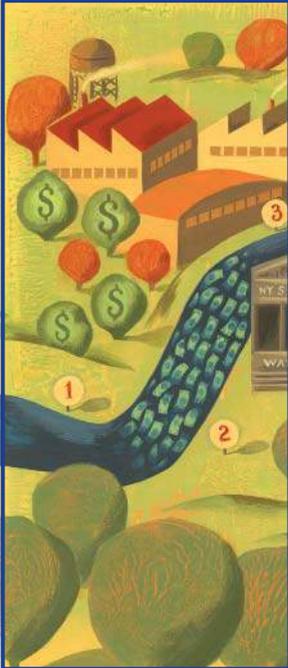


# RISK TOPICS AND REAL OPTIONS IN CAPITAL BUDGETING

## CHAPTER OUTLINE



### **Risk in Capital Budgeting— General Considerations**

Cash Flows as Random  
Variables

The Importance of Risk in  
Capital Budgeting

### **Incorporating Risk into Capital Budgeting—Numerical and Computer Methods**

Scenario/Sensitivity Analysis  
Computer (Monte Carlo)  
Simulation

Decision Tree Analysis

### **Real Options**

Real Options in Capital  
Budgeting

Valuing Real Options

Designing Real Options into  
Projects

### **Incorporating Risk into Capital Budgeting—The Theoretical Approach and Risk-Adjusted Rates of Return**

Estimating Risk-Adjusted Rates  
Using CAPM

Problems with the Theoretical  
Approach—Finding the  
Right Beta and Concerns  
about the Appropriate Risk  
Definition

## RISK IN CAPITAL BUDGETING—GENERAL CONSIDERATIONS

In our discussions in the last chapter, we emphasized the idea that cash flow estimates are subject to a good deal of error. Different people will make different estimates of the same thing, and actual flows are apt to vary substantially from anybody's estimates. A more concise way to put the same thing is just to say that cash flow estimates are *risky*.

In recent years the subject of risk has been given great attention in financial theory, especially in the area of portfolio theory (Chapter 9). In this section we'll take a look at some attempts that have been made to incorporate risk into capital budgeting, including one approach that applies portfolio theory methods to capital budgeting problems.

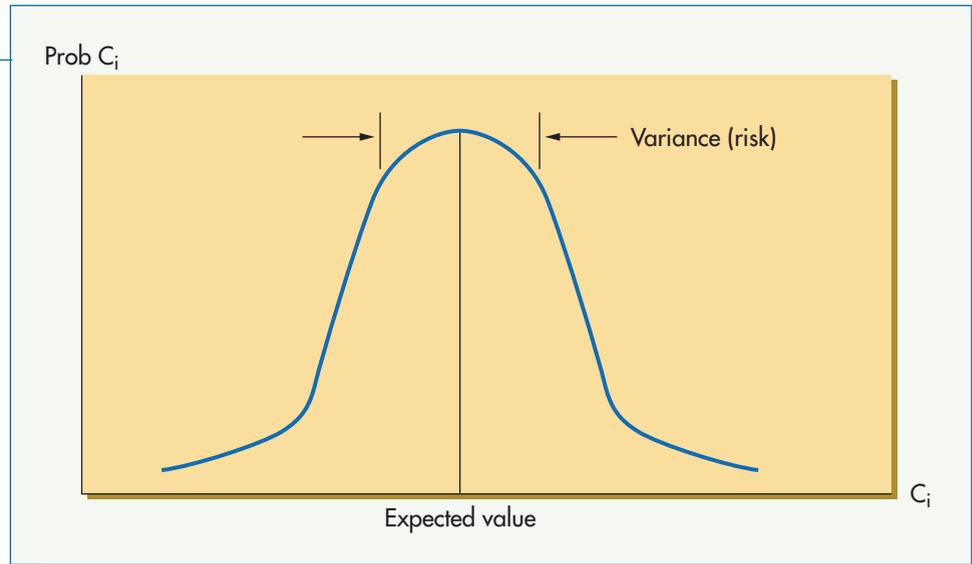
### CASH FLOWS AS RANDOM VARIABLES

In everyday usage the term "risk" is associated with the probability that something bad will happen. In financial theory, however, we associate risk with random variables and their probability distributions. Risk is the chance that a random variable will take a value significantly different from the one we expect, regardless of whether the deviation is favorable or unfavorable. In terms of a probability distribution, the value we expect is the mean (expected value), and the chance that an observation will be significantly different from the mean is related to the variance.

Recall that in portfolio theory (Chapter 9) the return on an investment is viewed as a random variable with an associated probability distribution, and "risk" is defined as the variance or standard deviation

Figure 12.1

### The Probability Distribution of a Future Cash Flow as a Random Variable



[http://](http://www.usda.gov/agency/oce/oracba/)

See how the U.S. Department of Agriculture assesses the costs and benefits of USDA policies at <http://www.usda.gov/agency/oce/oracba/>

In capital budgeting the **estimate** of each future period's **cash flow** is a **random variable**.

The **NPV** and **IRR** of any project are **random variables** with expected values and variances that reflect **risk**.

of that distribution. In capital budgeting, the risk inherent in estimated cash flows can be defined in a similar way. Each future cash flow can be thought of as a separate random variable with its own probability distribution. In each case, the risk associated with the flow is related to the variance of the distribution. The idea is illustrated in Figure 12.1, in which the random variable  $C_i$  is the forecast cash flow in the  $i$ th period.

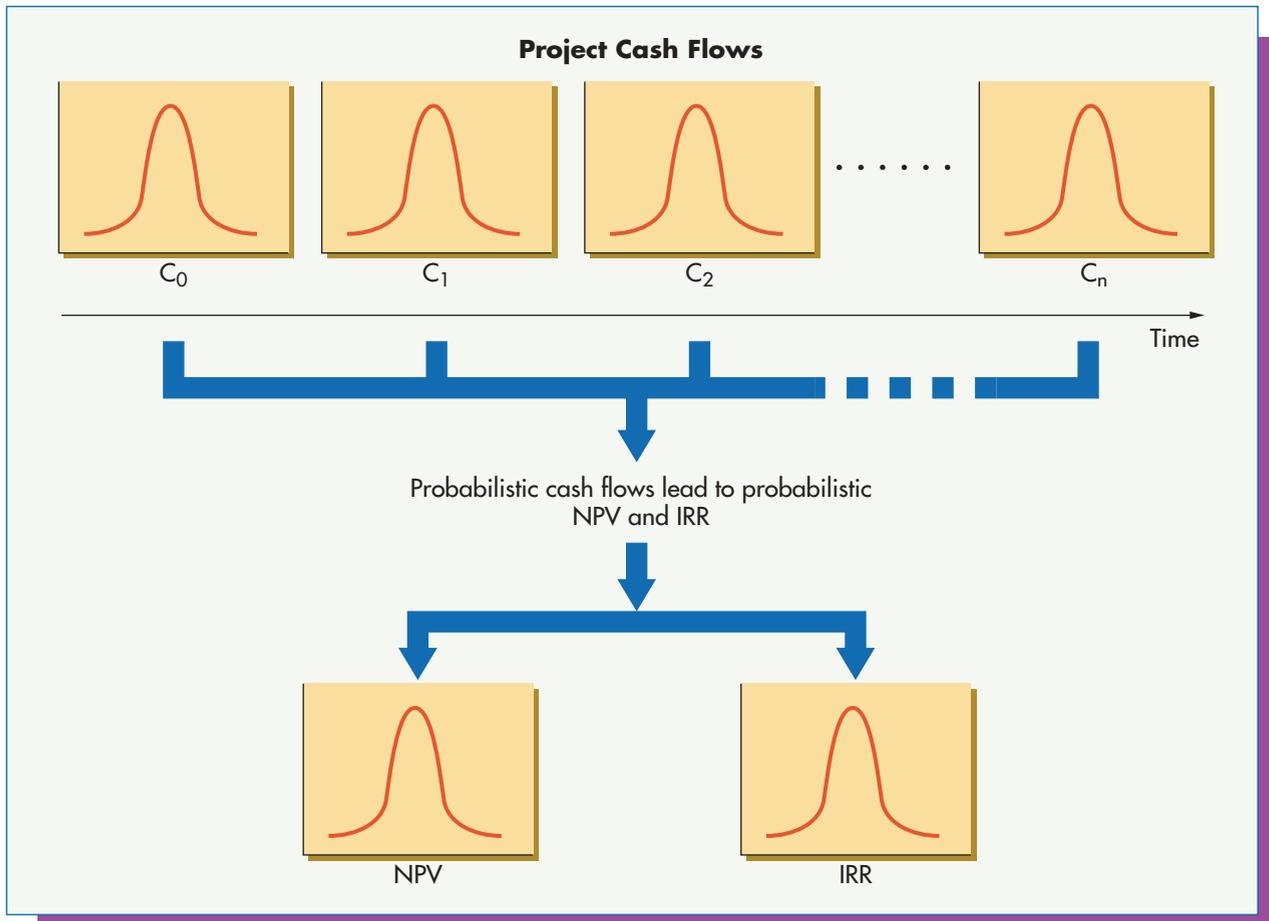
When cash flows are viewed like this, the **NPVs and IRRs of projects are also random variables** with their own probability distributions. That's because they're calculated as functions of the various cash flows in a project, which are random variables themselves. The idea is conceptually illustrated in Figure 12.2.

This view makes explicit the idea that estimated cash flows as well as the resulting NPVs and IRRs have most likely (expected, mean) values, but will probably turn out to be somewhat different from those values. The amount by which the actual value is likely to differ from the expected value is related to the distribution's variance or standard deviation, which can be visualized intuitively as the width of the bell-shaped curve.

## THE IMPORTANCE OF RISK IN CAPITAL BUDGETING

Up until now we've thought of each cash flow as a *point estimate*. That's a single number rather than a range of possibilities with a probability distribution attached. When we do that, we're computing NPVs and IRRs that are also point estimates, and ignoring the possibility that the true NPV or IRR could turn out to be higher or lower. That means there's a good chance we'll be making *wrong decisions* by using NPVs and IRRs that come from risky cash flow estimates.

For example, suppose we're making a capital investment decision that involves a choice between two projects with NPVs that look like those shown in Figure 12.3. Notice that  $NPV_B$  has a higher expected value than  $NPV_A$ , but is also more risky. The capital budgeting techniques we considered in Chapter 10 will invariably choose project B over project A, because it has a higher expected NPV and the methods ignore project risk. But there's a good chance that project B's NPV (and IRR) will actually turn out to be less than project A's, perhaps by quite a bit. If that happens we will have made the wrong decision at a potential cost of millions.

**Figure 12.2** Risk in Estimated Cash Flows


### Risk Aversion

The principle of risk aversion that we studied in portfolio theory applies to capital budgeting just as it does to investing. All other things equal, we prefer less risky capital projects to those with more risk.

To make the point plainer, imagine that projects A and B in Figure 12.3 have exactly the same expected NPV. The NPV technique would be indifferent between them, yet any rational manager would prefer the one with the lower risk.

### Changing the Nature of the Company

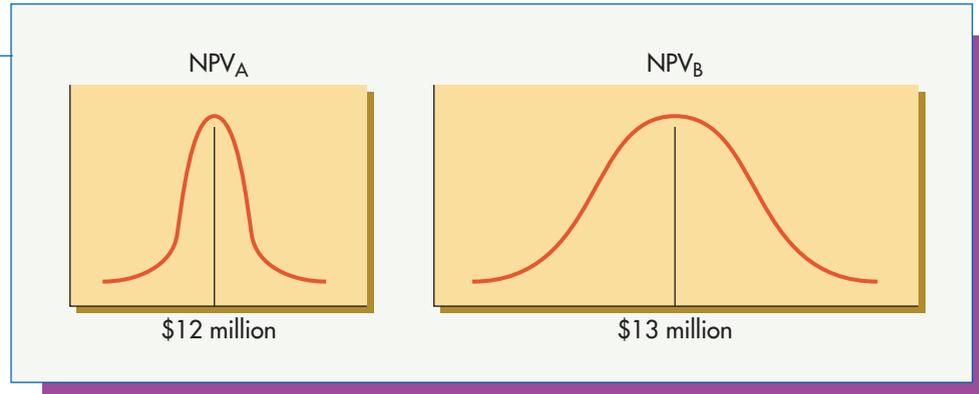
Another dimension to the risk issue goes beyond individual projects and relates to the fundamental nature of the firm as an investment. Companies are characterized by investors largely in terms of risk. That was the point of our study of portfolio theory in Chapter 9. When people buy stocks and bonds, expected returns matter, but risk matters just as much.

In capital budgeting we think of projects as incremental to the normal business of the firm. We view them as sort of *stuck onto* the larger body of what goes on every day.

**Ignoring risk** in capital budgeting can lead to **incorrect decisions** and **change the risk character** of the firm.

**Figure 12.3**

**Project NPVs  
Reflecting Risky  
Cash Flows**



Yet every project affects the totality of the company, just as every stock added to a portfolio changes the nature of that portfolio. In the long run, a company is no more than a collection of all the projects it has undertaken that are still going on. In a very real sense, *a company is a portfolio of projects*.

Hence, if a firm takes on new projects without regard for risk, it's in danger of changing its fundamental nature as perceived by investors. A firm that starts to adopt riskier projects than it has in the past will slowly become a riskier company. The higher risk will be reflected in a more volatile movement of the firm's return, which in turn will result in a higher beta. And that higher beta can generally be expected to have a negative impact on the price of the company's stock.

We can conclude that some consideration of risk *should* be included in capital project analysis. If it isn't, the full impact of projects simply isn't understood at the time they're chosen and implemented.

## INCORPORATING RISK INTO CAPITAL BUDGETING — NUMERICAL AND COMPUTER METHODS

Once the idea that risk *should* be incorporated in the capital budgeting process is accepted, the question of *how* to do it has to be addressed. Considering the capital budgeting techniques we studied in the last chapter, it's not at all obvious how we ought to go about factoring in risk-related ideas.

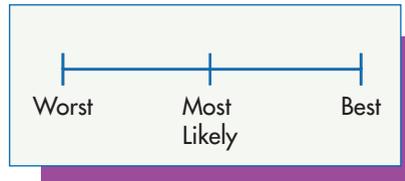
Quite a bit of thought has been given to the subject and several approaches have been developed. We'll look at some numerical methods and then examine more theoretical approaches.

### SCENARIO/SENSITIVITY ANALYSIS

The fundamental idea behind risk in capital budgeting is that cash flows aren't likely to turn out exactly as estimated. Therefore, actual NPVs and IRRs are likely to be different from those based on estimated cash flows. The management question is just *how much* an NPV or an IRR will change given some deviation in cash flows. A good idea of the relationship between the two changes is available with a procedure called scenario analysis.

In the following discussion we'll refer only to NPV, understanding that the comments also apply to IRR and other capital budgeting techniques.

Suppose a project is represented by a number of estimated future cash flows, each of which can actually take a range of values around the estimate. Also suppose we have an idea of what the best, worst, and most likely values of each cash flow are. Graphically the idea involves a picture like this for *each* cash flow.



The most likely value of each cash flow is the estimate we've been working with up until now, sometimes called a *point estimate*.

If we calculate the project's NPV using the most likely value of each cash flow, we generally get the most likely NPV for the project. If we do the calculation with the worst possible value of each  $C_i$ , we'll get the worst possible NPV. Similarly, we'll get the best NPV if we use all the best cash flows. Notice that we can calculate an NPV with *any* combination of cash flows. That is, we could pick a worst case for  $C_1$ , a best case for  $C_2$ , something in between for  $C_3$ , and so on. All we have to do to calculate an NPV is to choose one value for each cash flow.

Every time we choose a value for every one of the project's cash flows, we define what is called a *scenario*, one of the many possible outcomes of the project. When we calculate the NPV of several scenarios we're performing a **scenario analysis**.

This procedure results in a range of values for NPV along with a good estimate of the most likely value. But it doesn't give a very good notion of the probability of various values within the range. We can choose as many scenarios as we like, however, by selecting any number of different sets of outcomes for the cash flows. Evaluating a number of scenarios gives a subjective feel for the variability of the NPV to changes in our assumptions about what the cash flows will turn out to be.

**Example 12.1** Project A has an initial outflow of \$1,400 and three variable cash inflows defined as follows.

	$C_1$	$C_2$	$C_3$
Worst case	\$450	\$400	\$700
Most likely	550	450	800
Best case	650	500	900

Analyze project A's NPV.

**SOLUTION:** The worst possible NPV will result if the three lowest cash flows all occur. Assume the cost of capital is 9%. Then the worst NPV is

$$\begin{aligned}
 \text{NPV} &= -\$1,400 + \$450[\text{PVF}_{9,1}] + \$400[\text{PVF}_{9,2}] + \$700[\text{PVF}_{9,3}] \\
 &= -\$1,400 + \$450[.9174] + \$400[.8417] + \$700[.7722] \\
 &= -\$109.95
 \end{aligned}$$

Similar calculations lead to a best-case scenario with an NPV of \$312.14, and an NPV of \$101.10 for the scenario involving the most likely cash flow for every  $C_i$ , which is the project's traditional NPV.

Now suppose management feels pretty good about the estimates in the first two years, but is uncomfortable with the high cash flow numbers forecast for year 3. They essentially want to know what will happen to the traditional NPV if year 3 turns out badly.

To answer that question, we form a scenario including the most likely flows from years 1 and 2 and the worst case from year 3. Verify that the NPV from that scenario is \$23.88. Notice that management's concern is well founded, as a worst case in the third year alone yields a marginally positive NPV.

**Scenario/sensitivity analysis** selects worst, middle, and best outcomes for each cash flow and computes NPV for a variety of combinations.

Another name for essentially the same process is **sensitivity analysis**. That is, we investigate the *sensitivity* of the traditionally calculated NPV to changes in the  $C_t$ . In the last part of the last example we saw that a change of \$100 in the year 3 cash flow led to a change of  $(\$101.10 - \$23.88 =)$  \$77.22 in the project's NPV. In other words, the NPV changed by about 77% of the change in year 3 cash flow. The mathematically astute will recognize that in this simple example 77% is just the present value factor for 9% and three years.

## COMPUTER (MONTE CARLO) SIMULATION

The power of the computer can help to incorporate risk into capital budgeting through a technique called *Monte Carlo* simulation. The term "Monte Carlo" implies that the approach involves the use of numbers drawn randomly from probability distributions.<sup>1</sup>

Figure 12.2 intuitively suggests the approach. Reexamine that illustration on page 486. Notice that each cash flow is itself a random variable with a probability distribution, and that all combine to create the probability distributions of the project's NPV (and IRR).

Monte Carlo simulation involves making assumptions that specify the shapes of the probability distributions for *each* future cash flow in a capital budgeting project. These assumed distributions are put into a computer model so that random observations<sup>2</sup> can be drawn from each.<sup>3</sup>

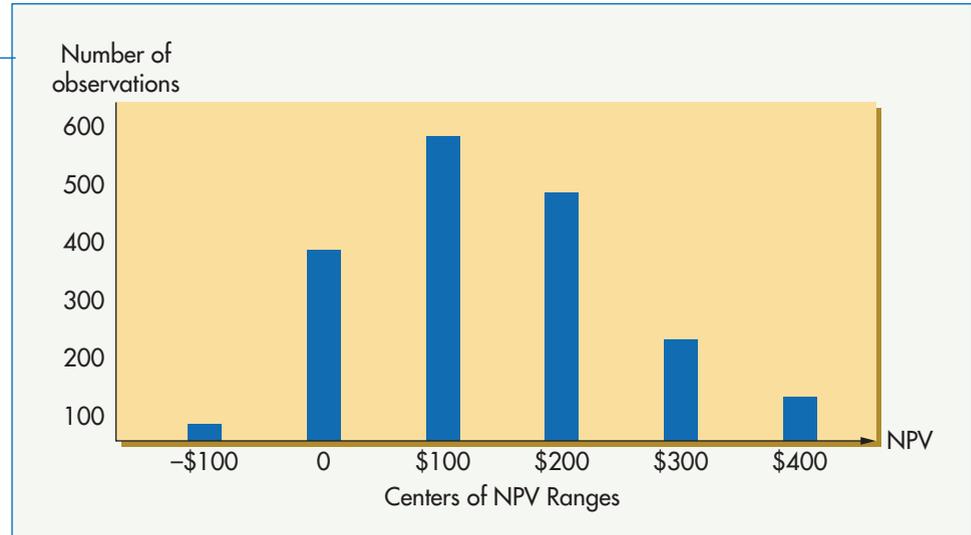
Once all the probability distributions are specified, the computer simulates the project by drawing one observation from the distribution of each cash flow. Having those, it calculates the project's NPV and records the resulting value. Then it draws a new set of random observations for each of the cash flows, discards the old set, and calculates and records another value for NPV. Notice that the second NPV will probably be different from the first because it is based on a different set of randomly drawn cash flows.

The computer goes through this process many times, generating a thousand or more values (observations) for NPV. The calculated values are sorted into ranges and displayed as histograms reflecting the number of observations in each range. Figure 12.4 is a sample of the resulting display, where the numbers along the horizontal axis represent the centers of ranges of values for the calculated NPVs. For example, the value of 600 over the NPV value of \$100 means that 600 simulation calculations resulted in NPVs between \$50 and \$150.

1. Monte Carlo is the site of a famous gambling casino in the south of France.

2. In this context, the term "observation" refers to a number drawn from a probability distribution or to the result of calculations made from such numbers.

3. In more detailed models, a probability distribution can be assumed for *each* of the elements that goes into the periodic cash flow estimates. For example, if period cash flows are the difference between revenue and cost, one might specify distributions for both, and calculate cash flow as the difference between an observation on revenue and one on cost.

**Figure 12.4****Results of Monte Carlo Simulation for NPV**

If the height of each column is restated as a percentage of the total number of observations, the histogram becomes a good approximation of the probability distribution of the project's NPV *given the assumptions made about the distributions of the individual cash flows*.

Armed with this risk-related information, managers can make better choices among projects. For example, look back at Figure 12.3 on page 487. Simulation would give us approximations of the shapes of the distributions shown, as well as the most likely values of NPV. In the case illustrated, decision makers might well choose project A over project B in spite of B's NPV advantage because of A's lower risk.

**Simulation** models cash flows as random variables and repeatedly calculates NPV, building its distribution.

### Drawbacks

Using the simulation approach has a few drawbacks. An obvious problem is that the probability distributions of the cash flows have to be estimated subjectively. This can be difficult. However, it's always easier to estimate a distribution for a simple element of a problem, like a single cash flow, than for a more complex element, like the final NPV or IRR.

A related issue is that the distributions of the individual cash flows generally aren't independent. Project cash flows tend to be positively *correlated* so that if early flows are low, later flows are also likely to be low. Unfortunately, it's hard to estimate the extent of that correlation.

Another problem is the interpretation of the simulated probability distributions. There aren't any decision rules for choosing among projects with respect to risk. Just how much risk is too much or how much variance is needed to overcome a certain NPV advantage isn't written down anywhere. Such judgments are subjective, and depend on the wisdom and experience of the decision makers.

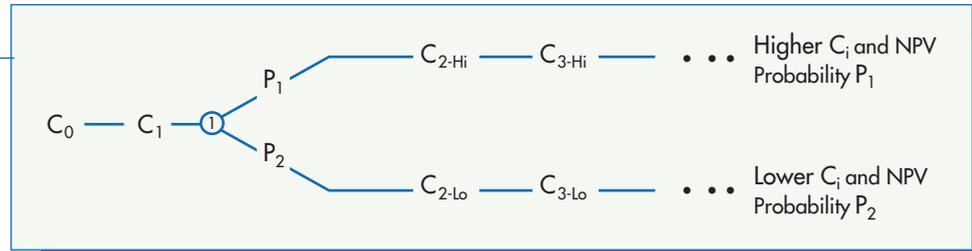
In spite of these problems, simulation can be a relatively practical approach to incorporating risk into capital budgeting analyses.

## DECISION TREE ANALYSIS

We made the point earlier that scenario analysis gives us a feel for the possible variation in NPV (and IRR) in a capital budgeting project, but doesn't tell us much

Figure 12.5

## A Simple Decision Tree



A **decision tree** is a graphic representation of a business project in which events have multiple outcomes, each of which is assigned a probability.

about the probability distribution of the NPV outcome. Decision tree analysis lets us approximate the NPV distribution if we can estimate the probability of certain events within the project. A **decision tree** is essentially an expanded time line that “branches” into alternate paths wherever an event can turn out in more than one way.

For example, suppose a capital budgeting project involves some engineering work with an uncertain outcome that won’t be completed until the project has been underway for a year. If the engineering turns out well, subsequent cash flows will be higher than if it doesn’t. The situation is captured in the decision tree diagram shown in Figure 12.5.

The project starts with initial outlay,  $C_0$ , followed by cash flow  $C_1$ , but after that there are two possibilities depending on the success of the engineering work. Each of the two possible outcomes is represented by a *branch* of the decision tree. The place at which the branches separate is called a *node*, and is commonly shown as a small numbered circle to help keep track of complex projects.

The estimated probability that a branch will occur is indicated ( $P_1, P_2$ ) just after the node at which it starts. In this case, the upper branch represents an engineering success, which results in high cash flows indicated by  $C_{2-Hi}, C_{3-Hi} \dots$ . The lower branch represents less success and lower cash flows  $C_{2-Lo}, C_{3-Lo} \dots$ .

Any number of branches can emanate from a node, but their probabilities must sum to 1.0, indicating that one of the branches *must* be taken.

A *path* through the tree starts on the left at  $C_0$  and progresses through node 1 along one branch or the other. There are obviously just two possible paths in Figure 12.5. An overall NPV outcome is associated with each path. In this case, the more favorable outcome is along the upper path and has cash flows  $C_0, C_1, C_{2-Hi}, C_{3-Hi} \dots$ , while the less favorable lower path has cash flows  $C_0, C_1, C_{2-Lo}, C_{3-Lo} \dots$ .

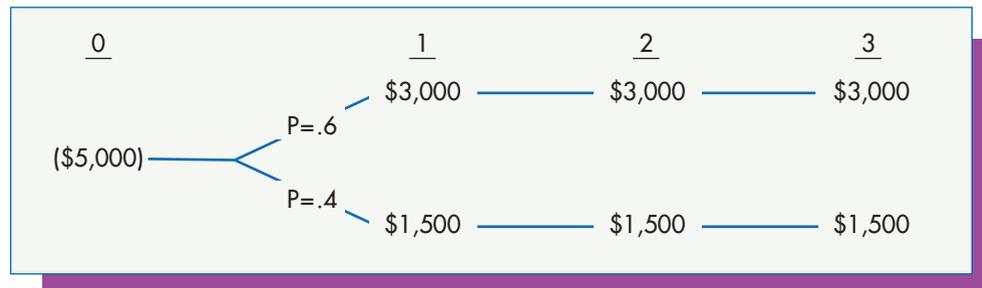
Evaluating a project involves calculating NPVs along all possible paths and associating each with a probability. From that a probability distribution for NPV can be developed. The technique is best understood through an example. (We’re working with NPV, but everything we say is equally applicable to IRR. Read the following example carefully; we will build on it throughout the rest of this section and the next.)

A **probability distribution** of a project’s **NPV** can be developed using **decision tree** analysis.

**Example 12.2** The Wing Foot Shoe Company is considering a three-year project to market a running shoe based on new technology. Success depends on how well consumers accept the new idea and demand the product. Demand can vary from great to terrible, but for planning purposes management has collapsed that variation into just two possibilities: good and poor. A market study indicates a 60% probability that demand will be good and a 40% chance that it will be poor.

It will cost \$5 million to bring the new shoe to market. Cash flow estimates indicate inflows of \$3 million per year for three years *at full manufacturing capacity* if demand is good, but just \$1.5 million per year if it’s poor. Wing Foot’s cost of capital is 10%. Analyze the project and develop a rough probability distribution for NPV.

**SOLUTION:** First draw a decision tree diagram for the project (\$000).



Next calculate the NPV along each path, using equation 10.3 (page 438), which we'll repeat here for convenience (\$000).

$$(10.3) \quad \text{NPV} = C_0 + C[\text{PVFA}_{k,n}]$$

Good consumer demand:

$$\text{NPV} = -\$5,000 + \$3,000[\text{PVFA}_{10,3}]$$

$$\text{NPV} = -\$5,000 + \$3,000(2.4869)$$

$$\text{NPV} = -\$5,000 + \$7,461$$

$$\text{NPV} = \$2,461$$

Poor consumer demand:

$$\text{NPV} = -\$5,000 + \$1,500(2.4869)$$

$$\text{NPV} = -\$5,000 + \$3,730$$

$$\text{NPV} = -\$1,270$$

Notice that we now have the elements of a probability distribution for the project's NPV. We know there's a 60% chance of an NPV of \$2,461,000 along the upper path and a 40% chance of an NPV of -\$1,270,000 along the lower path.

The expected NPV (the mean or expected value of the probability distribution of values for NPV) is calculated by multiplying every possible NPV by its probability and summing the results (\$000). (See the review of statistics at the beginning of Chapter 9 if necessary.)

Demand	NPV	Probability	Product
Good	\$2,461	.60	\$1,477
Poor	(1,270)	.40	(508)
Expected NPV =			\$ 969

Summarizing, we can say that the project's most likely NPV outcome is approximately \$1.0 million, and that there's a good chance (60%) of making about \$2.5 million, *but* there's also a substantial chance (40%) of losing about \$1.3 million.

Notice that Wing Foot's management gets a much better idea of the new running shoe project's risk from this analysis than it would from a projection of a single value of \$1.0 million for NPV. The decision tree result explicitly calls out the fact that a big loss is quite possible. That information is important because a loss of that size could ruin a small company. It could also damage the reputation of whoever is recommending the project.

The analysis also shows that if things turn out well, the reward for bearing the risk will probably be about half the size of the initial investment. That's also an important observation,

because people are less likely to take substantial risks for modest returns than for outcomes that multiply their investment many times over.

*The end result of the analysis in this case might well be a rejection of the project on the basis of risk even though the expected NPV is positive.*

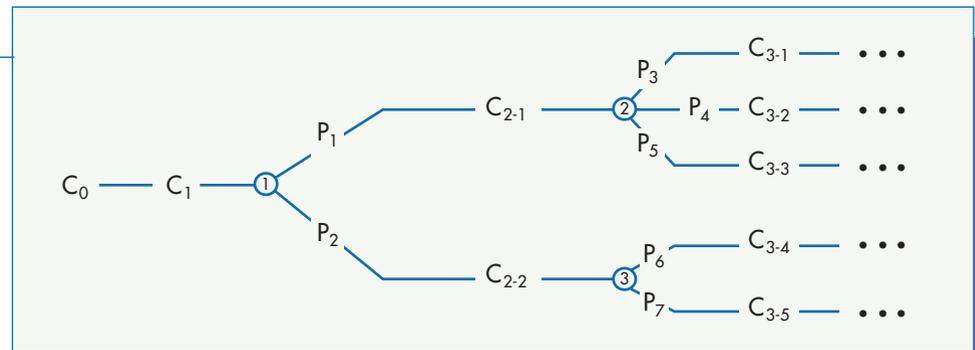


### More Complex Decision Trees and Conditional Probabilities

Most processes represented by decision trees involve more than one uncertain event that can be characterized by probabilities. Each such event is represented by a node from which two or more new branches emerge, and the tree widens quickly toward the right. A more typical tree is illustrated in Figure 12.6.

**Figure 12.6**

#### A More Complex Decision Tree



Notice that there are additional nodes along the branches that emanate from node 1, each splitting the original branch into two or three more. In this diagram there are five paths from left to right through the tree. Each starts at  $C_0$  and ends along one of the branches on the far right. Each path has an NPV calculated using all of the cash flows along that path.

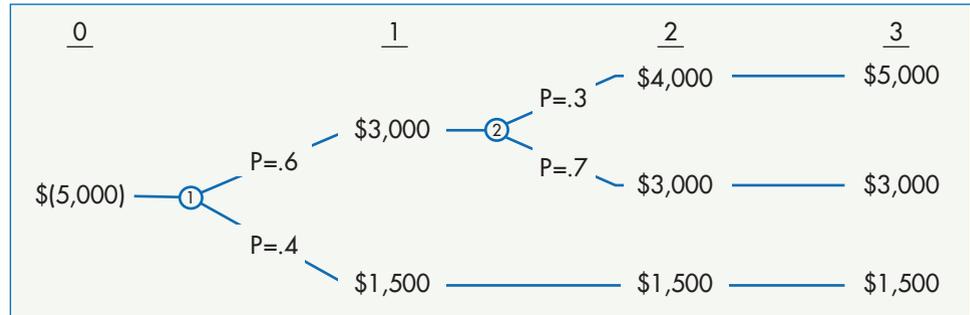
The probability of a path is the product of all of the branch probabilities along it. These are known as *conditional* probabilities, meaning that the probabilities coming out of node 2 are conditional on the upper branch out of node 1 happening.<sup>4</sup> Keep in mind that the probabilities out of each node must sum to 1.0. For example,  $P_1 + P_2 = 1.0$  and  $P_3 + P_4 + P_5 = 1.0$ .

The **probabilities emerging** from any decision tree **node** must **sum to 1.0**.

**Example 12.3** The Wing Foot Shoe Company of Example 12.2 has refined its market study and has some additional information about potential customer acceptance of the new product. Management now feels that there are two possibilities along the upper branch. Consumer response can be good, or it may be excellent. The study indicates that *if* demand is good during the first year, there's a 30% chance it will grow and be excellent in the second and third years. Of course, this also means there's a 70% chance that demand in years 2 and 3 won't change.

If consumer response to the product turns out to be excellent, an additional investment of \$1 million in a factory expansion will allow the firm to make and sell enough product to generate cash inflows of \$5 million rather than \$3 million in both years 2 and 3. Hence, the net cash inflows for the project will be (\$5 million – \$1 million =) \$4 million in year 2 and \$5 million in year 3. (The expansion is necessary to achieve the better financial results because Example 12.2 stated that the factory was at capacity along the upper path.) A decision tree for the project with this additional possibility is as follows.

4. The probability of a path is also called the *joint* probability of the individual branches along that path.



The probabilities coming out of node 2 are conditional probabilities, meaning that they exist only along the good demand path. In other words, they are *conditional upon* good demand happening out of node 1, which itself has a probability of .6. The probability of arriving at the end of any path through the decision tree is calculated by multiplying all of the probabilities along the path. Hence, the probability of the upper path is  $(.6 \times .3 =) .18$ , the middle path is  $(.6 \times .7 =) .42$ , and the lower path is just .40 as it was before. It's important to notice that these probabilities sum to 1.0, indicating that all possible outcomes are achieved by routes through the tree.

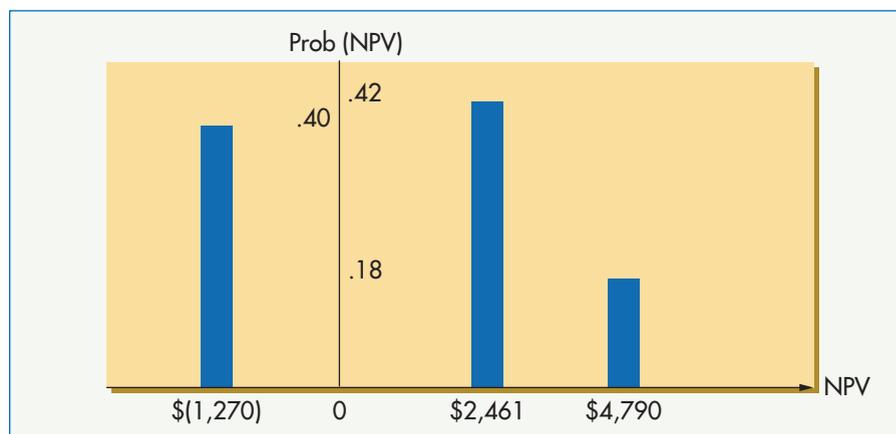
The NPV along each path is calculated in the traditional manner using all of the cash flows along the path. The middle and lower paths have the same cash flows as the paths in Example 12.2, so we've already calculated those NPVs. The NPV for the new upper path is just the sum of three present value of an amount calculations added to the initial outlay (\$000).

$$\begin{aligned}
 \text{NPV} &= -\$5,000 + \$3,000[\text{PVF}_{10,1}] + \$4,000[\text{PVF}_{10,2}] + \$5,000[\text{PVF}_{10,3}] \\
 &= -\$5,000 + \$3,000(.9091) + \$4,000(.8264) + \$5,000(.7513) \\
 &= -\$5,000 + \$2,727 + \$3,306 + \$3,757 \\
 &= \$4,790
 \end{aligned}$$

Then the probability distribution for the project and the calculation of the expected return are as follows.

Acceptance	NPV	Probability	Product
Excellent	\$4,790	.18	\$ 862
Good	2,461	.42	1,034
Poor	(1,270)	.40	(508)
			Expected NPV = \$1,388

The distribution is shown graphically as follows.



Probabilities out of later nodes are **conditional** upon the outcome at earlier nodes along the same path.

Once again it's important to notice how much more information is available through decision tree analysis than would be from a single point estimate of NPV. In this case the additional information tells us there's a fairly good chance (18%) of doing very well on the project. But there's still a substantial chance (40%) of losing money. As in Example 12.2, that outcome could be ruinous, and a prudent management might still avoid the project even though the expected value of the NPV is somewhat more positive than before.

## REAL OPTIONS

An option is the ability or right to take a certain course of action, which in business situations generally leads to a financially favorable result.

Here's an example. Suppose a business sells sports apparel in a shopping mall, and specializes in jackets and sweatshirts bearing the insignia of professional football teams. Also suppose the business depends on bank credit to support routine operations, meaning it generally needs to have a loan outstanding just to keep going.<sup>5</sup> Assume its typical loan is \$1 million. Now suppose the local pro football team has a chance at the Super Bowl this year. If the team makes it, the demand for football jackets will double, and the business will need \$2 million in bank credit. But if the extra credit isn't available, the additional sales will be lost.

The situation puts the business owner in a dilemma. He doesn't want to borrow the extra \$1 million and pay interest on it all year, because he isn't sure the additional sales will materialize. But he also knows that if he goes to the bank for an incremental loan at the last minute, he may not get it, because the bank may be short of funds at that time.

The solution may be an arrangement with the bank in which it makes a *commitment* to lend the extra money in return for a *commitment fee*, which is usually about  $1/4\%$  per year of the committed but unborrowed amount. If the business does borrow the money, the bank just charges its normal interest rate while the loan is outstanding. If it doesn't, it just pays the commitment fee, ( $\$1 \text{ million} \times .0025 =$ ) \$2,500 in this case.

The arrangement gives the business owner the ability to take advantage of the potential increase in demand for football apparel in that he has the *option* of borrowing the extra money to support the increased sales. We call that ability a **real option**. The word *real* means the option exists in a real, physical business sense. It's inserted to distinguish real options from financial options.<sup>6</sup>

Notice that the real option has a value to the business owner. It's worth at least as much as the commitment fee he pays the bank, and it may be worth a lot more depending on the probability of the local team getting into the Super Bowl and the profit he'd make on the additional sales if that happened.

## REAL OPTIONS IN CAPITAL BUDGETING

Real options frequently occur in capital budgeting projects. Their impact is best seen when the project is analyzed using a probabilistic approach such as decision tree analysis. A real option's presence generally increases the expected NPV of a project. That increase is often a good estimate of the option's value.

5. That in itself doesn't mean the business is weak or in danger of failing. We'll learn about this kind of financing in Chapter 16 when we study working capital.

6. The most common financial option is the right to purchase stock at a fixed price for a specified period. That right is known as a *call option* and is for sale at an *option price*. If the stock's market price rises above the fixed price during the period, the option holder buys the stock and immediately sells it for a profit. If the market price doesn't exceed the fixed price during the period, the option expires, and the investor loses what she paid for it. Stock options were treated in detail in Chapter 8.

A **real option** is a course of action that **can be made available**, usually at a cost, which **improves financial results** under certain conditions.

The **value** of a **real option** can be **estimated** as the **increase in project NPV** that its inclusion brings about.

**Example 12.4** Consider the Wing Foot Shoe Company's situation after the possibility of excellent demand is introduced as described in Example 12.3.

- Is a real option present?
- Suppose space at Wing Foot's plant is scarce, and room for an expansion is available only at \$.5 million cost at the project's outset. This is in addition to the \$1 million the expansion will cost in year 2 if it's done. In other words, the project's initial outlay will increase by \$.5 million if the expansion option is included. If demand isn't excellent, that money will be wasted. Should the expansion space be purchased under the conditions presented in Example 12.3?

**SOLUTION:**

- Notice that in Example 12.2, Wing's factory is at full capacity at a sales level consistent with good consumer acceptance of the new product (page 491). This is shown along the top branch of the decision tree. If capacity expansion isn't possible, there's nothing management can do to take advantage of higher than expected demand. The situation differs in Example 12.3 because the firm has the option of investing an additional \$1 million in an expansion if larger demand is experienced. Then the project could generate more sales and increased cash flows that might more than offset the cost of the new capacity.

The opportunity to respond to the realization that consumer acceptance is excellent by expanding the plant is a real option. In other words, management has the *option* of expanding capacity at an incremental cost to meet higher than expected demand. There's no cost associated with this real option as described so far. We'll consider the implications of a real option with a cost in part b.

- Having the extra space from the beginning of the running shoe project gives management the real option to expand. Without it management doesn't have that choice. Hence, in order to decide whether it's wise to purchase extra space, we have to place a value on the ability to expand capacity. We'll then compare that value with the cost of the option which is \$.5 million.

It's relatively easy to make a first approximation of the value of the real option in this case. It's just the difference in the *expected values* of the project's NPV calculated with and without the option. That makes sense because expected NPV is the basic measure of the project's value to the firm.

We calculated the expected NPV without the option in Example 12.2 and with it in Example 12.3. The option was the only difference in those situations. From those examples we have the following.

Expected NPV with option	\$1,388
Expected NPV without option	969
Real option value	\$ 419 <sup>7</sup>

Since the value of the real option is less than its \$.5 million cost, it seems that management shouldn't buy the space for the potential expansion ahead of time. However, we'll see shortly that there may be another reason to consider keeping the expansion option alive.

7. It's important not to confuse the value of the option in an expected value sense and with what it's worth if the expansion actually happens. Look at the calculation of the expected value of the project's NPV in Example 12.3. If demand is excellent and the expansion happens, NPV is \$4,790 along the top path. If demand is just good, NPV is \$2,461 along the middle path. The difference between those figures is \$2,329. That's the amount the expansion capability contributes if demand actually turns out to be excellent.

However, at the beginning of the project, when we're doing capital budgeting, we don't know whether that will happen. At that time we just know there's an 18% chance of excellent demand. Recognizing this, the expected value calculation adds 18% of \$2,329 to the project's expected NPV, which, within rounding error, is \$419 ( $\$2,329 \times .18 = \$419.22$ ).

## The Abandonment Option

Look at the decision tree in Example 12.3 (pages 493–495) once again. Notice that the lower path representing poor demand has a negative NPV of \$(1,270), indicating the project will be a money-losing failure if customers are reluctant to buy the new design. Once management realizes demand is poor, say after the first year, does it make sense to continue producing the running shoes in years 2 and 3, earning inflows of just \$1,500? It does if there are no alternate uses for the resources involved in making the shoes, since a positive cash contribution of \$1,500 per year is better than nothing.

But suppose the facilities and equipment used to make the new shoe can be redeployed into something else. Under those conditions it may make sense to abandon the project altogether.

The ability to **abandon** a project that is performing poorly is a common **real option** that is often inexpensive.

**Example 12.5** Wing Foot has other lines of shoes in which most of the equipment purchased for the running shoe project can be used if the new idea is abandoned. Management estimates that at the end of the first year the equipment's value in those other uses will be \$4.5 million. How does this information impact the analysis of the running shoe project?

**SOLUTION:** If the project is abandoned and the equipment is redeployed at the end of the first year, cash flows along the bottom path of the decision tree in Example 12.3 (page 494) would be (\$1,500 + \$4,500 =) \$6,000 in the first year and zero in years 2 and 3. The NPV along the bottom path would then be as follows.

$$\begin{aligned} \text{NPV} &= -\$5,000 + \$6,000[\text{PVF}_{10,1}] \\ &= -\$5,000 + \$6,000(.9091) \\ &= -\$5,000 + \$5,455 \\ &= \$455 \end{aligned}$$

Recalculate the project's expected NPV, assuming the bottom path is replaced by abandonment. To do that repeat the calculation in Example 12.3 replacing the NPV of \$(1,270) along the bottom path with \$455.

Acceptance	NPV	Probability	Product
Excellent	\$4,790	.18	\$ 862
Good	2,461	.42	1,034
Poor	455	.40	182
			Expected NPV = \$2,078

Notice that the expected NPV has increased from \$1,388 to \$2,078.

It's very important to appreciate two things about the calculations we've just done. First, abandonment is a course of action available to management that improves the project's expected NPV. Therefore, if abandonment is possible, it's a real option.

Second, the existence of the abandonment option lowers the project's risk substantially. We can see that by looking at the diagram in Example 12.3 that graphically displays the probability distribution of the project's NPV (page 494). Notice that the project as originally presented has a 40% probability of a negative NPV of \$(1,270). This is essentially a loss of that amount. We commented earlier that such a loss could ruin a small firm and might be a reason to avoid the project altogether.

But if the abandonment option exists as we've described it, that outcome is pushed to the right and becomes a 40% probability of a small gain of \$455. That makes the project taken as a whole a lot less risky. Indeed, it's unlikely that a firm would need to avoid the project because of the risk of ruin if this abandonment option exists.

The **value** of a real option is **at least** the **increase in NPV** it brings about.

A real option may be **worth more** than the increase it causes in NPV, because it also **reduces project risk**.

## VALUING REAL OPTIONS

In Example 12.4 we calculated the value of a real option as the increase it created in the NPV of the project in which it is embedded. That's a good starting point for valuation, but it doesn't capture the whole story because of the risk reduction we've just described.

In fact, real options are generally worth more than their expected NPV impact because of the effect they have on risk. Recall that individuals and managers are *risk averse*, meaning they prefer less risky undertakings when expected returns or NPVs are equal. That preference generally means people are willing to pay something for risk reduction over and above the amount by which a real option increases expected NPV. Unfortunately it's difficult to say just how much more, because neither a precise measure of risk nor a relationship between risk and value exists in the capital budgeting context. In other words, we know the value of real options may be enhanced by their effect on risk, but we can't say by how much.

### An Approach through Rates of Return

One possible approach to valuing real options involves *risk adjusted rates* of return. We'll discuss the idea in detail in the next section. For now it's enough to understand that lower risk should be associated with a lower rate of return in our NPV calculations. Hence, if a real option lowers a project's risk, it may be appropriate to recalculate its NPV using a lower interest rate than the firm's cost of capital. Since lower interest rates produce higher present values, this procedure makes the recalculated NPV larger, thereby assigning a higher value to the real option. The difficult question is choosing the right risk adjusted rate.

### The Risk Effect Is Tricky

Consider the expansion option of Example 12.4 in which we indicated that the expected benefit of the option may not be worth its cost. (Recall that the expected NPV increase was \$419,000 while the cost of preserving the option was \$500,000.) We arrived at that tentative conclusion without considering the option's effect on risk. We just said that the risk reduction properties of real options lend them extra value. If that's the case isn't it possible that the option to expand is worth more than \$419,000?

Pause for a moment and answer that question before reading on. (*Hint: Compare the effect of the abandonment option and the expansion option on the probability distribution of NPV for the project.*)

Although real options often reduce risk, the risk effect of the expansion option probably doesn't help to enhance its value. We can see that by comparing its effect with that of the abandonment option carefully. The risk-reducing effect of the abandonment option is significant because it eliminates the risk of a substantial loss. The expansion option, on the other hand, makes a larger profit available if things go really well, but doesn't change the fact that there's a 40% chance of a large loss which might ruin the firm. Since that large, high probability loss is the key risk issue, there's little or no risk-reducing value in the expansion option.



## REAL APPLICATIONS

### Volatile Energy Prices and Real Options Thinking Can Lead to Big Profits on Inefficient Facilities

Real options thinking has become especially popular in industries that require big investments in capital equipment. Classic examples are air transportation, which requires giant jet planes with enormous price tags, and the electric power industry, in which providers build costly power plants. Prior to its descent into disgrace and bankruptcy in 2001, Enron Corp. was a large energy company whose base business involved building and running electric power plants as well as natural gas pipelines.\* The firm's application of real options thinking to power plants in the late 1990s provides a fascinating example of the scope of the technique.

Real options reasoning was used to justify building three electric power plants in Mississippi and Tennessee that were inefficient by design. They're so inefficient that the electricity they produce costs 50 to 70% more than the industry standard. The plants cost a lot less to build than state-of-the-art facilities, but that's not the reason they were put in place.

At the time deregulation in the electric utility industry had led to amazingly volatile wholesale prices for electric power. (See the Real Applications box in Chapter 7, page 301). Indeed the price of power varied from a normal level per megawatt hour of about \$40 to an unbelievable \$7,000. That volatility coupled with real options thinking made the inefficient plants not only feasible, but a great idea.

The plants weren't intended to operate all the time. They were to be fired up only when energy rates spiked to levels so high that production costs didn't matter. For example, if a megawatt hour of electricity was selling for \$1,000, it didn't matter much whether it cost \$20 or \$30 to produce.

The inefficient power plants gave their owner the option to generate and sell more electricity when rates peaked. At other times they were simply left idle. The cost of building the plants was the cost of having that option. This is a classic real options situation. If the probability of peak prices is fairly high, the expected value of the extra profits the plants bring in exceeds the cost of building those plants, and having them increases the expected NPV of power-generating operations.

Under these conditions the plants may have had to operate only a week or two each year to more than pay for themselves. The plants represented a *flexibility option*, because they gave their owner the flexibility to respond to high electricity prices with expanded output.

\*Electric power and gas pipelines were only a small part of Enron's business in the early 2000s. By that time it had largely focused on the risky business of trading contracts for the future delivery of natural gas, electric power, and other commodities. The firm became financially overextended in those areas and filed for bankruptcy protection in late 2001. That failure was essentially unrelated to its power plant operations.

**Sources:** "Exploiting Uncertainty," *Business Week* (June 7, 1999); and Daniel Kadlec, "Power Failure: As Enron crashes, angry workers and shareholders ask, Where were the firm's directors? The regulators? The stock analysts?" *Time* (December 10, 2001): 68.

All of this says that the value of real options has to be considered carefully on a case-by-case basis. A good deal of advanced theoretical work is currently being done in the area.

### DESIGNING REAL OPTIONS INTO PROJECTS

It makes sense to design projects so that they contain beneficial real options whenever possible. We've already seen two examples in which thinking about real options at the beginning of a project might make a big difference later on.

The **abandonment option** discussed in Example 12.5 increased expected NPV and lowered risk at the same time. Hence, the example illustrates that it's a good idea to design the ability to quit into projects. Unfortunately that isn't always easy. Contractual obligations, for example, can make abandonment tough. In our illustration, suppose Wing Foot guaranteed retailers the new shoes for three years, signed a lease for factory space, and entered long-term purchasing contracts with suppliers. Then stopping after one year would require breaking the contracts, which could be difficult and costly. Prudent managers should always try to avoid entanglements that make exit hard.

**Expansion options** like the one illustrated in Example 12.4 are very common. When the ability to expand costs extra money early in the project's life, a careful financial analysis is necessary, as we've indicated. However, the option frequently requires little or no early commitment and should be planned in whenever possible.

**Investment timing options** also come up frequently. Here's an example. Suppose a company is looking at a project to build a new factory, and has identified an unusually good site, but it can't make a final decision for six months. Management doesn't want to buy the property now, because there's a chance the firm won't build the factory. But management doesn't want to lose out to another buyer because if it does decide to build later on, it would then have to start looking for a site all over again.

The solution can be a *land option contract* in which the landowner grants the company the right to buy the site at any time in the next six months at a fixed price in return for a nonrefundable fee called the *option price*.

The option is a purchase contract between a buyer and a seller that's suspended at the discretion of the buyer for a limited time. If the buyer doesn't *exercise* the option by the end of that time, it just expires. The land option lets the firm delay its investment in the land until it's sure about other relevant issues and problems.

**Flexibility options** let companies respond more easily to changes in business conditions. For example, suppose a firm buys the same part from two suppliers for \$1 per unit. If it gives all of its business to one supplier, the price would be \$.90 per unit. But if that single supplier fails, the firm's business will suffer while it's unable to get the part. Hence, the flexibility of having both suppliers available may be worth the extra \$.10 per unit.

## INCORPORATING RISK INTO CAPITAL BUDGETING—THE THEORETICAL APPROACH AND RISK-ADJUSTED RATES OF RETURN

The theoretical approach to incorporating risk into capital budgeting focuses on rates of return. Recall that an *interest rate* plays a central role in both the NPV and IRR methods. Until now we've taken that key rate to be the firm's cost of capital. Let's briefly review how it is used in both techniques.

In the NPV method, we calculate the present value of cash flows using the cost of capital as the discount rate. A higher discount rate produces a lower NPV, which reduces the chances of project acceptance. In the IRR method, the decision rule involves comparing a project's return on invested funds with the cost of capital. A higher cost of capital means a higher IRR is required for acceptance, which also lowers the chance of the project being qualified.

In summary, the acceptance or rejection of projects depends on this key interest rate in both methods, with higher rates implying less likely acceptance. In what follows we'll investigate the implications of doing the calculations with an interest rate other than the cost of capital.

The **cost of capital** plays a **key role** in both NPV and IRR.

## Riskier Projects Should Be Less Acceptable

The idea behind incorporating risk into capital budgeting is to make particularly risky projects less acceptable than others with similar *expected* cash flows. Notice that this is exactly what happens under capital budgeting rules if projects are evaluated using higher interest rates. A higher discount rate lowers the calculated NPV for any given set of cash flows, while a higher threshold rate means calculated IRRs have to be larger to qualify projects.

Therefore, a logical way to incorporate risk into capital budgeting is to devise an approach that uses the NPV and IRR methods, but analyzes riskier projects using higher interest rates in place of the cost of capital. Logically, the higher the risk, the higher the interest rate that should be used. This approach will automatically create a bias against accepting higher risk projects. Higher rates used to compensate for riskiness in financial analysis are called **risk-adjusted rates**.

Using a higher, **risk-adjusted rate** for **risky** projects **lowers their chance of acceptance**.

## The Starting Point for Risk-Adjusted Rates

Earlier in this chapter we said that in the long run a company can be viewed as a collection of projects, and that adopting a large number of relatively risky endeavors can change its fundamental nature to that of a more risky enterprise.

It makes sense to take the current status of a firm as the starting point for risk measurement and to let the cost of capital be the interest rate representing that point. Then it's logical to analyze projects that are consistent with the current riskiness of the company using the cost of capital and to use higher rates for riskier projects.

## Relating Interest Rates to Risk

These ideas are consistent with the interest rate fundamentals we studied in Chapter 5. Recall that every interest rate is made up of two parts: a base rate and a premium for risk. The idea was expressed as an equation that we'll repeat here for convenience.

$$(5.1) \quad k = \text{base rate} + \text{risk premium}$$

This equation says that investors demand a higher risk premium and consequently a higher interest rate if they are to bear increased risk. In capital budgeting, the company is investing in the project being analyzed, and the interest rate used in the analysis is analogous to the rate of return demanded by an investor from a security.

If the project's risk is about the same as the company's overall risk, using the firm's cost of capital is appropriate. If the project's risk is higher, a rate with a higher risk premium is needed.

Projects with **risk** consistent with **current** operations should be evaluated using the **cost of capital**.

## Choosing the Risk-Adjusted Rate for Various Projects

The ideas we've described in this section make logical sense, but run into practical problems when they're implemented. The stumbling block is the arbitrariness of choosing the appropriate risk-adjusted rate for a particular project.

Projects are generally presented with point estimates of future cash flows. Assessing the riskiness or variability of those cash flows is usually a subjective affair, so there's little on which to base the choice of a risk-adjusted rate. However, some logical thinking can help.

Recall that projects fit into three categories of generally increasing risk: replacement, expansion, and new venture. Replacements are usually a continuation of what was being done before, but with new equipment. Because the function is already part of the business, its risk will be consistent with that of the present business. Therefore,

the cost of capital is nearly always the appropriate discount rate for analyzing replacement projects.

Expansion projects involve doing more of the same thing in some business area. They're more risky than the current level, but usually not very much more. In such cases a rule of thumb of adding one to three percentage points to the cost of capital is usually appropriate.<sup>8</sup>

New venture projects are the big problem. They usually involve a great deal more risk than current operations, but it's hard to quantify exactly how much. So choosing a risk-adjusted rate is difficult and arbitrary. However, *sometimes* we can get help from portfolio theory.

## ESTIMATING RISK-ADJUSTED RATES USING CAPM

Portfolio theory and the capital asset pricing model (Chapter 9) deal with assigning risk to investments. Under certain circumstances, the techniques developed there can be used to generate risk-adjusted rates for capital budgeting.

### The Project as a Diversification

When a company undertakes a new venture, the project can be viewed as a diversification similar to adding a new stock to a portfolio. We can look at this idea in two ways.

The first involves seeing the firm as a collection of projects. A new venture simply adds another enterprise to the company's project portfolio, which then becomes more diversified. In the second view, the project diversifies the investment portfolios of the firm's shareholders into the new line of business.

This second idea is important and profound; let's explore it more deeply. Suppose a firm is in the food processing business. Stockholders have chosen to invest in the company because they're comfortable with the risks and rewards of that business. Now suppose the firm takes on a venture in electronics. To the extent of the new project, stockholders are now subject to the risks and rewards of the electronics business. They could have accomplished the same thing by selling off some of their food processing company stock and buying stock in an electronics firm. In essence the company has done that for them, probably without their permission.

### Diversifiable and Nondiversifiable Risk for Projects

In Chapter 9 we separated investment risk into systematic and unsystematic components. Unsystematic (business-specific) risk is specific to individual firms or industries and can be diversified away by having a wide variety of stocks in a portfolio. Systematic (market) risk, on the other hand, is related to movement with the entire market and can't be entirely eliminated through diversification.

Projects viewed as investments have two levels of diversifiable risk because they're effectively in two portfolios at the same time. Some risk is diversified away within the firm's portfolio of projects, and some is diversified away by the stockholders' investment portfolios.

These ideas lead to an additional, intermediate concept of risk, the undiversified risk added to a company by the addition of a project. The idea is illustrated in Figure 12.7.

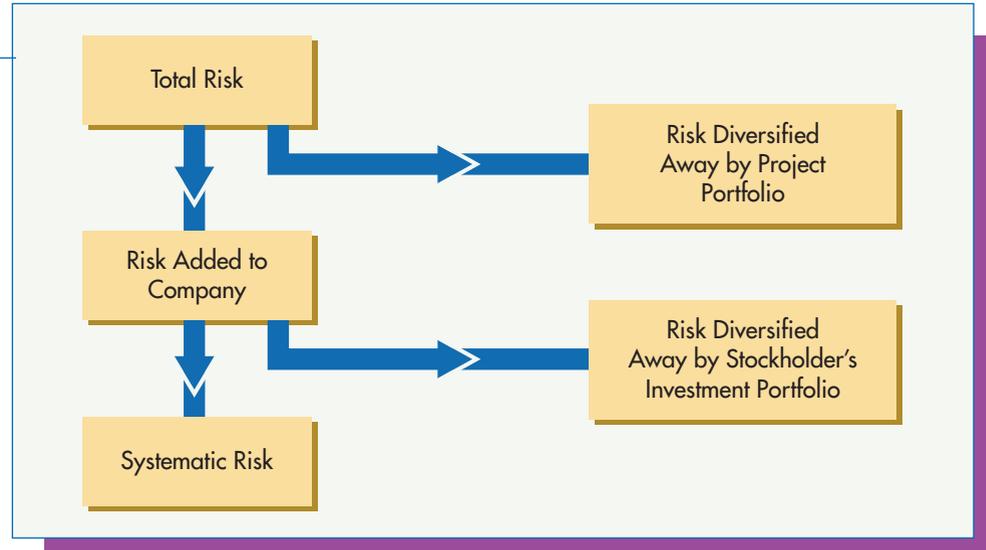
Notice that the risk left over after the two kinds of diversifiable risk are removed is systematic (market) risk. This is the same concept of systematic (market) risk used in portfolio theory, but here it's associated with a project rather than a company.

A new venture **diversifies** the company and its shareholders.

8. If the expansion is very large, a bigger adjustment may be necessary.

Figure 12.7

## Components of Project Risk



## Estimating the Risk-Adjusted Rate through Beta

The capital asset pricing model we studied in Chapter 9 gives us an approach to measuring *systematic risk* for companies by using the security market line (SML). The SML (equation 9.4) defines the firm's required rate of return in terms of a base rate and a risk premium. We'll repeat it here for convenience.

$$(9.4) \quad k_X = k_{RF} + (k_M - k_{RF})b_X$$

where  $k_X$  is the required rate of return for company X,  $k_{RF}$  is the risk-free rate,  $k_M$  is the return on the market, and  $b_X$  is company X's beta.

The term

$$(k_M - k_{RF})b_X$$

is the risk premium for company X's stock, which is a function of  $b_X$ , the company's beta. Beta in turn measures only systematic (market) risk (page 398). But the bottom block in Figure 12.7 also represents systematic (market) risk. In other words, the SML gives us a risk-adjusted interest rate related to a particular kind of risk for the stock of a company, and we find that same kind of risk in the analysis of projects.

*If a capital budgeting project is viewed as a business in a particular field, it may make sense to use a beta common to that field in the SML to estimate a risk-adjusted rate for analysis of the project.*

Recall, for example, the food processing company that takes on a venture in electronics. It might be appropriate to use a beta typical of electronics companies in the SML to arrive at a risk-adjusted rate to analyze the project. This line of thinking is especially appropriate when an independent, publicly traded company can be found that is in the same business as the venture and whose beta is known. The approach is known as the **pure play** method of establishing a risk-adjusted rate. The **pure play company** has to be solely in the business of the venture; otherwise its beta won't be truly appropriate.

Under certain conditions the **SML** can be used to determine a **risk-adjusted rate** for a **new venture project**.

**Example 12.6** Orion Inc. is a successful manufacturer of radio communications equipment sold in consumer and commercial markets. Management is considering producing a sophisticated tactical radio for sale to the Army, but is concerned because the military market is known to be quite risky.

The military radio market is dominated by Milrad Inc., which holds a 60% market share. Antex Radio Corp. is another established competitor with a 20% share. Both Milrad and Antex make only military radios. Milrad's beta is 1.4 and Antex's is 2.0. Orion's beta is 1.1. The return on an average publicly traded stock ( $k_M$ ) is about 10%. The yield on short-term treasury bills ( $k_{RF}$ ) is currently 5%. Orion's cost of capital is 8%.

The military radio project is expected to require an initial outlay of \$10 million. Subsequent cash inflows are expected to be \$3 million per year over a five-year contract.

On the basis of a five-year evaluation, should Orion undertake the project?

**SOLUTION:** The military business is clearly riskier than Orion's radio communications equipment business judging by the relative betas of Orion and its potential rivals. Therefore, a CAPM-based risk-adjusted rate is appropriate for the analysis. Milrad and Antex are both pure play companies, but the fact that Milrad is the market leader probably reduces its risk. If Orion enters the field it will be in a position similar to Antex's, so a risk-adjusted rate based on that firm's beta is most appropriate.

First we calculate the risk-adjusted rate using the SML and Antex's beta.

$$\begin{aligned} k &= k_{RF} + (k_M - k_{RF})b_{\text{Antex}} \\ &= 5\% + (10\% - 5\%)2.0 \\ &= 15.0\% \end{aligned}$$

Notice that this rate is considerably higher than Orion's cost of capital (8%).

Next calculate the proposed project's NPV using the risk-adjusted rate.

$$\begin{aligned} (\$ \text{ millions}) \quad \text{NPV} &= C_o + C[\text{PVFA}_{k,n}] \\ &= -\$10.0 + \$3[\text{PVFA}_{15,5}] \\ &= -\$10.0 + \$3(3.3522) \\ &= \$0.1 \end{aligned}$$

Notice that the risk-adjusted NPV is barely positive, indicating that the project is marginal.

If Orion's 8% cost of capital had been used in the analysis, the result would have been as follows.

$$\begin{aligned} (\$ \text{ millions}) \quad \text{NPV} &= -\$10.0 + \$3[\text{PVFA}_{8,5}] \\ &= -\$10.0 + \$3(3.9927) \\ &= -\$10.0 + \$12.0 \\ &= \$2.0 \end{aligned}$$

Compare these two results. The capital budgeting rule unadjusted for risk would clearly have accepted the project, but consideration of risk has shown it to be a very marginal undertaking. This can be a crucial managerial insight! However, in the next section we'll see that there are more questions lurking about.

## PROBLEMS WITH THE THEORETICAL APPROACH—FINDING THE RIGHT BETA AND CONCERNS ABOUT THE APPROPRIATE RISK DEFINITION

Using the CAPM to estimate risk-adjusted rates as illustrated in the last section appears straightforward and unambiguous. However, it would be rather unusual for the technique to fit into the real world as neatly as it did in the example. Generally, the

biggest problem is finding a pure play company from which to get an appropriate beta. For example, if Milrad and Antex were divisions of larger companies, their separate betas wouldn't be available, and the betas of their parent companies would be influenced by the operations of divisions in other fields. As a result, we're usually reduced to estimating betas based on those of firms in similar rather than exactly the same businesses. This reduces the credibility of the technique by quite a bit.

However, there's another, more basic problem. Look back at Figure 12.7. Notice that three levels of risk are attached to projects, and that the CAPM technique uses the last level, systematic risk. But systematic risk is a concept that's really only relevant in the context of a well-diversified portfolio of financial assets. It excludes all unsystematic risks that may be associated with the project itself or with the company. In the context of a firm making day-to-day business decisions, disregarding unsystematic risk may not be appropriate.

For example, suppose the military radio project in Example 12.6 fails because Orion's management doesn't know how to deal with the government.<sup>9</sup> That risk isn't included in systematic risk because it's related specifically to Orion. But shouldn't Orion be concerned about risks like that when considering the project? Most people would agree that it should.

This reasoning suggests that total risk as pictured in Figure 12.7 is the more appropriate measure for capital budgeting. But CAPM doesn't give us an estimate of that. All we can say is that total risk is higher than systematic risk.

Let's look at Example 12.6 again in that light. The military radio project is marginal at a risk-adjusted rate reflecting only systematic risk. If a broader definition of risk is appropriate, the risk-adjusted rate should be even higher, which would lower NPV and make the project clearly undesirable.

### Projects in Divisions—The Accounting Beta Method

Sometimes a large company has divisions in different businesses, each of which has substantially different risk characteristics. In such cases, the cost of capital for the entire firm can't be associated with any particular division, so some kind of a proxy rate has to be found for capital budgeting within divisions.

The pure play method just described might be used if pure play companies can be found in the right businesses, but that's often not possible. If an appropriate surrogate can't be found, and a division has separate accounting records, an approximate approach can be used. The approximation involves developing a beta for the division from its accounting records rather than from stock market performance. This is accomplished by regressing historical values of the division's return on equity against the return on a major stock market index like the S&P 500. The slope of the regression line is then the division's approximate beta and the SML can be used to estimate a risk-adjusted rate. This approach is called the *accounting beta method*.

### A Final Comment on Risk in Capital Budgeting

Adjusting capital budgeting procedures to recognize risk makes a great deal of sense. However, the methods available to implement the concept are less than precise. As a result, risk-adjusted capital budgeting remains more in the province of the theorist than of the financial manager.

*To put it another way, virtually everyone uses capital budgeting techniques, but only a few overtly try to incorporate risk. Business managers do recognize risk, but they do it through judgments overlaid on the results of analysis when decisions are finally made.*

from the **CFO**

9. This is a very real problem. Government and commercial markets are entirely different worlds.

Nevertheless, it's important that students understand the risk issue, because it's a very real part of decision making. Recognizing risk is a major step toward bringing theory in line with the real world. Even though we can't precisely put the idea that cash flows are subject to probability distributions into our analysis, we'll make better decisions for having thought about it.

## QUESTIONS

1. In 1983 the Bell telephone system, which operated as AT&T, was broken up, resulting in the creation of seven regional telephone companies. AT&T stockholders received shares of the new companies and the continuing AT&T, which handled long distance services. Prior to the breakup, telephone service was a regulated public utility. That meant AT&T had a monopoly on the sale of its service, but couldn't charge excessive prices due to government regulation. Regulated utilities are classic examples of low risk–modest return companies. After the breakup, the “Baby Bells,” as they were called, were freed from many of the regulatory constraints under which the Bell system had operated, and at the same time had a great deal of money. The managements of these young giants were determined to make them more than the staid, old-line telephone companies they'd been in the past. They were quite vocal in declaring their intentions to undertake ventures in any number of new fields, despite the fact that virtually all of their experience was in the regulated environment of the old telephone system. Many stockholders were alarmed and concerned by these statements. Comment on what their concerns may have been.
2. A “random variable” is defined as the outcome of one or more chance processes. Imagine that you're forecasting the cash flows associated with a new business venture. List some of the things that come together to produce cash flows in future periods. Describe how they might be considered to be outcomes of chance processes and therefore random variables. Cash flow forecasts for a project are used in equations 10.1 and 10.2 to calculate the project's NPV and IRR. That makes NPV and IRR random variables as well. Is their variability likely to be greater or less than the variability of the individual cash flows making them up?
3. One of the problems of using simulations to incorporate risk in capital budgeting is related to the idea that the probability distributions of successive cash flows usually are not independent. If the first period's cash flow is at the high end of its range, for example, flows in subsequent periods are more likely to be high than low. Why do you think this is generally the case? Describe an approach through which the computer might adjust for this phenomenon to portray risk better.
4. Why is it desirable to construct capital budgeting rules so that higher-risk projects become less acceptable than lower-risk projects?
5. Rationalize the appropriateness of using the cost of capital to analyze normally risky projects and higher rates for those with more risk.
6. Evaluate the conceptual merits of applying CAPM theory to the problem of determining risk-adjusted interest rates for capital budgeting purposes. Form your own opinion based on your study of CAPM (Chapter 9) and the knowledge of capital budgeting you're now developing. The issue is concisely summarized by Figure 12.7. Is the special concept of risk developed in portfolio theory applicable here? Don't

be intimidated into thinking that because the idea is presented in textbooks, it's necessarily correct. Many scholars and practitioners feel this application stretches theory too far. On the other hand, others feel it has a great deal of merit. What do you think and why?

### BUSINESS ANALYSIS

1. Ed Draycutt is the engineering manager of Airway Technologies, a firm that makes computer systems for air traffic control installations at airports. He has proposed a new device whose success depends on two separate events. First the Federal Aviation Administration (FAA) must adopt a recent proposal for a new procedural approach to handling in-flight calls from planes experiencing emergencies. Everyone thinks the probability of the FAA accepting the new method is at least 98%, but it will take a year to happen. If the new approach is adopted, radio makers will have to respond within another year with one of two possible changes in their technology. These can simply be called A and B. The A response is far more likely, also having a probability of about 98%. Ed's device works with the A system and is a stroke of engineering genius. If the A system becomes the industry standard and Airway has Ed's product, it will make a fortune before anyone else can market a similar device. On the other hand if the A system isn't adopted, Airway will lose whatever it has put into the new device's development.

Developing Ed's device will cost about \$20 million, which is a very substantial investment for a small company like Airway. In fact, a loss of \$20 million would put the firm in danger of failing.

Ed just presented his idea to the executive committee as a capital budgeting project with a \$20 million investment and a huge NPV and IRR reflecting the adoption of the A system. Everyone on the committee is very excited. You're the CFO and are a lot less excited. You asked Ed how he reflected the admittedly remote possibility that the A system would never be put in place. Ed, obviously proud of his business sophistication, said he'd taken care of that with a statistical calculation. He said adoption of the A system required the occurrence of two events, each of which has a 98% probability. The probability of both happening is  $(.98 \times .98 = .96)$  96%. He therefore reduced all of his cash inflow estimates by 4%. He maintains this correctly accounts for risk in the project.

Does Ed have the right expected NPV? What's wrong with his analysis? Suggest an approach that will give a more insightful result. Why might the firm consider passing on the proposal in spite of the tremendous NPV and IRR Ed has calculated?

2. Might Ed's case in the preceding problem be helped by a real option? If so, what kind? How would it help?
3. Charlie Henderson, a senior manager in the Bartok Company, is known for taking risks. He recently proposed that the company expand its operations into a new and untried field. He put together a set of cash flow projections and calculated an IRR of 25% for the project. The firm's cost of capital is about 10%. Charlie maintains that the favorability of the calculated IRR relative to the cost of capital makes the project an easy choice for acceptance, and urges management to move forward immediately.

Several knowledgeable people have looked at the proposal and feel Charlie's projections represent an optimistic scenario that has about one chance in three of

happening. They think the project also has about one chance in three of failing miserably. An important consideration is that the project is large enough to bankrupt the company if it fails really badly.

Charlie doesn't want to talk about these issues, claiming the others are being "negative" and that he has a history of success with risky ventures like this. When challenged, he falls back on the 25% IRR versus the 10% cost of capital as justification for his idea.

The company president has asked you for your comments on the situation. Specifically address the issue of the 25% IRR versus the 10% cost of capital. Should this project be evaluated using different standards? How does the possibility of bankruptcy as a result of the project affect the analysis? Are capital budgeting rules still appropriate? How should Charlie's successful record be factored into the president's thinking?

4. In evaluating the situation presented in the previous problem, you've found a pure play company in the proposed industry whose beta is 2.5. The rate of return on short-term treasury bills is currently 8% and a typical stock investment returns 14%. Explain how this information might affect the acceptability of Charlie's proposal. What practical concerns would you overlay on top of the theory you've just described? Do they make the project more or less acceptable? Does the fact that Bartok has never done this kind of business before matter? How would you adjust for that inexperience? Is the risk of bankruptcy still important? What would you advise doing about that? All things considered, would you advise the president to take on the project or not?

## PROBLEMS

1. The Glendale Corp. is considering a real estate development project that will cost \$5 million to undertake and is expected to produce annual inflows between \$1 million and \$4 million for two years. Management feels that if the project turns out really well the inflows will be \$3 million in the first year and \$4 million in the second. If things go very poorly, on the other hand, inflows of \$1 million followed by \$2.5 million are more likely. Develop a range of NPVs for the project if Glendale's cost of capital is 12%.
2. If Glendale's management in the previous problem attaches a probability of .7 to the better outcome, what is the project's most likely (expected) NPV?
3. Keener Clothiers Inc. is considering investing \$2 million in an automatic sewing machine to produce a newly designed line of dresses. The dresses will be priced at \$200, and management expects to sell 12,000 per year for six years. There is, however, some uncertainty about production costs associated with the new machine. The production department has estimated operating costs at 70% of revenues, but senior management realizes that this figure could turn out to be as low as 65% or as high as 75%. The new machine will be depreciated at a rate of \$200,000 per year (straight line, zero salvage). Keener's cost of capital is 14%, and its marginal tax rate is 35%. Calculate a point estimate along with best- and worst-case scenarios for the project's NPV.
4. Assume that Keener Clothiers of the previous problem assigns the following probabilities to production cost as a percent of revenue.

% of Revenue	Probability
65%	.30
70	.50
75	.20

Sketch a probability distribution (histogram) for the project's NPV, and compute its expected NPV.

5. The Blazingame Corporation is considering a three-year project that has an initial cash outflow ( $C_0$ ) of \$175,000 and three cash inflows that are defined by the following independent probability distributions. All dollar figures are in thousands. Blazingame's cost of capital is 10%.

$C_1$	$C_2$	$C_3$	Probability
\$50	\$ 40	\$75	.25
60	80	80	.50
70	120	85	.25

- Estimate the project's most likely NPV by using a point estimate of each cash flow. What is its probability?
- What are the best and worst possible NPVs? What are their probabilities?
- Choose a few outcomes at random, calculate their NPVs and the associated probabilities, and sketch the probability distribution of the project's NPV.

[Hint: The project has 27 possible cash flow patterns ( $3 \times 3 \times 3$ ), each of which is obtained by selecting one cash flow from each column and combining with the initial outflow. The probability of any pattern is the product of the probabilities of its three uncertain cash flows. For example, a particular pattern might be as follows.

	$C_0$	$C_1$	$C_2$	$C_3$
$C_i$	\$(175)	\$50	\$120	\$80
Probability	1.0	.25	.25	.50

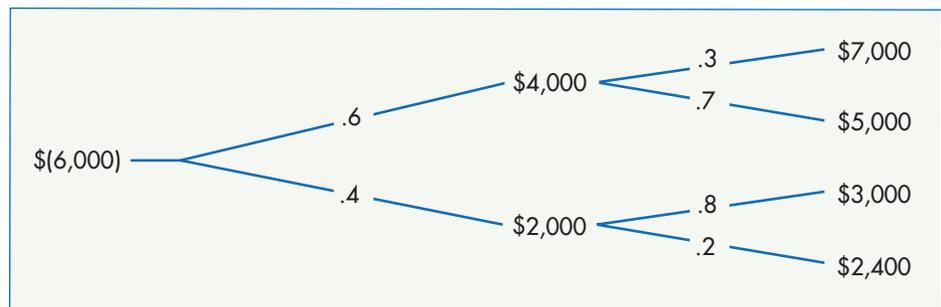
The probability of this pattern would be

$$.25 \times .25 \times .50 = .03125.]$$

6. Sanville Quarries is considering acquiring a new drilling machine that is expected to be more efficient than the current machine. The project is to be evaluated over four years. The initial outlay required to get the new machine operating is \$675,000. Incremental cash flows associated with the machine are uncertain, so management developed the following probabilistic forecast of cash flows by year (\$000). Sanville's cost of capital is 10%.

Year 1	Prob	Year 2	Prob	Year 3	Prob	Year 4	Prob
\$150	.30	\$200	.35	\$350	.30	\$300	.25
175	.40	210	.45	370	.25	360	.35
300	.30	250	.20	400	.45	375	.40

- a. Calculate the project's best and worst NPV's and their probabilities.
  - b. What are the value and probability of the most likely NPV outcome?
  - c. Sketch the results of (a) and (b) on a probability distribution.
7. Using the information from the previous problem, randomly select four NPV outcomes from the data. (Select one cash flow from each year and compute the project NPV and the probability of that NPV implied by those selections.) Plot the results on your distribution. Do your selections give a sense of where NPV outcomes are likely to cluster?
8. Work Station Inc. manufactures office furniture. The firm is interested in "ergonomic" products that are designed to be easier on the bodies of office workers who suffer from ailments such as back and neck pain due to sitting for long periods. Unfortunately customer acceptance of ergonomic furniture tends to be unpredictable, so a wide range of market response is possible. Management has made the following two-year probabilistic estimate of the cash flows associated with the project arranged in decision tree format (\$000).



Work Station is a relatively small company, and would be seriously damaged by any project that lost more than \$1.5 million. The firm's cost of capital is 14%.

- a. Develop a probability distribution for NPV based on the forecast. In other words, calculate the project's NPV along each path of the decision tree and the associated probability.
  - b. Calculate the project's expected NPV.
  - c. Analyze your results, and make a recommendation about the project's advisability considering both expected NPV and risk.
9. Resolve the last problem assuming Work Station Inc. has an abandonment option at the end of the first year under which it will recover \$5 million of the initial investment in year 2. What is the value of the ability to abandon the project? How does your overall recommendation change?
10. Vaughn Video is considering refurbishing its store at a cost of \$1.4 million. Management is concerned about the economy and whether a competitor, Viola Video, will open a store in the neighborhood. Vaughn estimates that there is a 60% chance that Viola will open a store nearby next year. The state of the economy probably won't affect Vaughn until the second year of the plan. Management thinks there is a 40% chance of a strong economy and a 60% chance of a downturn in the second year. Incremental cash flows are as follows:
- Year 1:  
 Viola opens a store—\$700,000  
 Viola doesn't open a store—\$900,000

Year 2:

Viola opens a store, strong economy—\$850,000

Viola opens a store, weak economy—\$700,000

Viola doesn't open a store, strong economy—\$1,500,000

Viola doesn't open a store, weak economy—\$1,200,000

Perform a decision tree analysis of the refurbishment project. Draw the decision tree diagram, and calculate the probabilities and NPVs along each of its four paths. Then calculate the overall expected NPV. Assume that Vaughn's cost of capital is 10%.

11. Vaughn Video of the previous problem has a real option possibility. Carlson Flooring has expressed an interest in trading buildings with Vaughn after Vaughn is refurbished. Carlson has offered to reimburse Vaughn for 70% of its refurbishment costs at the end of the first year if they make the trade. Vaughn would then forgo all incremental cash flows for the second year. Carlson is willing to keep the option open for one year in return for a non-refundable payment of \$150,000 now. Should Vaughn pay the \$150,000 to keep the option available?
12. Spitfire Aviation Inc. manufactures small, private aircraft. Management is evaluating a proposal to introduce a new high-performance plane. High-performance aviation is an expensive sport undertaken largely by people who are both young and wealthy. Spitfire sees its target market as affluent professionals under 35 who have made a lot of money in the stock market in recent years.
 

Stock prices have been rising rapidly for some time, so investment profits have been very handsome, but lately there are serious concerns about a market downturn. If the market remains strong, Spitfire estimates it will sell 50 of the new planes a year for five years, each of which will result in a net cash flow contribution of \$200,000. If the market turns down, however, only about 20 units a year will be sold. Economists think there's about a 40% chance the market will turn down in the near future.

There are also some concerns about the design of the new plane. Not everyone is convinced it will perform as well as the engineering department thinks. Indeed, the engineers have sometimes been too optimistic about their projects in the past. If performance is below the engineering estimate, word-of-mouth communication among fliers will erode the product's reputation, and unit sales *after the first year* will be 50% of the preceding forecasts. Management thinks there's a 30% chance the plane won't perform as well as the engineers think it will. The cost to bring the plane through design and into production is estimated at \$15 million. Spitfire's cost of capital is 12%.

  - a. Draw and fully label the decision tree diagram for the project.
  - b. Calculate the NPV and probability along each path.
  - c. Calculate the project's expected NPV.
  - d. Sketch a probability distribution for NPV.
  - e. Describe the risk situation in words compared to a point estimate of NPV.
13. If Spitfire elects to do the project, what is an abandonment option at the end of year 1 worth if Spitfire can recover \$8 million of the initial investment into other uses at that time? If the recovery is \$13 million?
14. The New England Brewing Company produces a super premium beer using a recipe that's been in the owner's family since colonial times. Surprisingly, the firm doesn't own its brewing facilities, but rents time on the equipment of large brewers who have excess capacity. Other small brewers have been doing the same thing lately, so capacity has become difficult to find, and must be contracted several years in advance.

New England's sales have been increasing steadily, and marketing consultants think there's a possibility that demand will really take off soon. Last year's sales generated net cash flows after all costs and taxes of \$5 million. The consultants predict that sales will probably be at a level that will produce net cash flows of \$6 million per year for the next three years, but they also see a 20% probability that sales could be high enough to generate net cash inflows of \$8 million per year.

Meeting such an increase in demand presents a problem because of the advance contracting requirements for brewing capacity. Unless New England arranges for extra facilities now, there's a 70% chance that brewing capacity won't be available if the increased demand materializes. An option arrangement is available with one of the large brewers under which it will hold capacity for New England until the last minute for an immediate, nonrefundable payment of \$1 million. New England's cost of capital is 9%.

- a. Draw a decision tree reflecting New England's cash flows for the next three years without the option, and calculate the expected NPV of operating cash flows. (Note that there's no need to include an initial outlay because we're dealing with ongoing operations.)
  - b. Redraw the decision tree to include the capacity option as a real option in your calculations. What is its value? Should it be purchased?
  - c. Does the real option reduce New England's risk in any way?
15. Hudson Furniture specializes in office furniture for self-employed individuals who work at home. Hudson's furniture emphasizes style rather than utility and has been quite successful. The firm is now considering entering the more competitive industrial furniture market where volumes are higher but pricing is more competitive. A \$10 million investment is required to enter the new market. Management anticipates positive cash flows of \$1.7 million annually for eight years if Hudson enters the field. An average stock currently earns 8%, and the return on treasury bills is 4%. Hudson's beta is .5, while that of an important competitor who operates solely in the industrial market is 1.5. Should Hudson consider entering the industrial furniture market?

16. Crest Concrete Inc. has been building basements and slab foundations for new homes in La Crosse, Wisconsin for more than 20 years. However, new home sales have slowed recently and residential construction work is hard to get. As a result, management is considering a venture into commercial construction. Although Crest would still be pouring concrete in commercial building, almost everything else about the business differs substantially from homebuilding which is all the firm has done until now.

The local commercial concrete business is dominated by two firms. Readi-Mix Inc., and Toddy Concrete Inc. Readi-Mix has been in business for 50 years, has a market share of 70%, and a beta of 1.3. Toddy has been in the area for only five years and has a beta of 2.4. Crest's own beta is .9 and its cost of capital is 9.3%. Both of these were developed during a long period in which the housing market was prosperous and growing steadily. The stock market is currently returning 11% and treasury bills are yielding 4.2%.

Crest will have to spend \$950,000 to get started in the commercial field, and expects net cash inflows of \$250,000 in the first year, \$400,000 in the second year and \$700,000 in the third.

Should Crest give commercial construction a try?

17. Illinois Fabrics Inc. makes upholstery that's used in high-quality furniture, largely chairs and sofas. Illinois has traditionally sold their fabric to manufacturers who

use it to cover furniture frames they produce. These manufacturers then wholesale the finished product to furniture stores. Management has analyzed the finished chairs and sofas of several manufacturers and found that the highest value element they contain is the Illinois fabric. They further found that generally the frames were shoddily produced.

Illinois' VP of Manufacturing, Harrison Flatley, has proposed starting a new business called Illinois Furniture which will produce and market the end product using the fabric the firm already manufactures. Harrison has put together a proposal to start such a venture which results in a steady stream of cash income of \$5 million per year after an initial investment of \$25 million to be spent on manufacturing facilities and the development of a sales relationship with retailers. The analysis comes up with an NPV for the project assuming the income stream is a perpetuity and taking its present value at Illinois' 10% cost of capital.

$$\text{NPV} = -\$25\text{M} + \$5\text{M}/.10 = -\$25\text{M} + \$50\text{M} = \$25\text{M}$$

Top management likes the idea but is concerned about risk in two areas. First, furniture manufacturing seems to be a riskier business than making fabric as manufacturing firms are always entering and leaving the industry. The average beta of the publicly traded end product manufacturers is a relatively high 1.9. By contrast, Illinois' beta is .9.

Second, management fears that an economic downturn would impact a new business more seriously than it would the existing competitors. Management fears that there's a 40% chance of a downturn in the near future which would reduce Harrison's income projections by 20%.

Re-analyze Harrison's proposal and make a recommendation to management. Treasury bills are yielding 4% and the S&P 500 index is yielding 10%.