 million.

Assuming this information is correct, the NPV for the marina project is a positive €750 000 (€4.25 million – €3.50 million). Management should accept the project because the excess of market value over cost increases the value of the firm by €750 000. Why is a positive NPV a *direct* measure of how much a capital project will increase the value of the firm? If management wanted to, the firm could sell the marina for €4.25 million, pay the €3.50 million in expenses and deposit €750 000 in the bank. The value of the firm would increase by the €750 000 deposited in the bank. In sum, the NPV method tells us which capital projects to select and how much value they add to the firm.

NPV and Value Creation

We have just said that any project with a positive NPV should be accepted because it will increase the value of the firm. Let us take a moment to think about this proposition. What makes a capital asset worth more than it costs? In other words, how does management create value with capital investments?

How Value is Created

Suppose that when you were at university, you worked part time at a successful pizza restaurant near your campus. During this time, you learned a lot about the pizza business. After graduation, you purchased a pizza restaurant for €100 000 that was in a good location but had been forced to close because of a lack of profits. The owners had let the restaurant and the quality of the pizzas deteriorate and the staff had been rude, especially to students. Once you purchased the restaurant, you immediately invested €40 000 to fix it up: you painted the building, spruced up the interior, replaced some of the dining room furniture and added an eye-catching, 1950s-style neon sign to attract attention. You also spent €15 000 for a one-time advertising campaign to quickly build a customer base. More important, you improved the quality of the pizzas you sold and you built a profitable takeout business. Finally, you were careful who you hired as staff and trained them to be customer friendly.

Almost immediately the restaurant was earning a substantial profit and generating substantial cash flows. The really good news was that several owners of local pizzerias wanted to buy your restaurant. After intense negotiations with several of the potential buyers, you accepted a cash offer of €475 000 for the business shortly after you purchased it.

What is the NPV for the pizza restaurant? For this investment, the NPV is easy to calculate. We do not need to estimate future cash flows and discount them because we already have an estimate of the present value of the cash flows the pizza restaurant is expected to produce – €475 000. Someone is willing to pay you €475 000 because they believe the future cash flows are worth that amount. The cost of your investment includes the purchase price of the restaurant, the cost to fix it up and the cost of the initial advertising campaign, which totals €155 000 (€100 000 + €40 000 + €15 000). Thus, the NPV for the pizza restaurant is:

$$\begin{aligned} \text{NPV} &= \text{PV(Project's future cash flows)} \\ &\quad - \text{PV(Cost of the project)} \\ &= €475\,000 - €155\,000 \\ &= €320\,000 \end{aligned}$$

The €475 000 price paid for the pizza restaurant exceeds the cost (€155 000) by €320 000. You have created €320 000 in value. How did you do this? You did it by improving the food, customer service and dining ambiance while keeping prices competitive. Your management skills and knowledge of the pizza business resulted in significant growth in the current year's cash flows and the prospect of even larger cash flows in the future.

Where did the €320 000 in value you created go? The NPV of your investment is the amount that your personal net worth increased because of the investment. For an ongoing business, the result would have been a €320 000 increase in the value of the firm.

How about the original owners? Why would they sell a business worth €475 000 to you for €100 000? The answer is simple: if they could have transformed the business as you did, they would have done so. Instead, when they ran the business, it lost money! They sold it to you because you offered them a price reflecting its value to them.

Market Data versus Discounted Cash Flows

Our pizza restaurant example is greatly simplified by the fact that we can observe the price that someone is willing to pay for the asset. In most capital project analyses, we have to estimate the market value of the asset by *forecasting* its future cash flows and discounting them by the cost of capital. The discounted value of a project's future cash flows is an estimate of its value or the market price for which it can be sold.

Framework for Calculating NPV

We now describe a framework for analysing capital budgeting decisions using the NPV method. As you will see, the NPV technique uses the discounted cash flow technique developed in Chapters 5 and 6 and applied in Chapters 8 and 9. The good news, then, is that the NPV method requires only the application of what you already know.

The five-step framework discussed in this section and the accompanying cash flow worksheet (Exhibit 10.2) can help you systematically organise a project's cash flow data and compute its NPV. Most mistakes people make when working capital budgeting problems result from problems with cash flows: not identifying a cash flow, getting a cash flow in the wrong time period or assigning the wrong sign to a cash flow. What can make cash flow analysis difficult in capital budgeting is this: there are often multiple cash flows in a single time period, and some are cash inflows and others are cash outflows.

As always, we recommend that you prepare a time line when doing capital budgeting problems. A sample time line is shown in Exhibit 10.2, along with an identification of the cash flows for each period. Our goal is to compute the net cash flow (NCF) for each time period t, where $NCF_t = (\text{Cash inflows} - \text{Cash outflows})$ for the period t. For a capital project, the time periods (t) are usually in years and t varies from the current period ($t = 0$) to some finite time period that is the estimated life of the project ($t = n$). Recall that getting the correct sign on each cash flow is critical to getting the correct answer to a problem. As you have seen in earlier chapters, the convention in finance problem solving is that cash inflows carry a positive sign and cash outflows carry a negative sign. Finally, note that all cash flows in this chapter are on an after-tax basis. We will make adjustments for tax consequences on specific transactions such as the calculation of a project's salvage value.

Time line	0	1	2	3	4	5 Year
Cash Flows:						
Initial cost	$-CF_0$					
Inflows (CIF)		CIF_1	CIF_2	CIF_3	CIF_4	CIF_5
Outflows (COF)		$-COF_1$	$-COF_2$	$-COF_3$	$-COF_4$	$-COF_5$
Salvage value						SV
Net cash flow	$-NCF_0$	NCF_1	NCF_2	NCF_3	NCF_4	NCF_5

$$NPV = -NCF_0 + \sum_{t=1}^{5} \frac{NCF_t}{(1+k)^t}$$

Exhibit 10.2: Sample Worksheet for Net Present Value Analysis In addition to following the five-step framework for solving NPV analysis problems, we recommend that you use a worksheet with a time line like the one shown here to help you determine the proper cash flows for each period.

Our five-step framework for analysis is as follows:

1. **Determine the cost of the project.** We first need to identify and add up all of the expense items related to the cost of the project. In most cases, the cost of a project is incurred during the first year; hence, this cash outflow is already in current money. However, some projects have negative cash flows for several years because it takes two or three years to get the projects up and running. If the cash payments for the project extend beyond one year, the money paid in the second year and beyond must be discounted for the appropriate time period. Negative cash flows can also occur when a project sustains an operating loss during the start-up years. Turning to Exhibit 10.2, we have incurred a single negative cash flow ($-CF_0$) for the total cost of the project, where $NCF_0 = -CF_0$; thus, NCF_0 has a negative value.
2. **Estimate the project's future cash flows over its expected life.** Capital projects typically generate some cash inflows from revenues (CIF_t) for each period, along with some cash outflows (COF_t) that represent expenses incurred to generate the revenues. In most cases revenues exceed expenses and, thus, NCF_t is positive where $t \geq 1$. However, this may not always be the case. For example, if the project is the purchase of a piece of equipment, it is possible for NCF_3 to have a negative value ($CIF_3 < COF_3$) if the equipment is projected to need a major overhaul or must be replaced during the third year. Finally, you also need to pay attention to a project's final cash flow, which is $t = 5$ in Exhibit 10.2. There may be a salvage value (SV) at the end of the project, which is a cash inflow. In that case $NCF = (CIF_5 - COF_5 + SV)$. The important point is that for each time period, we must identify all the cash flows that take place, assign each cash flow its proper sign and algebraically add up all the cash flows; the total is the NCF for that time period with the correct sign.
3. **Determine the riskiness of the project and the appropriate cost of capital.** The third step is to identify for each project its risk-adjusted cost of capital, which takes into account the riskiness of the project's cash flows. The riskier the project, the higher the project's cost of capital. The cost of capital is the discount rate used in determining the present value of the future expected cash flows. In this chapter, the cost of capital and any risk adjustments will be supplied and no calculations will be required for this step.
4. **Compute the project's NPV.** The NPV, as you know, is the present value of the net cash flows the project is expected to generate minus the cost of the project.
5. **Make a decision.** If the NPV is positive, the project should be accepted because all projects with a positive NPV will increase the value of the firm. If the NPV is negative, the project should be rejected; projects with negative NPVs will decrease the value of the firm.

You might be wondering about how to handle a capital project with an NPV of 0. Technically, management should be indifferent to accepting or rejecting projects such as this because they neither increase nor decrease the value of the firm. At a practical level, projects rarely have an NPV equal to 0 and most firms have more good capital projects (with NPV > 0) than they can fund. Thus, this is not an issue that generates much interest among practitioners.

Net Present Value Techniques

The NPV of a capital project can be stated in equation form as the present value of all net cash flows (inflows − outflows) connected with the project, whether in the current period or in the future. The NPV equation can be written as follows:

$$NPV = NCF_0 + \frac{NCF_1}{1+k} + \frac{NCF_2}{(1+k)^2} + \cdots + \frac{NCF_n}{(1+k)^n} \tag{10.1}$$

where:

NCF_t = net cash flow (cash inflows − cash outflows) in period t, where $t = 1, 2, 3, \ldots, n$
k = the cost of capital
n = the project's estimated life

Next, we will work an example to see how the NPV is calculated for a capital project. Suppose you are the president of a small regional firm located in Brescia that manufactures frozen pizzas, which are sold to grocery stores and to firms in the hospitality and food service industry. Your market research group has developed an idea for a 'pocket' pizza that can be used as an entrée with a meal or as an 'on the go' snack. The sales manager believes that, with an aggressive advertising campaign, sales of the product will be about €300 000 per year. The cost to modify the existing production line will also be €300 000, according to the plant manager. The marketing and plant managers estimate that the cost to produce the pocket pizzas, to market and advertise them and to deliver them to customers will be about €220 000 per year. The product's life is estimated to be five years and the specialised equipment necessary for the project has an estimated salvage value of €30 000. The appropriate cost of capital is 15%.

When analysing capital budgeting problems, we typically have a lot of data to sort through. The worksheet approach introduced earlier is helpful in keeping track of the data in an organised format. Exhibit 10.3 shows the time line and relevant cash flows for the pocket pizza project. The steps in analysing the project's cash flows and determining its NPV are as follows:

1. *Determine the cost of the capital project.* The cost of the project is the cost to modify the existing production line, which is €300 000. This is a cash outflow (negative sign).
2. *Estimate the capital project's future cash flows over its expected life.* The project's future cash inflows come from sales of the new product. Sales are estimated at €300 000 per year (inflow, therefore this has a positive sign). The cash outflows are the costs to manufacture and distribute the new product, which are €220 000 per year (negative sign). The life of the project is five years. The project has a salvage value of €30 000, which is a cash inflow (positive sign). The net cash flow (NCF) per time period is just the sum of the cash inflows and cash outflows for that period. For example, the NCF for period $t = 0$ is −€300 000, the NCF for period $t = 1$ is €80 000 and so on, as you can see in Exhibit 10.3.
3. *Determine the riskiness of the project and the appropriate cost of capital.* The discount rate is the cost of capital, which is 15%.
4. *Compute the project's NPV.* To compute the project's NPV, we apply Equation (10.1) by plugging in the NCF values for each time period and using the cost of capital, 15%, as the

Time line	0	1	2	3	4	5 Year
Cash Flows:						
Initial cost	–€300					
Inflows		€300	€300	€300	€300	€300
Outflows		–€220	–€220	–€220	–€220	–€220
Salvage						30
Net cash flow	–€300	€80	€80	€80	€80	€110

Exhibit 10.3: Pocket Pizza Project Time Line and Cash Flows (€ thousands) The worksheet introduced in Exhibit 10.2 is helpful in organising the data given for the pocket pizza project.

discount rate. The equation looks like this (the figures are in thousands of euros):

$$\begin{aligned}
\text{NPV} &= \sum_{t=0}^{n} \frac{\text{NCF}_t}{(1+k)^t} \\
&= -€300 + \frac{€80}{1.15} + \frac{€80}{(1.15)^2} + \cdots + \frac{€80}{(1.15)^4} \\
&\quad + \frac{(€80 + €30)}{(1.15)^5} \\
&= -€300 + €69.57 + €60.49 + €52.60 \\
&\quad + €45.74 + €54.69 \\
&= -€300 + €283.09 = -€16.91
\end{aligned}$$

The NPV for the pocket pizza project is therefore −€16 910.

5. *Make a decision.* The pocket pizza project has a negative NPV, which indicates that the project is not a good investment and should be rejected. If management undertook this project, the value of the firm would be reduced by €16 910 and, if the firm had 100 000 shares outstanding, we can estimate that the project would reduce the value of each share by about 17 cents (€16 910/100 000 shares).

Learning by Doing Application 10.1

The Dough is Up: The Self-Rising Pizza Project

Problem: Let us continue our frozen pizza example. Suppose the head of the research and development (R&D) group announces that R&D engineers have developed a breakthrough technology – self-rising frozen pizza dough that, when baked, rises and tastes exactly like fresh-baked dough.

The cost is €300 000 to modify the production line. Sales of the new product are estimated at €200 000 for the first year, €300 000 for the next two years and €500 000 for the final two years. It is estimated that production, sales and advertising costs will be €250 000 for the first year and will then decline to a constant €200 000 per year. There is no salvage value at the end of the product's life and the appropriate cost of capital is 15%. Is the project, as proposed, economically viable?

Approach: To solve the problem, work through the steps for NPV analysis given in the text.

Solution: Exhibit 10.4 shows the project's cash flows.

1. The cost to modify the production line is €300 000, which is a cash outflow and the cost of the project.
2. The future cash flows over the expected life of the project are laid out on the time line in Exhibit 10.4. The project's life is five years. The NCFs for the capital project are negative at the beginning of the project and in the first year (−€300 000 and −€50 000) and thereafter are positive.
3. The appropriate cost of capital is 15%.
4. The values are substituted into Equation (10.1) to calculate the NPV:

$$\begin{aligned}
\text{NPV} &= \text{NCF}_0 + \frac{\text{NCF}_1}{1+k} + \frac{\text{NCF}_2}{(1+k)^2} + \cdots \\
&\quad + \frac{\text{NCF}_n}{(1+k)^n} \\
&= -€300\,000 + \frac{€50\,000}{1.15} + \frac{€100\,000}{(1.15)^2} \\
&\quad + \frac{€100\,000}{(1.15)^3} + \frac{€300\,000}{(1.15)^4} + \frac{€300\,000}{(1.15)^5} \\
&= -€300\,000 + €47\,478 + €75\,614 \\
&\quad + €65\,752 + €171\,526 + €149\,153 \\
&= €118\,567
\end{aligned}$$

Time line	0	1	2	3	4	5 Year
Cash Flows:						
Initial cost	–€300					
Inflows		€200	€300	€300	€500	€500
Outflows		–€250	–€200	–€200	–€200	–€200
Salvage						
Net cash flow	–€300	–€50	€100	€100	€300	€300

Exhibit 10.4: Self-Rising Pizza Dough Project Time Line and Cash Flows (€ thousands) The worksheet shows the time line and cash flows for the self-rising pizza dough project in Learning by Doing Application 10.1. As always, it is important to assign each cash flow to the appropriate year and to give it the proper sign. Once you have computed the net cash flow for each time period, solving for the NPV is just a matter of plugging the data into the NPV formula.

The decision is based on the NPV. The NPV for the self-rising pizza dough project is €118 567. Because the NPV is positive, management should accept the project. The project is estimated to increase the value of the firm by €118 567.

USING EXCEL

Net Present Value

Net present value problems are most commonly solved using a spreadsheet program. The program's design is good for keeping track of all the cash flows and the periods in which they occur. The following spreadsheet setup for Learning by Doing Application 10.1 shows how to calculate the NPV for the self-rising pizza dough machine:

Notice that the NPV formula does not take into account the cash flow in year 0. Therefore, you only enter into the NPV formula the cash flows in years 1–5, along with the discount rate. You then add the cash flow in year 0 to the total from the NPV formula calculation to get the NPV for the investment.

	A	B	C	D	E
1					
2		**Net Present Value Calculations**			
3					
4		**Year**		**Cash Flow**	
5		0		-€ 300,000	
6		1		-50,000	
7		2		100,000	
8		3		100,000	
9		4		300,000	
10		5		300,000	
11					
12		Cost of capital		0.15	
13					
14		**NPV**		€ 118,567	
15		Formula used		=NPV(E12,E6:E10)+E5	
16					

Decision-Making Example 10.1

The IS Department's Capital Projects

Situation: Suppose you are the manager of the information systems (IS) department of the frozen pizza manufacturer we have been discussing. Your department has identified four possible capital projects with the following NPVs: (1) €4500, (2) €3000, (3) €0.0 and (4) −€1000. What should you decide about each project if the projects are independent? What should you decide if the projects are mutually exclusive?

Decision: If the projects are independent, you should accept projects 1 and 2, both of which have a positive NPV, and reject project 4. Project 3, with an NPV of zero, could be either accepted or rejected. If the projects are mutually exclusive and you can accept only one of them, it should be project 1, which has the largest NPV.

Concluding Comments on NPV

Some concluding comments about the NPV method are in order. First, as you may have noticed, the NPV computations are rather mechanical once we have the cash flows and have determined the cost of capital. The real difficulty is estimating or forecasting the future cash flows. Although this may seem to be a daunting task, firms with experience in producing and selling a particular type of product can usually generate fairly accurate estimates of sales volumes, prices and production costs. However, problems can arise with the cash flow estimates when a project team becomes 'enamoured' with a project. Wanting a project to succeed, a project team can be too optimistic about the cash flow projections.

Second, we must recognise that the calculated values for NPV are estimates based on management's informed judgement; they are not real market data. Like any estimate, they can be too high or too low. The only way to determine a project's 'true' NPV is to put the asset up for sale and see what price market participants are willing to pay for it. An example of this approach was the sale of our pizza restaurant; however, situations such as this are the exception, not the rule.

Finally, there is nothing wrong with using estimates to make business decisions as long as they are based on informed judgements and not guesses. Most business managers are routinely required to make decisions that involve expectations about future events. In fact, that is what business is really all about – dealing with uncertainty and making decisions that involve risk.

In conclusion, the NPV approach is the method we recommend for making capital investment decisions. The accompanying table summarises NPV decision rules and the method's key advantages and disadvantages.

Summary of Net Present Value (NPV) Method

Decision Rule: $NPV > 0$ ➪ Accept the project.
$NPV < 0$ ➪ Reject the project.

Key Advantages	Key Disadvantages
1. Uses the discounted cash flow valuation technique to adjust for the time value of money.	Can be difficult to understand without an accounting and finance background.
2. Provides a direct (monetary) measure of how much a capital project will increase the value of the firm.	
3. Consistent with the goal of maximising shareholder value.	

Before You Go On

1. What is the NPV of a project?
2. If a firm accepts a project with a €10 000 NPV, what is the effect on the value of the firm?
3. What are the five steps used in NPV analysis?

THE PAYBACK PERIOD

The payback period is one of the most widely used tools for evaluating capital projects. The **payback period** is defined as the number of years it takes for the cash flows from a project to recover the project's initial investment. With the payback method for evaluating projects, a project is accepted if its payback period is below some specified threshold. Although it has serious weaknesses, this method does provide some insight into a project's risk; the more quickly you recover the cash, the less risky is the project.

Payback period
the length of time required to recover a project's initial cost

Computing the Payback Period

Learning Objective 3
Describe the strengths and weaknesses of the payback period as a capital expenditure decision-making tool and be able to compute the payback period for a capital project.

To compute the payback period, we need to know the project's cost and estimate its future net cash flows. The net cash flows and the project cost are the same values that we used to compute the NPV calculations. The payback (PB) equation can be expressed as follows:

$$\text{PB} = \text{Years before cost recovery} + \frac{\text{Remaining cost to recover}}{\text{Cash flow during the year}} \qquad (10.2)$$

Exhibit 10.5 shows the net cash flows (row 1) and cumulative net cash flows (row 2) for a proposed capital project with an initial cost of €70 000. The payback period calculation for our example is:

$$\begin{aligned}\text{PB} &= \text{Years before cost recovery} + \frac{\text{Remaining cost to recover}}{\text{Cash flow during the year}}\\ &= 2\text{ years} + \frac{€70\,000 - €60\,000}{€20\,000}\\ &= 2\text{ years} + 0.5\\ &= 2.5\text{ years}\end{aligned}$$

We will now look at this calculation in more detail. Note in Exhibit 10.5 that the firm recovers cash flows of €30 000 in the first year and €30 000 in the second year, for a total of €60 000 over the two years. During the third year, the firm needs to recover only €10 000 (€70 000 – €60 000) to pay back the full cost of the project. The third-year cash flow is €20 000, so we will have to wait 0.5 year (€10 000/€20 000) to recover the final amount. Thus, the payback period for this project is 2.5 years (2 + 0.5).

The idea behind the payback period method is simple: the shorter the payback period, the faster the firm gets its money back and the more desirable the project. However, there is no economic rationale that links the payback method to shareholder value maximisation. Firms that use the payback method accept all projects having a

Time line (Year)	0	1	2	3	4
Net cash flow (NCF)	–€70,000	€30,000	€30,000	€20,000	€15,000
Cumulative NCF	–€70,000	–€40,000	–€10,000	€10,000	€25,000

Exhibit 10.5: Payback Period Cash Flows and Calculations The exhibit shows the net and cumulative net cash flows for a proposed capital project with an initial cost of €70 000. The cash flow data are used to compute the payback period, which is 2.5 years.

payback period under some threshold and reject those with a payback period over this threshold. If a firm has a number of projects that are mutually exclusive, the projects are selected in order of their payback rank – projects with the shortest payback period are selected first.

Learning by Doing Application 10.2

A Payback Calculation

Problem: A firm has two capital projects, A and B, which are under review for funding. Both projects cost €500 and the projects have the following cash flows:

Year	Project A	Project B
0	–€500	–€500
1	100	400
2	200	300
3	200	200
4	400	100

What is the payback period for each project? If the projects are independent, which project should management select? If the projects are mutually exclusive, which project should management accept? The firm's payback cut-off point is two years.

Approach: Use Equation (10.2) to calculate the number of years it takes for the cash flows from each project to recover the project's initial investment. If the two projects are independent, you should accept the projects that have a payback period that is less than or equal to two years. If the projects are mutually exclusive, you should accept the project with the shortest payback period if that payback period is also less than or equal to two years.

Solution: The payback for project A requires only that we calculate the first term in Equation (10.2) – years before recovery: the first year recovers €100, the second year €200 and the third year €200, for a total of €500 (€100 + 200 + €200). Thus, in three years, the €500 investment is fully recovered, so $PB_A = 3.00$.

For project B, the first year recovers €400 and the second year €300. Since we need only part of the second-year cash flow to recover the initial cost, we calculate both terms in Equation (10.2) to obtain the payback time.

$$PB = \text{Years before cost recovery} + \frac{\text{Remaining cost to recover}}{\text{Cash flow during the year}}$$

$$PB_A = 3 \text{ years}$$

$$PB_B = 1 \text{ year} + \frac{€500 - €400}{€300} = 1 \text{ year} + \frac{€100}{€300} = 1.33 \text{ years}$$

Whether the projects are independent or mutually exclusive, management should accept only project B since project A's payback period exceeds the two-year cut-off point.

How the Payback Period Performs

We have worked through some simple examples of how the payback period is computed. Now we will consider several more complex situations to see how well the payback period performs as a capital budgeting criterion. Exhibit 10.6 illustrates five different capital budgeting projects. The projects

EXHIBIT 10.6
PAYBACK PERIOD WITH VARIOUS CASH FLOW PATTERNS

Year	A	B	C	D	E
0	–€500	–€500	–€500	–€500	–€500
1	200	300	250	500	200
2	300	100	250	0	200
3	400	50	–250	0	200
4	500	0	250	–5000	5000
Payback (years)	2.0	∞	2.0/4.0	1.0/∞	2.5
NPV	€450	–€131	–€115	–€2924	€2815

Cost of capital = 15%

Each of the five capital budgeting projects shown in the exhibit calls for an initial investment of €500 but all have different cash flow patterns. The bottom part of the exhibit shows each project's payback period, along with its net present value for comparison.

all have an initial investment of €500 but each one has a different cash flow pattern. The bottom part of the exhibit shows each project's payback period, along with its net present value for comparison. We will assume that management has set a payback period of two years as the cut-off point for an acceptable project.

Project A: The cash flows for project A are €200 in the first year and €300 in the second, for a total of €500; thus, the project's payback period is two years. Under our acceptance criterion, management should accept this project. Project A also has a positive NPV of €450, so the two capital budgeting decision rules agree.

Project B: Project B never generates enough cash flows to pay off the original investment of €500: €300 + €100 + €50 = €450. Thus, the project payback period is infinite. With an infinite payback period, the project should be rejected. Also, as you would expect, project B's NPV is negative. So far, the payback period and NPV methods have agreed on which projects to accept.

Project C: Project C has a payback period of two years: €250 + €250 = €500. Thus, according to the payback criteria, it should be accepted. However, the project's NPV is a negative €115, which indicates that the project should be rejected. Why the conflict? Look at the cash flows after the payback period of two years. In year 3 the project requires an additional investment of €250 (a cash outflow) and now is in a deficit position; that is, the cash balance is now only €250 (€250 – €250 + €250). Then, in the final year, the project earns an additional €250, recovering the cost of the original investment. The project's payback is really four years. The payback period analysis can lead to erroneous decisions because the rule does not consider cash flows after the payback period.

Projects D and E: Projects D and E dramatically illustrate the problem when a capital budgeting evaluation tool fails to consider cash flows after the payback period. Project D has a payback period of one year, suggesting that it should be accepted, and project E has a payback period of 2.5 years, suggesting that it should be rejected. However, a simple look at the future cash flows suggests otherwise. It is clear that project D, with a negative €5000 cash flow in year 4, is a disaster and should be rejected, while project E, with a positive €5000 'windfall' in year 4, should be accepted.

Indeed, the NPV analysis confirms these conclusions: project D has a negative NPV of €2924 and project E has a positive NPV of €2815. In both instances, the payback rule led to the wrong economic decision. These examples illustrate that a rapid payback does not necessarily mean a good investment.

Discounted Payback Period

One of the weaknesses of the ordinary payback period is that it does not take into account the time value of money. All the monies received before the cut-off period are given equal weight. To address this problem, some financial managers use a variant of the payback period called the **discounted payback period**. This payback calculation is similar to the ordinary payback calculation except that the future cash flows are discounted by the cost of capital.

Discounted payback period

the length of time required to recover a project's initial cost, accounting for the time value of money

The major advantage of the discounted payback is that it tells management how long it takes a project to reach an NPV of zero. Thus, any capital project that meets a firm's decision rule must also have a positive NPV. This is an improvement over the standard payback calculation, which can accept projects with negative NPVs. Regardless of the improvement, the discounted payback method is not widely used by businesses and it still ignores all cash flows after the arbitrary cut-off period, which is a major flaw.

To see how the discounted payback period is calculated, turn to Exhibit 10.7. The exhibit shows the net cash flows for a proposed capital project along with both the cumulative and discounted cumulative cash flows; thus, we can compute both the ordinary and the discounted payback periods for the project and then compare them. The cost of capital is 10%.

The first two rows show the non-discounted cash flows and we can see by inspection that the ordinary payback period is two years. We do not need to make any additional calculations because the cumulative cash flows equal zero at precisely two years. Now let us turn our attention to the lower two rows, which show

Time line (Year)	0	1	2	3
Net cash flow (NCF)	–€40,000	€20,000	€20,000	€20,000
Cumulative NCF	–€40,000	–€20,000	€0	€20,000
Discounted NCF (at 10%)	–€40,000	€18,182	€16,529	€15,026
Cumulative discounted NCF	–€40,000	–€21,818	–€5,289	€9,737

Payback period = 2 years + 0/€20,000 = 2 years
Discounted payback period = 2 years + €5,289/€15,026 = 2.35 years
NPV = €49,737 – €40,000 = 9,737
Cost of capital = 10%

Exhibit 10.7: Discounted Payback Period Cash Flows and Calculations The exhibit shows the net and cumulative net cash flows for a proposed capital project with an initial cost of €40 000. The cash flow data are used to compare the discounted payback period for a 10% cost of capital, which is 2.35 years.

the project's discounted and cumulative discounted cash flows. Note that the first year's cash flow is €20 000 and its discounted value is €18 182 (€20 000 × 0.9091); the second year's cash flow is also €20 000 and its discounted value is €16 529 (€20 000 × 0.8264). Now, looking at the cumulative discounted cash flows row, notice that it turns positive between two and three years. This means that the discounted payback period is two years plus some fraction of the third year's discounted cash flow. The exact discounted payback period computed value is 2 + (€5289/€15 026) = 2 + 0.35 = 2.35.

As expected, the discounted payback period is longer than the ordinary payback period ($2 < 2.35$), and in 2.35 years the project will reach NPV = 0. The project NPV is positive (€9737); therefore, we should accept the project. But notice that the payback decision criteria are ambiguous. If we use 2.0 years as the payback criterion, we reject the project and if we use 2.5 or 3.0 years as criterion, the project is accepted. The lack of a definitive decision rule remains a major problem with the payback period as a capital budgeting tool.

Evaluating the Payback Rule

In spite of its lack of sophistication, the standard payback period is widely used in business in part because it provides an intuitive and simple measure of a project's liquidity risk. This makes sense because projects that pay for themselves quickly are less risky than projects whose paybacks occur further in the future. There is a strong feeling in business that 'getting your money back quickly' is an important standard when making capital investments. Probably the greatest advantage of the payback period is its simplicity; it is easy to calculate and easy to understand, making it especially attractive to business executives with little training in accounting and finance.

When compared with the NPV method, however, the payback method has some serious shortcomings. First, the standard payback method does not use discounting; hence, it ignores the time value of money. Second, it does not adjust or account for differences in the riskiness of projects. Another problem is that there is no economic rationale for establishing cut-off criteria. Who is to say that a particular cut-off, such as two years, is optimal with regard to maximising shareholder value?

Finally, perhaps the greatest shortcoming of the payback method is its failure to consider cash flows after the payback period, as illustrated by projects D and E in Exhibit 10.6. This is true whether or not the cash flows are discounted. As a result of this feature, the payback method is biased towards shorter-term projects, which tend to free up cash more quickly. Consequently, projects for which cash inflows tend to occur further in the future, such as research and development investments, new product launches and entry into new lines of business, are at a disadvantage when the payback method is used. The accompanying table summarises major features of the payback period.

Summary of Payback Method

Decision Rule: Payback period ≤ Payback cut off point ➩ Accept the project.
Payback period > Payback cut off point ➩ Reject the project.

	Key Advantages	Key Disadvantages
1.	Easy to calculate and understand for people without a strong finance background.	Most common version does not account for time value of money.
2.	A simple measure of a project's liquidity.	Does not consider cash flows past the payback period.
3.		Bias against long-term projects such as research and development and new product launches.
4.		Arbitrary cut-off point.

Before You Go On

1. What is the payback period?
2. Why does the payback period provide a measure of a project's liquidity risk?
3. What are the main shortcomings of the payback method?

THE ACCOUNTING RATE OF RETURN

Learning Objective 4

Explain why the accounting rate of return (ARR) is not recommended for use as a capital expenditure decision-making tool.

We turn next to a capital budgeting technique based on the **accounting rate of return** (**ARR**), sometimes called the *book value rate of return*. This method computes the return on a capital project using accounting numbers – the project's net income (NI) and book value (BV) – rather than cash flow data. The ARR can be calculated in a number of ways, but the most common definition is:

$$\text{ARR} = \frac{\text{Average net income}}{\text{Average book value}} \qquad (10.3)$$

where:

Average net income $= (\text{NI}_1 + \text{NI}_2 + \cdots + \text{NI}_n)/n$
Average book value $= (\text{BV}_1 + \text{BV}_2 + \cdots + \text{BV}_n)/n$
$n =$ the project's estimated life

Accounting rate of return (ARR)

a rate of return on a capital project based on average net income divided by average assets over the project's life; also called the *book value rate of return*

Although ARR is fairly easy to understand and calculate, as you probably guessed, it has a number of major flaws as a tool for evaluating capital expenditure decisions. Besides the fact that AAR is based on accounting numbers rather than cash flows, it is not really even an accounting-based rate of return. Instead of discounting a project's cash flows over time, it simply gives us a number based on average figures from the income statement and balance sheet. Thus, the ARR ignores the time value of money. Also, as with the payback method, there is no economic rationale that links a particular acceptance criterion to the goal of maximising shareholder value.

Because of these major shortcomings, the ARR technique should not be used to evaluate the viability of capital projects under any circumstances. You may wonder why we even included the ARR technique in the book if it is a poor criterion for evaluating projects. The reason is simply that we want to be sure that if you run across the ARR method at work, you will recognise it and be aware of its shortcomings.

Before You Go On

1. What are the major shortcomings of using the ARR method as a capital budgeting method?

INTERNAL RATE OF RETURN

Learning Objective 5

Be able to compute the internal rate of return (IRR) for a capital project and discuss the conditions under which the IRR technique and the NPV technique produce different results.

The **internal rate of return**, known in practice as the **IRR**, is an important and legitimate alternative to the NPV method. The NPV and IRR techniques are closely related in that both involve discounting the cash flows from a project; thus, both account for the time value of money. When we use the NPV method to evaluate a capital project, the discount rate is the rate of return required by investors for investments with similar risk, which is the project's opportunity cost of capital. When we use the IRR, we are looking for the rate of return associated with a project so that we can determine whether this rate is higher or lower than the project's opportunity cost of capital.

Internal rate of return (IRR)

the discount rate at which the present value of a project's expected cash inflows equals the present value of the project's outflows

We can define the IRR as the discount rate that equates the present value of a project's expected cash inflows to the present value of the project's outflows:

$$\text{PV(Project's future cash flows)} = \text{PV(Cost of the project)}$$

This means that we can also describe the IRR as the discount rate that causes the NPV to equal zero. This relation can be written in a general form as follows:

$$\text{NPV} = \text{NCF}_0 + \frac{\text{NCF}_1}{1+\text{IRR}} + \frac{\text{NCF}_2}{(1+\text{IRR})^2} + \cdots + \frac{\text{NCF}_n}{(1+\text{IRR})^n} = \sum_{t=0}^{n} \frac{\text{NCF}_t}{(1+\text{IRR})^t} = 0 \qquad (10.4)$$

Because of their close relation, it may seem that the IRR and the NPV are interchangeable – that is, either should accept or reject the same capital projects. After all, both methods are based on whether the project's return exceeds the cost of capital and, hence, whether the project will add value to the firm. In many circumstances, the IRR and NPV methods do give us the same answer. As you will see later, however, some of the mathematical properties of the IRR equation can lead to incorrect decisions concerning whether to accept or reject a particular capital project.

Calculating the IRR

The IRR is an expected rate of return like the yield to maturity we calculated for bonds in Chapter 8. Thus, in calculating the IRR, we need to apply the same trial-and-error method we used in Chapter 8. We will be doing IRR calculations by trial and error and interpolation so that you understand the process, but in practice it is helpful to use a spreadsheet or a financial calculator.

Trial-and-Error Method

Suppose that Volkswagen has an investment opportunity with cash flows as shown in Exhibit 10.8 and that the cost of capital is 12%. We want to find the IRR for this project. Using Equation (10.4), we will substitute various values for IRR into the equation to compute the project's IRR by trial and error. We continue this process until we find the IRR value that makes Equation (10.4) equal zero.

A good starting point is to use the cost of capital as the discount rate. Note that when we discount the NCFs by the cost of capital, we are calculating the project's NPV:

$$\text{NPV} = \text{NCF}_0 + \frac{\text{NCF}_1}{1+\text{IRR}} + \frac{\text{NCF}_2}{(1+\text{IRR})^2} + \cdots + \frac{\text{NCF}_n}{(1+\text{IRR})^n}$$

$$\text{NPV}_{12\%} = -€560 + \frac{€240}{1.12} + \frac{€240}{(1.12)^2} + \frac{€240}{(1.12)^3} = €16.44$$

Recall that the result we are looking for is zero. Because our result is €16.44, the discount rate of 12% is too low and we must try a higher rate. We will try 13%:

$$\text{NPV}_{13\%} = -€560 + \frac{€240}{1.13} + \frac{€240}{(1.13)^2} + \frac{€240}{(1.13)^3} = €6.68$$

	0	1	2	3 Year
Time line				
Net cash flow	–€560	€240	€240	€240

IRR = 13.7%
Cost of capital = 12%
NPV = €576.44 – €560.00 = €16.44

Exhibit 10.8: Time Line and Expected Net Cash Flows for the Volkswagen Project (€ thousands) The cash flow data in the exhibit are used to compute the project's IRR, which is 13.7%. Since the IRR is higher than Volkswagen's cost of capital, the IRR criterion indicates the project should be accepted. The project's NPV is also a positive €16 440, which indicates that Volkswagen should accept the project. Thus, the IRR and NPV methods have reached the same conclusion.

We are very close. We will try 14%:

$$NPV_{14\%} = -€560 + \frac{€240}{1.14} + \frac{€240}{(1.14)^2} + \frac{€240}{(1.14)^3}$$
$$= -€2.81$$

Because our result is now a negative number, we know the correct rate is between 13% and 14%, and looking at the magnitude of the numbers, we know that the answer is closer to 14%. Using interpolation, we find that the IRR is 13.7%:

$$i_{unknown} = i_{low} + \frac{(\text{Value}_{low\ i} - \text{Value}_{unknown\ i})}{(\text{Value}_{low\ i} - \text{Value}_{high\ i})} \times (i_{high} - i_{low})$$

$$IRR = 13\% + \frac{€6.68 - €0}{€6.68 + €2.81} \times (14\% - 13\%)$$
$$= 13\% + \frac{€6.68}{€9.49} \times 1\%$$
$$= 13\% + 0.7039 \times 1\% = 13.7\%$$

This means that the NPV of Volkswagen's capital project is zero at a discount rate of 13.7%. Volkswagen's required rate of return is the cost of capital, which is 12.0%. Since the project's IRR of 13.7% exceeds Volkswagen's cost of capital, the IRR criterion indicates that the project should be accepted.

The project's NPV is a positive €16 440, which also indicates that Volkswagen should go ahead with the project. Thus, both the IRR and NPV have reached the same conclusion.

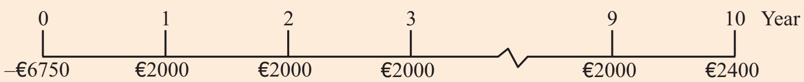
Learning by Doing Application 10.3

Calculating the IRR at Giuseppe's Gelateria

Problem: Giuseppe's Gelateria, based in Rome, is famous for its gourmet ice cream. However, some customers have asked for a low-calorie, soft yoghurt ice cream. The machine that makes this confection costs €5000 plus €1750 for installation. Giuseppe estimates that the machine will generate a net cash flow of €2000 a year (the shop closes during November–March of each year). Giuseppe also estimates the machine's life to be 10 years and that it will have a €400 salvage value. His cost of capital is 15%. Giuseppe thinks the machine is overpriced and as a result he will lose money on his investment. Is he right?

Approach: The IRR for an investment is the discount rate at which the NPV is zero. Thus, we can use Equation (10.4) to solve for the IRR and then compare this value with Giuseppe's cost of capital. If the IRR is greater than the cost of capital, the project has a positive NPV and should be accepted.

Solution: The total cost of the machine is €6750 (€5000 + €1750), and the final cash flow at year 10 is €2400 (€2000 + €400).



$$\text{NPV} = \text{NCF}_0 + \frac{\text{NCF}_1}{1+\text{IRR}} + \frac{\text{NCF}_2}{(1+\text{IRR})^2} + \cdots + \frac{\text{NCF}_n}{(1+\text{IRR})^n} = 0$$

$$\text{NPV}_{15\%} = -€6750 + \frac{€2000}{1.15} + \frac{€2000}{(1.15)^2} + \cdots + \frac{€2400}{(1.15)^3} = €3386.41$$

$$\text{NPV}_{27.08\%} = -€6750 + \frac{€2000}{1.2708} + \frac{€2000}{(1.2708)^2} + \cdots + \frac{€2400}{(1.2708)^3} = €0$$

The hand trial-and-error calculations are shown in these equations. The first calculation uses 15%, the cost of capital, our recommended starting point, and the answer is €3386.41 (which is also the project's NPV). Because the value is a positive number, we need to use a larger discount rate than 15%. Our guess based on interpolating 25% and 30% is 27.08%. At that value, NPV = 0; thus, the IRR for the yoghurt machine is 27.08%.

Because the project's IRR exceeds Giuseppe's cost of capital of 15%, the project should be accepted. Giuseppe is wrong.

When the IRR and NPV Methods Agree

In the Volkswagen example, the IRR and NPV methods agree. The two methods will *always* agree when you are evaluating *independent* projects and the projects' cash flows are *conventional*. As discussed earlier, an independent project is one that can be selected with no effect on any other project, assuming the firm faces no resource constraints. A project with **conventional cash flows** is one with an initial cash outflow followed by one or more future cash inflows. Put another way, after the initial investment is made (cash outflow), all the cash flows in each future year are positive (inflows). For example, the purchase of a bond involves a conventional cash flow. You purchase the bond for a price (cash outflow), and in the future you receive coupon payments and a principal payment at maturity (cash inflows).

Conventional cash flow

a cash flow pattern made up of an initial cash outflow that is followed by one or more cash inflows

Let us look more closely at the kinds of situations in which the NPV and the IRR methods agree. A good way to visualise the relation between the

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USING EXCEL

Internal Rate of Return

You know that calculating the IRR by hand can be tedious. The trial-and-error method with interpolation can take a long time and can lead to mistakes being made. Knowing all the cash flows and an approximate discount rate will allow you to use a spreadsheet formula to get the answer instantly.

The accompanying spreadsheet shows the layout and formula for calculating the IRR for the low-calorie yoghurt machine at Giuseppe's Gelateria that is described in Learning by Doing Application 10.3.

Here are a couple of important points to note about IRR calculations using spreadsheet programs:

	A	B	C	D	E
1					
2		**IRR Calculations**			
3					
4		**Year**		**Cash Flow**	
5		0		-€ 6,750	
6		1		€ 2,000	
7		2		€ 2,000	
8		3		€ 2,000	
9		4		€ 2,000	
10		5		€ 2,000	
11		6		€ 2,000	
12		7		€ 2,000	
13		8		€ 2,000	
14		9		€ 2,000	
15		10		€ 2,400	
16					
17		Cost of capital		0.15	
18					
19		IRR		27.08%	
20		Formula used		IRR(E5:E15, E17)	
21					
22	Remember to keep track of signs – cash outflows are				
23	negative and cash inflows are positive				
24					

1. Unlike the NPV formula, the IRR formula accounts for all cash flows, including the initial investment in year 0, so there is no need to add this cash flow later.
2. In order to calculate the IRR, you will need to provide a 'guess' value, or a number you estimate is close to the IRR. A good value to start with is the cost of capital. To learn more about why this value is needed, you should go to your spreadsheet's help menu and search for 'IRR'.

IRR and NPV methods is to graph NPV as a function of the discount rate. The graph, called an **NPV profile**, shows the NPV of the project at various costs of capital.

NPV profile

a graph showing NPV as a function of the discount rate

Exhibit 10.9 shows the NPV profile for the Volkswagen project. We have placed the NPVs on the vertical axis, or y-axis, and the discount rates on the horizontal axis, or x-axis. We used the calculations from our earlier example and made some additional NPV calculations at various discount rates, as follows:

Discount Rate	NPV (€ thousands)
0%	€160
5	94
10	37
15	–12
20	–54
25	–92
30	–124

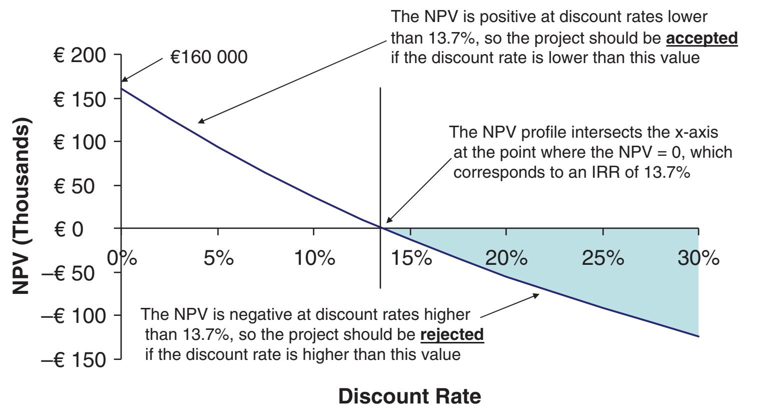


Exhibit 10.9: NPV Profile for the Volkswagen Project In the NPV profile for the Volkswagen project, the NPV value is on the vertical (*y*)-axis and the discount rate is on the horizontal (*x*)-axis. You can see that as the discount rate increases, the NPV profile curve declines smoothly and intersects the *x*-axis at precisely the point where the NPV is 0 and the IRR is 13.7% – the point at which the NPV changes from a positive to a negative value. Thus, the NPV and IRR methods lead to identical accept or reject decisions for the Volkswagen project.

As you can see, a discount rate of 0% corresponds to an NPV of €160 000; a discount rate of 5% to an NPV of €94 000; and so forth. As the discount rate increases, the NPV curve declines smoothly. Not surprisingly, the curve intersects the *x*-axis at precisely the point where the NPV is 0 and the IRR is 13.7%.

The NPV profile in Exhibit 10.9 illustrates why the NPV and IRR methods lead to identical accept/reject decisions for the Volkswagen project. The IRR of 13.7% precisely marks the point at which the NPV changes from a positive to a negative value. Whenever a project is independent and has conventional cash flows, the result will be as shown in the exhibit. The NPV will decline as the discount rate increases and the IRR and the NPV methods will result in the same capital expenditure decision.

When the NPV and IRR Methods Disagree

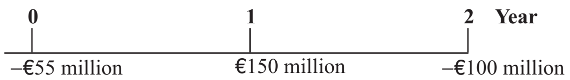
We have seen that the IRR and NPV methods lead to identical investment decisions for capital projects that are independent and that have conventional cash flows. However, if either of these conditions is not met, the IRR and NPV methods can produce different accept/reject decisions.

Unconventional Cash Flows

Unconventional cash flows can cause a conflict between the NPV and IRR decision rules. In some instances the cash flows for an unconventional project are just the reverse of those of a conventional project: the initial cash flow is positive and all subsequent cash flows are negative. For example, consider a life insurance company that sells a lifetime annuity to a retired person. The company receives a single cash payment, which is the price of the annuity (cash inflow), and then makes monthly payments to the retiree for the rest of his or her life (cash outflows). In this case, we need only reverse the IRR decision rule and accept the project if the IRR is *less* than the cost of capital to make the IRR and NPV methods agree. The intuition in this example is that the life insurance company is effectively borrowing money from the retiree and the IRR is a measure of the cost of that money. The cost of capital is the rate at which the life insurance company can borrow elsewhere. An IRR less than the cost of capital means that the lifetime annuity provides the insurance company with money at a lower cost than alternative sources.

When a project's future cash flows include both positive and negative cash flows, the situation is more complicated. An example of such a project is an assembly line that will require one or more major renovations over its lifetime. Another common business situation is a project that has conventional cash flows except for the final cash flow, which is negative. The final cash flow might be negative because extensive environmental cleanup is required at the end of the project, such as the cost for decommissioning a nuclear power plant, or because the equipment originally purchased has little or no salvage value and is expensive to remove.

Consider an example. Suppose a firm invests in a gold-mining operation that costs €55 million and has an expected life of two years. In the first year, the project generates a cash inflow of €150 million. In the second year, extensive environmental and site restoration is required, so the expected cash flow is a negative €100 million. The time line for these cash flows follows:



Once again, the best way to understand the effect of these cash flows is to look at an NPV profile. Shown here are NPV calculations we made at various discount rates to generate the data necessary to plot the NPV profile shown in Exhibit 10.10:

Discount Rate	NPV (€ millions)
0%	−€5.00
10	−1.28
20	0.56
30	1.21
40	1.12
50	0.56
60	−0.31
70	−1.37

Looking at the data in the table, you can probably spot a problem. The NPV is initially negative (−€5.00); then, at a discount rate of 20%, switches to positive (€0.56); and then, at a discount rate of 60%, switches back to negative (−€0.31).

The NPV profile in Exhibit 10.10 shows the results of this pattern: we have two IRRs, one at 16.05% and the other at 55.65%. Which is the correct IRR, or are both correct? Actually, there is no correct answer; the results are meaningless and you should not try to interpret them. Thus, in this situation, the IRR technique provides information that is suspect and should not be used for decision making.

How many IRR solutions can there be for a given cash flow? The maximum number of IRR solutions is equal to the number of sign reversals in the cash flow stream. For a project with a conventional cash flow, there is only one cash flow sign reversal; thus, there is only one IRR solution. In our mining example, there are two cash flow sign reversals; thus, there are two IRR solutions.

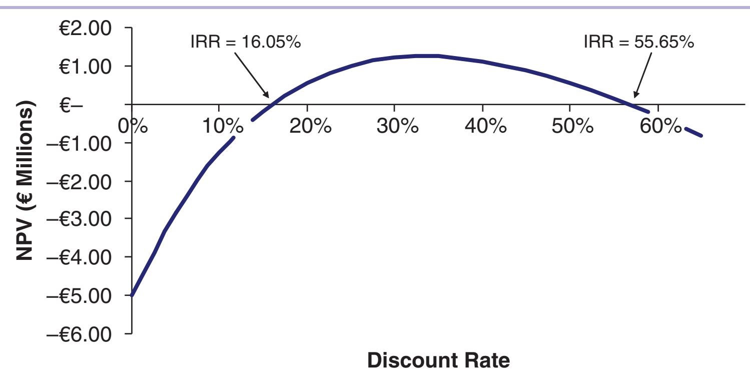


Exhibit 10.10: NPV for Gold Mining Operation Showing Multiple IRR Solutions The gold mining operation has unconventional cash flows. Because there are two cash flow sign reversals, we end up with two IRRs – 16.05% and 55.65% – neither of them correct. In situations like this, the IRR provides a solution that is suspect and therefore, the results should not be used for capital budgeting decisions.

Finally, for some cash flow patterns, it is impossible to compute an IRR. These situations can occur when the initial cash flow ($t = 0$) is either a cash inflow or outflow and is followed by cash flows with two or more sign reversals. An example of such a cash flow pattern is NCF_0 = €15, NCF_1 = −€25 and NCF_2 = €20. This type of cash flow pattern might occur on a building project where the contractor is given a prepayment, usually the cost of materials and supplies (€15); then does the construction and pays the labour cost (−€25); and finally, upon completion of the work, receives the final payment (€20). Note that when it is not possible to compute an IRR, the project either has a positive NPV or a negative NPV for all possible discount rates. In this example, the NPV is always positive.

Mutually Exclusive Projects

The other situation in which the IRR can lead to incorrect decisions is when capital projects are mutually exclusive – that is, when accepting one project means rejecting the other. For example, suppose you own a small store in the business district of Frankfurt that is currently vacant. You are looking at two business opportunities: opening an upscale coffee house or opening a copy centre. Clearly, you cannot pursue both projects at the same location; these two projects are mutually exclusive.

When you have mutually exclusive projects, how do you select the best alternative? If you are using the NPV method, the answer is easy. You select the project that has the highest NPV because it will increase the value of the firm by the largest amount. If you are using the IRR method, it would seem logical to select the project with the highest IRR. In this case, though, the logic is wrong! You cannot tell which mutually exclusive project to select just by looking at the projects' IRRs.

We will consider another example to illustrate the problem. The cash flows for two projects, A and B, are as follows:

Year	Project A	Project B
0	−€100	−€100
1	50	20
2	40	30
3	30	50
4	30	65

The IRR is 20.7% for project A and 19.0% for project B. Because the two projects are mutually exclusive, only one project can be accepted. If you were following the IRR decision rule, you would accept project A. However, as you will see, it turns out that project B might be the better choice.

The following table shows the NPVs for the two projects at several discount rates:

Discount Rate	NPV of Project A	NPV of Project B
0%	€50.0	€65.0
5%	34.5	42.9
10%	21.5	24.9
13%	14.8	15.7
15%	10.6	10.1
20%	1.3	−2.2
25%	−6.8	−12.6
30%	−13.7	−21.3
IRR	20.7%	19.0%

Notice that the project with the higher NPV depends on what rate of return is used to discount the cash flows. Our example shows a conflict in ranking order between the IRR and NPV methods at discount rates between 0% and 13%. In this range, project B has the lower IRR but it has the higher NPV and should be the project selected. If the discount rate is above 15%, however, project A has the higher NPV as well as the higher IRR. In this range there is no conflict between the two evaluation methods.

Now take a look at Exhibit 10.11, which shows the NPV profiles for projects A and B. As you can see, there is a point, called the **crossover point**, at which the NPV profiles for projects A and B intersect. The crossover point here is at a discount rate of 14.3%. For any cost of capital above 14.3%, the NPV for project A is higher than that for project B; thus, project A should be selected if its NPV is positive. For any cost of capital below the crossover point, project B should be selected.

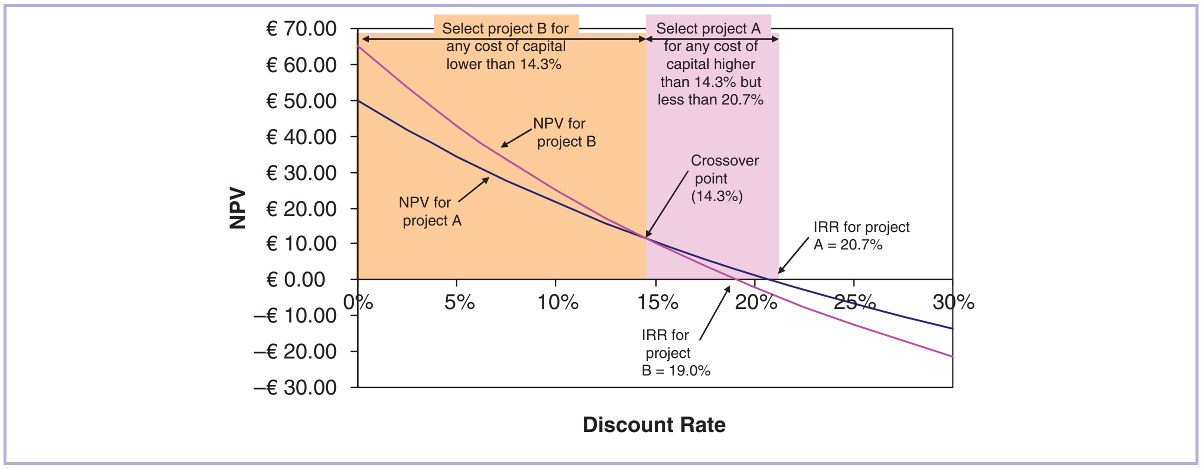


Exhibit 10.11: NPV Profiles for Two Mutually Exclusive Projects
The NPV profiles for two projects often cross over each other. When evaluating mutually exclusive projects, it is helpful to know where this crossover point is. For projects A and B in the exhibit, the crossover point is 14.3%. For any cost of capital above 14.3% but below 20.7%, the NPV for project A is higher than that for project B and is positive; thus, project A should be selected. For any cost of capital below the crossover point, the NPV of project B is higher and project B should be selected.

Crossover point

the discount rate at which the NPV profiles of two projects cross and, thus, at which the NPVs of the projects are equal

Another conflict involving mutually exclusive projects concerns comparisons of projects that have significantly different costs. The IRR does not adjust for these differences in size. What the IRR gives us is a rate of return on each unit of currency invested. In contrast, the NPV method computes the total monetary value created by the project. The difference in results can be significant, as can be seen in Decision-Making Example 10.2.

Decision-Making Example 10.2

The Lemonade Stand versus the Mini Market Store

Situation: Suppose you work for an entrepreneur who owns a number of small businesses in Barcelona, Spain, as well as a small piece of property near Barcelona University, which he believes would be an ideal site for a student-oriented mini market store. His 12-year-old son, who happens to be in the office after school, says he has a better idea: his father should open a lemonade stand. Your boss tells you to find the NPV and IRR for both projects, assuming a 10% discount rate. After collecting data, you present the following analysis:

Year	Lemonade Stand	Mini Market Store
0	–€1 000	–€1 000 000
1	850	372 000
2	850	372 000
3	850	372 000
4	850	372 000
IRR	76.2%	18.0%
NPV	€1 694	€179 190

Assuming the projects are mutually exclusive, which should be selected?

Decision: Your boss, who favours the IRR method, looks at the analysis and declares his son a genius. The IRR decision rule suggests that the lemonade stand, with its 76.2% rate of return, is the project to choose! You point out that the goal of capital budgeting is to select projects or combinations of projects that maximise the value of the firm, his business. The mini market store adds by far the greater value: €179 190 compared with only €1694 for the lemonade stand. Although the lemonade stand has a high rate of return, its small size precludes it from being competitive against the larger project.[2]

Modified Internal Rate of Return (MIRR)

A major weakness of the IRR method compared with the NPV method concerns the rate at which the cash flows generated by a capital project are reinvested. The NPV method assumes that cash flows from a project are reinvested at the cost of capital, whereas the IRR technique assumes they are reinvested at the IRR. Determining which is the better assumption depends on which rate better represents the rate that firms can actually earn when they reinvest a project's cash flows over time. It is generally believed that the cost of capital, which is often lower than the IRR, better reflects the rate that firms are likely to earn. Using the IRR may thus involve overly optimistic assumptions regarding reinvestment rates.

To eliminate the reinvestment rate assumption of the IRR, some practitioners prefer to calculate the **modified internal rate of return (MIRR)**. In this approach, each operating cash flow is converted to a future value at the end of the project's life, compounded at the cost of capital. These values are then summed up to get the project's *terminal value (TV)*. The MIRR is the interest rate that equates the project's cost (PV_{cost}), or cash outflows, with the future value of the project's cash inflows at the end of the project (PV_{TV}).[3] Because each future value is computed using the cost of capital as the interest rate, the reinvestment rate problem is eliminated.

Modified internal rate of return (MIRR)

an internal rate of return (IRR) measure which assumes that cash inflows are reinvested at the opportunity cost of capital until the end of the project

We can set up the equation for the MIRR in the same way we set up Equation (10.4) for the IRR:

$$\begin{aligned} \text{PV(Cost of the project)} &= \text{PV(Cash inflows)} \\ PV_{cost} &= PV_{TV} \\ PV_{cost} &= \frac{TV}{(1+\text{MIRR})^n} \end{aligned} \qquad (10.5)$$

To compute the MIRR, we have to make two preliminary calculations. First, we need to calculate the value of PV_{cost}, which is the present value of the cash outflows that make up the investment cost of the project. Since for most capital projects, the investment cost cash flows are incurred at the beginning of the project, $t = 0$, there is often no need to calculate a present value. If investment costs are incurred over time ($t > 0$), then the cash flows must be discounted at the cost of capital for the appropriate time period.

Second, we need to compute the terminal value (TV). To do this, we find the future value of each operating cash flow at the end of the project's life, compounded at the cost of capital. We then sum up these future values to get the project's TV. Mathematically, the TV can be expressed as:

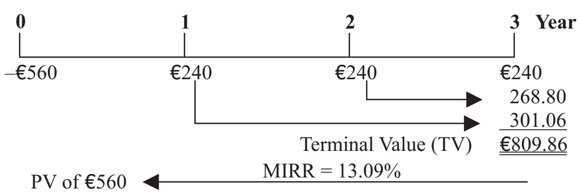
$$\begin{aligned}TV &= CF_1 \times (1+k)^{n-1} + CF_2 \times (1+k)^{n-2} + \cdots \\ &\quad + CF_n \times (1+k)^{n-n} \\ &= \sum_{t=1}^{n} CF_t \times (1+k)^{n-t}\end{aligned}$$

where:

TV = the project's terminal value
CF_t = cash flow from operations in period t
k = the cost of capital
n = the project life

Once we have computed the values of PV_{cost} and TV, we use Equation (10.5) to compute the MIRR.

To illustrate, let us return to the Volkswagen example shown in Exhibit 10.8. Recall that the cost of the project is €560, incurred at $t = 0$ and that the discount rate is 12%. To determine the MIRR for the project, we start by calculating the terminal value of the cash flows, as shown on the following time line:



The terminal value of €809.86 equals the sum of the €240 in year 1 compounded at 12% for two years plus the €240 in year 2 compounded at 12% for 1 year plus the €240 in year 3. Mathematically, this calculation is:

$$\begin{aligned}TV &= CF_1 \times (1+k)^{n-1} + CF_2 \times (1+k)^{n-2} + \cdots \\ &\quad + CF_n \times (1+k)^{n-n} \\ &= €240 \times (1.12)^2 + €240 \times (1.12) + €240 \\ &= €809.86\end{aligned}$$

With the information that the cost of the project is €560 and the TV is €809.86, we can calculate the MIRR using Equation (10.5):

$$\begin{aligned}PV_{cost} &= \frac{TV}{(1+MIRR)^n} \\ €560 &= \frac{€809.86}{(1+MIRR)^3} \\ (1+MIRR)^3 &= \frac{€809.86}{€560} = 1.4462 \\ (1+MIRR) &= \sqrt[3]{(1.4462)} = 1.1309 \\ MIRR &= 1.1309 - 1 = 0.1309 = 13.09\%\end{aligned}$$

At 13.09%, the MIRR is higher than Volkswagen's cost of capital of 12%, so the project should be accepted.

IRR versus NPV: A Final Comment

The IRR method, as noted, is an important alternative to the NPV method. As we have seen, it accounts for the time value of money, which is not true of methods such as the payback period and accounting rate of return. Furthermore, the IRR technique has great intuitive appeal. Many business practitioners are in the habit of thinking in terms of rates of return, whether the rates relate to their equity portfolios or their firms' capital expenditures. To these practitioners, the IRR method just seems to make sense. Indeed, we suspect that the IRR's popularity with business managers results more from its simple intuitive appeal than from its merit.

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To read an article that warns finance managers using the IRR about the method's pitfalls, visit: www.cfo.com/printable/article.cfm/3304945?f=options.

On the downside, we have seen that the IRR method has several flaws. One of these can be eliminated by using the MIRR. Nevertheless, we believe that the NPV should be the primary method used to make capital budgeting decisions. Decisions made by the NPV method are consistent with the goal of maximising the value of the firm's shares, and the NPV tells management the amount by which each project is expected to increase the value of the firm.

Review of Internal Rate of Return (IRR)

Decision Rule:

IRR > Cost of capital ⇨ Accept the project.
IRR < Cost of capital ⇨ Reject the project.

Key Advantages	Key Disadvantages
1. Intuitively easy to understand.	With non-conventional cash flows, IRR approach can yield no usable answer or multiple answers.
2. Based on discounted cash flow technique.	A lower IRR can be better if a cash inflow is followed by cash outflows.
3.	With mutually exclusive projects, IRR can lead to incorrect investment decisions.

CAPITAL BUDGETING IN PRACTICE

Learning Objective 6

Explain the benefits of a post-audit review of a capital project.

Capital expenditures are major investments for firms and for economies as a whole. For the second quarter of 2009, the gross fixed capital formation for the 16 countries of the Eurozone was €448.6 billion and for the year 2008, it was €20 020.8 billion.

Capital investments also represent large expenditures for individual firms, though the amount spent can vary widely from year to year. For example, over the last several years, the European Aeronautic Defence and Space Company NV (EADS), the parent company of Airbus described in the opening vignette, has been spending billions of euros in capital expenditure as the following table shows:

	Y2004	Y2005	Y2006	Y2007	Y2008
Capital expenditure (€ millions)	€3673	€2858	€2855	€2058	€1837
Capital expenditure as a percentage of Sales	11.56	8.36	7.24	5.26	4.25
Capital expenditure as a percentage of Total Assets	18.80	13.17	12.08	8.27	7.67

Before You Go On

1. What is the IRR method?
2. In capital budgeting, what is a conventional cash flow pattern?
3. Why should the NPV method be the primary decision tool used in making capital investment decisions?

The large expenditures between 2004 and 2007 relate to the investments required to launch the A380 Airbus, although EADS has invested heavily in other projects, such as the A400M military transport. Given the large sums and the strategic importance of capital expenditures, it should come as no surprise that corporate managers spend considerable time and energy analysing them.

EXHIBIT 10.12

CAPITAL BUDGETING TECHNIQUES USED BY BUSINESS FIRMS

Capital Budgeting Tool	US*	UK	Netherlands	Germany	France
Payback period	56.7	69.2	64.7	50.0	50.9
Accounting rate of return (ARR)	20.3	38.1	25.0	32.2	16.1
Internal rate of return (IRR)	75.6	53.1	56.0	42.2	44.1
Net present value (NPV)	74.9	47.0	70.0	47.6	35.1

*Data for the USA relates to 1999; data for European firms was collected in 2002.

Source: D. Brounen, A. de Jong and K. Koedij, 'Corporate finance in Europe: confronting theory with practice', *Financial Management*, Winter 2004. Reproduced by permission of Wiley-Blackwell.

The exhibit summarises evidence that examined the use of capital budgeting techniques by European and United States businesses using the same method of investigation. While NPV was the most used technique in the USA, it was only the most popular technique in the Netherlands. In the other countries surveyed the payback period was the dominant technique. Surprisingly, the accounting rate of return method was used by over a quarter of respondents in Europe.

Practitioners' Methods of Choice

Given the importance of capital budgeting, over the years a number of surveys have asked financial managers what techniques they actually use in making capital investment decisions. Exhibit 10.12, which summarises the results from a large-scale survey of European CFOs, shows the percentage of firms that use the different techniques.

Exhibit 10.12 shows that, rather surprisingly, the payback period is the most frequently used capital budgeting tool. In comparison, for the USA, it is only the third most popular tool after IRR and NPV, which are used regularly by three-quarters of the firms surveyed. Amongst European firms the use of discounting techniques is much less common. Only the Netherlands shows a marked preference for NPV, with 70% of firms using this method regularly, although payback is the second most popular method. In the other countries surveyed, the choice of NPV versus IRR differs depending on the country, with the UK and France showing a slight preference for IRR over NPV and Germany the opposite. However, the use of the techniques is not as advanced in these countries, with the highest utilisation rate being for IRR in the UK at just over half of firms and the lowest in Germany where only four in ten firms use the technique. The results also indicate that financial managers use multiple capital budgeting tools for analysing capital projects.

Ongoing and Post-Audit Reviews

Management should systematically review the status of all ongoing capital projects and perform post-audit reviews on all completed capital projects. In a **post-audit review**, management compares the actual performance of a project with what was projected in the capital budgeting proposal. For example, suppose a new passenger aircraft variant was expected to earn a 20% IRR but the product's actual IRR turned out to be 9%. A post-audit examination would determine why the project failed to achieve its expected financial goals. Project reviews keep all people involved in the capital budgeting process honest because they know that the project and their performance will be reviewed and that they will be held accountable for the results.

Post-audit review

an audit to compare actual project results with the results projected in the capital budgeting proposal

Managers should also conduct *ongoing reviews* of capital projects in progress. Such a review should challenge the business plan, including the cash flow projections and the operating cost assumptions. For example, Airbus undoubtedly has periodically reviewed the viability of its A380 project and made adjustments to reflect changing market conditions for wide-bodied aircraft. Business plans are management's best estimates of future events at the time they are prepared but as new information becomes available, the decision to undertake a capital project and the nature of that project must be reassessed.

Management must also evaluate people responsible for implementing a capital project. They should monitor whether the project's revenues and expenses are meeting projections. If the project is not at plan, the difficult task for management is to determine whether the problem is a flawed plan or poor execution by the implementation team. Good plans can fail if they are poorly executed at the operating level.

Before You Go On

1. What do you think accounts for the prevalence of the payback period as the dominant capital budgeting tool used by European companies?

SUMMARY OF LEARNING OBJECTIVES

1. **Discuss why capital budgeting decisions are the most important investment decisions made by a firm's management.**

   Capital budgeting is the process by which management decides which productive assets the firm should invest in. Because capital expenditures involve large amounts of money, are critical to achieving the firm's strategic plan, define the firm's line of business over the long term and determine the firm's profitability for years to come, they are considered the most important investment decisions made by management.
2. **Explain the benefits of using the net present value (NPV) method to analyse capital expenditure decisions and be able to calculate the NPV for a capital project.**

   The net present value (NPV) method leads to better investment decisions than other techniques because the NPV method does the following: (1) it uses the discounted cash flow valuation approach, which accounts for the time value of money, and (2) provides a direct measure of how much a capital project is expected to increase the value of the firm. Thus, NPV is consistent with the top management goal of maximising shareholder value. NPV calculations are described, see also Learning by Doing Application 10.1.
3. **Describe the strengths and weaknesses of the payback period as a capital expenditure decision-making tool and be able to compute the payback period for a capital project.**

   The payback period is the length of time it will take for the cash flows from a project to recover the cost of the project. The payback period is widely used, mainly because it is simple to apply and easy to understand. It also provides a simple measure of liquidity risk because it tells management how quickly the firm will get its money back. The payback period has a number of shortcomings, however. For one thing, the payback period, as most commonly computed, ignores the time value of money. We can overcome this objection by using discounted cash flows to calculate the payback period. Regardless of how the payback period is calculated, however, it fails to take account of cash flows recovered after the payback period. Thus, the payback period is biased in favour of short-lived projects. Also, the hurdle rate used to identify what payback period is acceptable is arbitrarily determined. Payback period calculations are described, see also Learning by Doing Application 10.2.

4. **Explain why the accounting rate of return (ARR) is not recommended as a capital expenditure decision-making tool.**

   The ARR is based on accounting numbers, such as book value and net income, rather than cash flow data. As such, it is not a true rate of return. Instead of discounting a project's cash flows over time, it simply gives us a number based on average figures from the income statement and balance sheet. Furthermore, as with the payback method, there is no economic rationale for establishing the hurdle rate. Finally, the ARR does not account for the size of the projects when a choice between two projects of different sizes must be made.

5. **Be able to compute the internal rate of return (IRR) for a capital project, and discuss the conditions under which the IRR technique and the NPV technique produce different results.**

   The IRR is the expected rate of return for an investment project; it is calculated as the discount rate that equates the present value of a project's expected cash inflows to the present value of the project's outflows – in other words, as the discount rate at which the NPV is equal to zero. Calculations are shown, see also Learning by Doing Application 10.3. If a project's IRR is greater than the required rate of return, the cost of capital, the project is accepted. The IRR rule often gives the same investment decision for a project as the NPV rule. However, the IRR method does have operational pitfalls that can lead to incorrect decisions. Specifically, when a project's cash flows are unconventional, the IRR calculation may yield no solution or more than one IRR. In addition, the IRR technique cannot be used to rank projects that are mutually exclusive because the project with the highest IRR may not be the project that would add the greatest value to the firm if accepted – that is, the project with the highest NPV.

6. **Explain the benefits of a post-audit review of a capital project.**

   Post-audit reviews of capital projects allow management to determine whether the project's goals were met and to quantify the benefits or costs of the project. By conducting these reviews, managers can avoid similar mistakes and possibly better recognise opportunities.

SUMMARY OF KEY EQUATIONS

Equation	Description	Formula
(10.1)	Net present value	$\text{NPV} = \text{NCF}_0 + \frac{\text{NCF}_1}{1+k} + \frac{\text{NCF}_2}{(1+k)^2} + \cdots + \frac{\text{NCF}_n}{(1+k)^n} = \sum_{t=0}^{n} \frac{\text{NCF}_t}{(1+k)^t}$
(10.2)	Payback period	$\text{PB} = \text{Years before cost recovery} + \frac{\text{Remaining cost to recover}}{\text{Cash flow during year}}$

(10.3)	Accounting rate of return	$ARR = \frac{\text{Average net income}}{\text{Average book value}}$
(10.4)	Internal rate of return	$NPV = \sum_{t=0}^{n} \frac{NCF_t}{(1 + IRR)^t} = 0$
(10.5)	Modified internal rate of return	$PV_{cost} = \frac{TV}{(1 + MIRR)^n}$

SELF-STUDY PROBLEMS

10.1. GreenTech Manufacturing plc is evaluating two forklift systems to use in its plant that produces the towers for a windmill power farm. The costs and the cash flows from these systems are shown here. If the company uses a 12% discount rate for all projects, determine which forklift system should be purchased using the net present value (NPV) approach.

	Year 0	Year 1	Year 2	Year 3
Caterpillar Forklifts	–€3 123 450	€979 225	€1 358 886	€2 111 497
Hyster Forklifts	–€4 137 410	€875 236	€1 765 225	€2 865 110

10.2. Markameer Baggaren NV has invested €100 000 in a project that will produce cash flows of €45 000, €37 500 and €42 950 over the next three years. Find the payback period for the project.

10.3. Les Artisanats de Limoges SA is evaluating two independent capital projects that will each cost the company €250 000. The two projects will provide the following cash flows:

Year	Project A	Project B
1	€80 750	€32 450
2	93 450	76 125
3	40 235	153 250
4	145 655	96 110

Which project will be chosen if the company's payback criterion is three years? What if the company accepts all projects as long as the payback period is less than five years?

10.4. Terrell Towels plc is looking into purchasing a machine for its business that will cost £117 250 and will be depreciated on a straight-line basis over a five-year period. The sales and expenses (excluding depreciation) for the next five years are shown in the following table. The company's tax rate is 34%.

	Year 1	Year 2	Year 3	Year 4	Year 5
Sales	£123 450	£176 875	£242 455	£255 440	£267 125
Expenses	£137 410	£126 488	£141 289	£143 112	£133 556

The company will accept all projects that provide an accounting rate of return (ARR) of at least 45%. Should the company accept this project?

10.5. Refer to Problem 10.1. Compute the IRR for each of the two systems. Is the choice different from the one determined by NPV?

SOLUTIONS TO SELF-STUDY PROBLEMS

10.1. NPVs for two forklift systems.
NPV for Caterpillar Forklifts:

$$\begin{aligned}
NPV &= \sum_{t=0}^{n} \frac{NCF_t}{(1+k)^t} \\
&= -€3\,123\,450 + \frac{€970\,225}{1+0.12} \\
&\quad + \frac{€1\,358\,886}{(1.12)^2} + \frac{€2\,111\,497}{(1.12)^3} \\
&= -€3\,123\,450 + €874\,308 \\
&\quad + €1\,083\,296 + €1\,502\,922 \\
&= €337\,076
\end{aligned}$$

NPV for Hyster Forklifts:

$$\begin{aligned}
NPV &= \sum_{t=0}^{n} \frac{NCF_t}{(1+k)^t} \\
&= -\ €4\,137\,410 + \frac{€875\,236}{1+0.12} \\
&\quad + \frac{€1\,765\,225}{(1.12)^2} + \frac{€2\,865\,110}{(1.12)^3} \\
&= -\ €4\,137\,410 + €781\,461 \\
&\quad + €1\,407\,227 + €2\,039\,329 \\
&= €90\,607
\end{aligned}$$

GreenTech should purchase the Caterpillar forklift since it has a larger NPV.

10.2. Payback period for the Markameer Baggaren project:

Year	CF	Cumulative Cash Flow
0	(€100 000)	(€100 000)
1	45 000	(55 000)
2	37 500	(17 500)
3	42 950	25 450

$$\begin{aligned}
\text{Payback period} &= \text{Years before cost recovery} \\
&\quad + \frac{\text{Remaining cost to recover}}{\text{Cash flow during the year}} \\
&= 2 + \frac{€17\,500}{€42\,950} = 2.41 \text{ years}
\end{aligned}$$

10.3. Payback periods for Les Artisanats de Limoges projects A and B:

Project A

Year	Cash Flow	Cumulative Cash Flows
0	(€250 000)	(€250 000)
1	80 750	(169 250)
2	93 450	(75 800)
3	40 235	(35 565)
4	145 655	110 090

Project B

Year	Cash Flow	Cumulative Cash Flows
0	(€250 000)	(€250 000)
1	32 450	(217 550)
2	76 125	(141 425)
3	153 250	11 825
4	96 110	107 935

Payback period for project A:

$$\begin{aligned}
\text{Payback period} &= \text{Years before cost recovery} \\
&\quad + \frac{\text{Remaining cost to recover}}{\text{Cash flow during the year}} \\
&= 3 + \frac{€35\,565}{€145\,655} \\
&= 3.24 \text{ years}
\end{aligned}$$

Payback period for project B:

$$\begin{aligned}
\text{Payback period} &= \text{Years before cost recovery} \\
&\quad + \frac{\text{Remaining cost to recover}}{\text{Cash flow during the year}} \\
&= 2 + \frac{€141\,425}{€153\,250} \\
&= 2.92 \text{ years}
\end{aligned}$$

If the payback period is three years, project B will be chosen. If the payback period is five years, both A and B will be chosen.

10.4. Evaluation of Terrell Towels project:

	Year 1	Year 2	Year 3	Year 4	Year 5
Sales	£123 450	£176 875	£242 455	£255 440	£267 125
Expenses	137 410	126 488	141 289	143 112	133 556
Depreciation	23 450	23 450	23 450	23 450	23 450
EBIT	(£37 410)	£26 937	£77 716	£88 878	£110 119
Taxes (34%)	12 719	9 159	26 423	30 219	37,440
Net Income	(£24 691)	£17 778	£51 293	£58 659	£72 679
Beginning Book Value	117 250	93 800	70 350	46 900	23 450
Less: Depreciation	(23 450)	(23 450)	(23 450)	(23 450)	(23 450)
Ending Book Value	£93 800	£70 350	£46 900	£23 450	£0

$$\text{Average net income} = (-€24\,691 + €17\,778 + €51\,293 + €58\,659 + €72\,679)/5 = €35\,143.60$$

$$\text{Average book value} = (€93\,800 + €70\,350 + €46\,900 + €23\,450 + €0)/5 = €46\,900.00$$

$$\text{Accounting rate of return} = €35\,143.60/€46\,900.00 = 74.93\%$$

The company should accept the project.

10.5. IRRs for the two forklift systems.

Caterpillar Forklifts:

First compute the IRR by the trial-and-error approach.

NPV(Caterpillar) = €337 075 > 0

Use a higher discount rate to get NPV = 0!

At $k = 15\%$:

$$= -€3\,123\,450 + \frac{€970\,225}{1+0.15} + \frac{€1\,358\,886}{(1.15)^2} + \frac{€2\,111\,497}{(1.15)^3}$$

$$= -€3\,123\,450 + €851\,500 + €1\,027\,513 + €1\,388\,344$$

$$= €143\,907$$

Try a higher rate. At $k = 17\%$:

$$= -€3123\,450 + \frac{€970\,225}{1+0.17} + \frac{€1\,358\,886}{(1.17)^2} + \frac{€2\,111\,497}{(1.17)^3}$$

$$= -€3\,123\,450 + €836\,944 + €992\,685 + €1\,318\,357 = €24\,536$$

Try a higher rate. At $k = 17.5\%$:

$$= -€3\,123\,450 + \frac{€970\,225}{1+0.175} + \frac{€1\,358\,886}{(1.175)^2} + \frac{€2\,111\,497}{(1.175)^3}$$

$$= -€3\,123\,450 + €833\,383 + €984\,254 + €1\,301\,598 = -€4215$$

Thus, the IRR for Caterpillar is less than 17.5%. Using interpolation, we find that the exact rate is 17.43%:

$$i_{\text{unknown}} = i_{\text{low}} + \frac{(\text{Value}_{\text{low } i} - \text{Value}_{\text{unknown } i})}{(\text{Value}_{\text{low } i} - \text{Value}_{\text{high } i})} \times (i_{\text{high}} - i_{\text{low}})$$

$$\text{IRR} = 17\% + \frac{€24\,536 - 0}{€24\,536 - -€4215}(17.5\% - 17\%)$$

$$= 17\% + 0.8534 \times 0.5\%$$

$$= 17\% + 0.43\% = 17.43\%$$

Hyster Forklifts:
First compute the IRR using the trial-and-error approach.
NPV(Hyster) = €90 606 > 0
Use a higher discount rate to get NPV = 0!
At k = 15%:

$$= -€4\,137\,410 + \frac{€875\,236}{1+0.15} + \frac{€1\,765\,225}{(1.15)^2} + \frac{€2\,865\,110}{(1.15)^3}$$

$$= -€4\,137\,410 + €761\,075 + €1\,334\,764 + €1\,883\,856 = -€157\,715$$

Applying interpolation, we get:

$$i_{\text{unknown}} = i_{\text{low}} + \frac{(\text{Value}_{\text{low } i} - \text{Value}_{\text{unknown } i})}{(\text{Value}_{\text{low } i} - \text{Value}_{\text{high } i})} \times (i_{\text{high}} - i_{\text{low}})$$

$$\text{IRR} = 12\% + \frac{€90\,607 - €0}{€90\,607 - -€157\,715}(15\% - 12\%)$$

$$= 12\% + 0.3649 \times 3\% = 12\% + 1.095\% = 13.1\%$$

Thus, the IRR for Hyster is 13.1%. The exact rate is 13.06%. Based on the IRR, we would still pick the Caterpillar over the Hyster forklift systems.

CRITICAL THINKING QUESTIONS

10.1. Explain why the cost of capital is referred to as the 'hurdle' rate in capital budgeting.

10.2. **a.** A company is building a new plant on the outskirts of a small town. The town has offered to donate the land and, as part of the agreement, the company will have to build an access road from the main highway to the plant. How will the project of building the road be classified in capital budgeting analysis?

b. Systèmes Informatique SA is considering two projects: a plant expansion and a new computer system for the firm's production department. Classify each of these projects as independent, mutually exclusive or contingent projects and explain your reasoning.

c. Your firm is currently considering the upgrading of the operating systems of all the firm's computers. The firm can choose the Linux operating system that a local computer services firm has offered to install and maintain. Microsoft has also put in a bid to install the new Windows 7 operating system for businesses. What type of project is this?

10.3. In the context of capital budgeting, what is 'capital rationing'?

10.4. Explain why we use discounted cash flows instead of actual market price data.

10.5. **a.** A firm takes on a project that would earn a return of 12%. If the appropriate cost of capital is also 12%, did the firm make the right decision? Explain.

b. What is the impact on the firm if it accepts a project with a negative NPV?

10.6. Identify the weaknesses of the payback period method.

10.7. What are the strengths and weaknesses of the accounting rate of return approach?

10.8. Under what circumstances might the IRR and NPV approaches have conflicting results?

10.9. A company estimates that an average-risk project has a cost of capital of 8%, a below-average-risk project has a cost of capital of 6% and an above-average-risk project has a cost of capital of 10%. Which of the following independent projects should the company accept? Project A has below-average risk and a return of 6.5%. Project B has above-average risk and a return of 9%. Project C has average risk and a return of 7%.

10.10. Oporto Construção SA has an overall (composite) cost of capital of 12%. This cost of capital reflects the cost of capital for an Oporto Construção project with average risk. However, the firm takes on projects of various risk levels. The company experience suggests that low-risk projects have a cost of capital of 10% and high-risk projects have a cost of capital of 15%. Which of the following projects should the company select to maximise shareholder wealth?

Project	Expected Return	Risk
1. Single-family homes	13%	Low
2. Multi-family residential	12	Average
3. Commercial	18	High
4. Single-family homes	9	Low
5. Commercial	13	High

QUESTIONS AND PROBLEMS

Basic

10.1. **Net present value:** Riggs plc is planning to spend £650 000 on a new marketing campaign. It believes that this action will result in additional cash flows of £325 000 over the next three years. If the discount rate is 17.5%, what is the NPV on this project?

10.2. **Net present value:** Kluwer AG is looking to add a new machine at a cost of €4 133 250. The company expects this equipment will lead to cash flows of €814 322, €863 275, €937 250, €1 017 112, €1 212 960 and €1 225 000 over the next six years. If the appropriate discount rate is 15%, what is the NPV of this investment?

10.3. **Net present value:** Croissant D'Or SA is planning to replace some existing machinery in its plant. The cost of the new equipment and the resulting cash flows are shown in the accompanying table. If the firm uses an 18% discount rate for projects like this, should the firm go ahead with the project?

Year	Cash Flow
0	–€3 300 000
1	875 123
2	966 222
3	1 145 000
4	1 250 399
5	1 504 445

10.4. **Net present value:** Confettiere Agostina, a bonbon producer, is looking to purchase a new jellybean-making machine at a cost of €312 500. The company projects that the cash flows from this investment will be €121 450 for the next seven years. If the appropriate discount rate is 14%, what is the NPV for the project?

10.5. **Payback:** Broderie de Bretagne SA is purchasing machinery at a cost of €3 768 966. The company expects, as a result, cash flows of €979 225, €1 158 886 and €1 881 497 over the next three years. What is the payback period?

10.6. **Payback:** Norge Spesialiteter ASA just purchased inventory-management computer software at a cost of NKr 1 645 276. Cost savings from the investment over the next six years will be reflected in the following cash flow stream: NKr 212 455, NKr 292 333, NKr 387 479, NKr 516 345, NKr 645 766 and NKr 618 325. What is the payback period on this investment?

10.7. Payback: Nakamichi Bank has made an investment in banking software at a cost of ¥1 875 000 000. The institution expects productivity gains and cost savings over the next several years. If the firm is expected to generate cash flows of ¥586 212 000, ¥713 277 000, ¥431 199 000 and ¥318 697 000 over the next four years, what is the investment's payback period?

10.8. Average accounting rate of return (ARR): Klariol AG is expecting to generate after-tax income of €63 435 over each of the next three years. The average book value of their equipment over that period will be €212 500. If the firm's acceptance decision on any project is based on an ARR of 37.5%, should this project be accepted?

10.9. Internal rate of return: Refer to Problem 10.4. What is the IRR that Confettiere Agostina can expect on this project?

10.10. Internal rate of return: Holberg Reisen Hotels AG, a resort company, is refurbishing one of its hotels at a cost of €7.8 million. The firm expects that this will lead to additional cash flows of €1.8 million for the next six years. What is the IRR of this project? If the appropriate cost of capital is 12%, should it go ahead with this project?

Intermediate

10.11. Net present value: Copenhagen Infosystems A/S is investigating two computer systems. The Alpha 8300 costs DKr 31 223 000 and will generate annual cost savings of DKr 13 455 000 over the next five years. The Beta 2100 system costs DKr 37 500 000 and will produce cost savings of DKr 11 250 000 in the first three years and then DKr 20 million for the next two years. If the company's discount rate for similar projects is 14%, what is the NPV for the two systems? Which one should be chosen based on the NPV?

10.12. Net present value: Briarcrest Condiments plc of Galway, Ireland, is a spice-making firm. Recently, it developed a new process for producing spices. This calls for acquiring machinery that would cost €1 968 450. The machine will have a life of five years and will produce cash flows as shown in the table. What is the NPV if the discount rate is 15.9%?

Year	Cash Flow
1	€512 496
2	−242 637
3	814 558
4	887 225
5	712 642

10.13. Net present value: Picard Submersibles SA is expanding its product line and its production capacity. The costs and expected cash flows of the two independent projects are given in the following table. The firm uses a discount rate of 16.4% for such projects.

a. Are these projects independent or mutually exclusive?

b. What are the NPVs of the two projects?

c. Should both projects be accepted, or either, or neither? Explain your reasoning.

Year	Product Line Expansion	Production Capacity Expansion
0	−€2 575 000	−€8 137 250
1	600 000	2 500 000
2	875 000	2 500 000
3	875 000	2 500 000
4	875 000	2 500 000
5	875 000	2 500 000

10.14. Net present value: Thanet Mills plc is evaluating two heating systems. Costs and projected energy savings are given in the following table. The firm uses 11.5% to discount such project cash flows. Which system should be chosen?

Year	System 100	System 200
0	–£1 750 000	–£1 735 000
1	275 223	750 000
2	512 445	612 500
3	648 997	550 112
4	875 000	384 226

10.15. Payback: Creative Solutions, Inc., has invested $4 615 300 in equipment. The firm uses payback period criteria of not accepting any project that takes more than four years to recover costs. The company anticipates cash flows of $644 386, $812 178, $943 279, $1 364 997, $2 616 300 and $2 225 375 over the next six years. Does this investment meet the firm's payback criteria?

10.16. Discounted payback: Tempus Fabricerend NV is evaluating two projects. The company uses payback criteria of three years or less. Project A has a cost of €912 855 and project B's cost will be €1 175 000. Cash flows from both projects are given in the following table. What are their discounted payback periods and which will be accepted with a discount rate of 8%?

Year	Project A	Project B
1	€86 212	€586 212
2	313 562	413 277
3	427 594	231 199
4	285 552	

10.17. Payback: Vestidos Regente SA is evaluating three competing pieces of equipment. Costs and cash flow projections for all three are given in the following table. Which would be the best choice based on payback period?

Year	Type 1	Type 2	Type 3
0	–€1 311 450	–€1 415 888	–€1 612 856
1	212 566	586 212	786 212
2	269 825	413 277	175 000
3	455 112	331 199	175 000
4	285 552	141 442	175 000
5	121 396		175 000
6			175 000

10.18. Discounted payback: Deutsche Telecom AG is investing €9 365 000 in new technologies. The company expects significant benefits in the first three years after installation (as can be seen by the cash flows) and a constant amount for four more years. What is the discounted payback period for the project assuming a discount rate of 10%?

Years	1	2	3	4–7
Cash Flows	€2 265 433	€4 558 721	€3 378 911	€1 250 000

10.19. Modified internal rate of return (MIRR): Morningside Bakeries of Edinburgh, Scotland, has recently purchased equipment at a cost of £650 000. The firm expects to generate cash flows of £275 000 in each of the next four years. The cost of capital is 14%. What is the MIRR for this project?

10.20. Modified internal rate of return (MIRR): Norges Vindu is looking to acquire a new machine that can create customised windows. The equipment will cost NKr.263 400 and will generate cash flows of NKr.85 000 over each of the next six years. If the cost of capital is 12%, what is the MIRR on this project?

10.21. Internal rate of return: Great Flights, Inc., an aviation firm, is exploring the purchase of three aircraft at a total cost of $161 million. Cash flows from leasing these aircraft are expected to build slowly as shown in the following table. What is the IRR on this project? The required rate of return is 15%.

Years	Cash Flow
1–4	$23 500 000
5–7	72 000 000
8–10	80 000 000

10.22. Internal rate of return: Compute the IRR on the following cash flow streams:

a. An initial investment of €25 000 followed by a single cash flow of €37 450 in year 6.

b. An initial investment of €1 million followed by a single cash flow of €1 650 000 in year 4.

c. An initial investment of €2 million followed by cash flows of €1 650 000 and €1 250 000 in years 2 and 4, respectively

10.23. Internal rate of return: Compute the IRR for the following project cash flows.

a. An initial outlay of €3 125 000 followed by annual cash flows of €565 325 for the next eight years.

b. An initial investment of €33 750 followed by annual cash flows of €9430 for the next five years.

c. An initial outlay of €10 000 followed by annual cash flows of €2500 for the next seven years.

Advanced

10.24. Kupio Sahatavara Käsittely Oy is evaluating two independent projects. The company uses a 13.8% discount rate for such projects. Cost and cash flows are shown in the table. What are the NPVs of the two projects?

Year	Project 1	Project 2
0	–€8 425 375	–€11 368 000
1	3 225 997	2 112 589
2	1 775 882	3 787 552
3	1 375 112	3 125 650
4	1 176 558	4 115 899
5	1 212 645	4 556 424
6	1 582 156	
7	1 365 882	

10.25. Refer to Problem 10.24.

a. What are the IRRs for both projects?

b. Does the IRR decision criterion differ from the earlier decisions?

c. Explain how you would expect the management of Kupio Sahatavara Käsittely to decide.

10.26. Košice Dravid A.S. is currently evaluating three projects that are independent. The cost of funds can be either 13.6% or 14.8% depending on their financing plan. All three projects cost the same at €500 000. Expected cash flow streams are shown in the following table. Which projects would be accepted at a discount rate of 14.8%? What if the discount rate was 13.6%?

Year	Project 1	Project 2	Project 3
1	€0	€0	€245 125
2	125 000	0	212 336
3	150 000	500 000	112 500
4	375 000	500 000	74 000

10.27. Trabajo Impávido SA is looking to invest in two or three independent projects. The costs and the cash flows are given in the following table. The appropriate cost of capital is 14.5%. Compute the IRRs and identify the projects that will be accepted.

Year	Project 1	Project 2	Project 3
0	–€275 000	–€312 500	–€500 000
1	63 000	153 250	212 000
2	85 000	167 500	212 000
3	85 000	112 000	212 000
4	100 000		212 000

10.28. Hansel und Gretel AG is evaluating two mutually exclusive projects. Their cost of capital is 15%. Costs and cash flows are given in the following table. Which project should be accepted?

Year	Project 1	Project 2
0	–€1 250 000	–€1 250 000
1	250 000	350 000
2	350 000	350 000
3	450 000	350 000
4	500 000	350 000
5	750 000	350 000

10.29. Masai Automotive, a manufacturer of auto parts, is planning to invest in two projects. The company typically compares project returns to a cost of funds of 17%. Compute the IRRs based on the given cash flows, and state which projects will be accepted.

Year	Project 1	Project 2
0	–R 475 000	–R 500 000
1	300 000	117 500
2	110 000	181 300
3	125 000	244 112
4	140 000	278 955

10.30. EXCEL® Compute the IRR for each of the following cash flow streams:

Year	Project 1	Project 2	Project 3
0	–€10 000	–€10 000	–€10 000
1	4 750	1 650	800
2	3 300	3 890	1 200
3	3 600	5 100	2 875
4	2 100	2 750	3 400
5		800	6 600

10.31. EXCEL® Primus Lagerung Überführen AG is planning to convert an existing warehouse into a new plant that will increase its production capacity by 45%. The cost of this project will be €7 125 000. It will result in additional cash flows of €1 875 000 for the next eight years. The discount rate is 12%.

a. What is the payback period?
b. What is the NPV for this project?
c. What is the IRR?

10.32. EXCEL® Quasar Tech Co. is investing $6 million in new machinery that will produce the next-generation routers. Sales to its customers will amount to $1 750 000 for the next three years and then increase to $2.4 million for three more years. The project is expected to last six years and cost the firm annually $898 620 (excluding depreciation). The machinery will be depreciated to zero by year 6 using the straight-line method. The company's tax rate is 30% and the cost of capital is 16%.

a. What is the payback period?
b. What is the average accounting return (ARR)?
c. Calculate the project NPV.
d. What is the IRR for the project?

10.33. EXCEL® Approvisionnement en Vol SA, an airline caterer, is purchasing refrigerated trucks at a total cost of €3.25 million. After-tax net income from this investment is expected to be €750 000 for the next five years. Annual depreciation expense was €650 000. The cost of capital is 17%.

a. What is the discounted payback period?
b. Compute the ARR.
c. What is the NPV on this investment?
d. Calculate the IRR.

10.34. EXCEL® Dreizack AG is evaluating two independent projects. The costs and expected cash flows are given in the following table. The cost of capital is 10%.

Year	A	B
0	–€312 500	–€395 000
1	121 450	153 552
2	121 450	158 711
3	121 450	166 220
4	121 450	132 000
5	121 450	122 000

a. Calculate the project's NPV.
b. Calculate the project's IRR.
c. What is the decision based on NPV? What is the decision based on IRR? Is there a conflict?

d. If you are the decision maker for the firm, which project or projects will be accepted? Explain your reasoning.

10.35. EXCEL® Colocador de Telhas SA is looking to move to a new technology for its production. The cost of equipment will be €4 million. The discount rate is 12%. Cash flows that the firm expects to generate are as follows.

Years	CF
0	–€4 000 000
1–2	0
3–5	845 000
6–9	1 450 000

a. Compute the payback and discounted payback period for the project.
b. What is the NPV for the project? Should the firm go ahead with the project?
c. What is the IRR, and what would be the decision under the IRR?

CFA Problems

10.36. Given the following cash flows for a capital project, calculate the NPV and IRR. The required rate of return is 8%.

Year	0	1	2	3	4	5
Cash Flow	–€50 000	€15 000	€15 000	€20 000	€10 000	€5000

The NPV and IRR are:

	NPV	IRR
a.	€1905	10.9%
b.	€1905	26.0%
c.	€3379	10.9%
d.	€3379	26.0%

10.37. Given the following cash flows for a capital project, calculate its payback period and discounted payback period. The required rate of return is 8%.

Year	0	1	2	3	4	5
Cash Flow	–€50 000	€15 000	€15 000	€20 000	€10 000	€5000

The discounted payback period is:
a. 0.16 year longer than the payback period.
b. 0.80 year longer than the payback period.
c. 1.01 years longer than the payback period.
d. 1.85 years longer than the payback period.

10.38. An investment of €100 generates after-tax cash flows of €40 in year 1, €80 in year 2 and €120 in year 3. The required rate of return is 20%. The net present value is closest to
a. €42.22
b. €58.33
c. €68.52
d. €98.95

10.39. An investment of €150 000 is expected to generate an after-tax cash flow of €100 000 in one year and another €120 000 in two years. The cost of capital is 10%. What is the internal rate of return?
a. 28.19%
b. 28.39%
c. 28.59%
d. 28.79%

10.40. An investment has an outlay of 100 and after-tax cash flows of 40 annually for four years. A project enhancement increases the outlay by 15 and the annual after-tax cash flows by 5. As a result, the vertical intercept of the NPV profile of the enhanced project shifts

a. up and the horizontal intercept shifts left;
b. up and the horizontal intercept shifts right;
c. down and the horizontal intercept shifts left;
d. down and the horizontal intercept shifts right.

SAMPLE TEST PROBLEMS

10.1. Net present value: Techno Systèmes SA is considering developing new computer software. The cost of development will be €675 000 and the company expects the revenue from the sale of the software to be €195 000 for each of the next six years. If the discount rate is 14%, what is the net present value of this project?

10.2. Payback method: Parker Office Supplies is looking to replace its outdated inventory-management software. The cost of the new software will be $168 000. Cost savings is expected to be $43 500 for each of the first three years and then to drop off to $36 875 for the next two years. What is the payback period for this project?

10.3. Accounting rate of return: Frescati S.p.A. is expecting to generate after-tax income of €156 435 over each of the next three years. The average book value of its equipment over that period will be €322 500. If the firm's acceptance decision on any project is based on an ARR of 40%, should this project be accepted?

10.4. Internal rate of return: Refer to Problem 10.1. What is the IRR on this project?

10.5. Net present value: Port de Brest needs a new overhead crane and two alternatives are available. Crane T costs €1.35 million and will produce cost savings of €765 000 for the next three years. Crane R will cost €1.675 million and will lead to annual cost savings of €815 000 for the next three years. The required rate of return is 15%. Which of the two options should Port de Brest choose based on NPV calculations, and why?

ENDNOTES

1. Although Airbus is a European company and reports its financial statements in euros, the market for commercial airliners is US dollar-denominated and prices are quoted in US dollars.
2. The solution ignores the opportunity cost of the land. As we will discuss in Chapter 11, if your boss could sell the land or use it in some other way that has value, then there is an opportunity cost associated with using it for the convenience store.
3. As we pointed out in Chapter 5, financial decision-making problems can be solved either by discounting cash flows to the beginning of the project or by using compounding to find the future value of cash flows at the end of a project's life.