

# Risk Analysis, Real Options, and Capital Budgeting

## OPENING CASE

In the summer of 2009, *The Land of the Lost*, starring Will Ferrell and Anna Friel, debuted in theaters. With a slogan of “To get lost,” the movie lost many critics, with one describing it as “Not exactly a hundred million dollars’ worth of classic comedy.” The movie brought an even more harsh critic to say “Space-time vortexes suck.”

Looking at the numbers, Universal Pictures spent close to \$100 million making the movie, plus millions more for marketing and distribution, but the film pulled in only about \$49 million in the U.S. In fact, about 4 of 10 movies lose money at the box office, though DVD sales often help the final tally. Of course, there are movies that do quite well. Also in 2009, the Twentieth Century Fox movie *Avatar* raked in about \$2.5 billion worldwide at a production cost of \$237 million.

Obviously, Universal Pictures didn’t *plan* to lose \$50 or so million on *The Land of the Lost*, but it happened. As the money sucked into *The Land of the Lost* shows, projects don’t always go as companies think they will. This chapter explores how this can happen, and what companies can do to analyze and possibly avoid these situations.

## 9.1 DECISION TREES

There is usually a sequence of decisions in NPV project analysis. This section introduces the device of **decision trees** for identifying these sequential decisions.

Imagine you are the treasurer of the Solar Electronics Corporation (SEC), and the engineering group has recently developed the technology for solar-powered jet engines. The jet engine is to be used with 150-passenger commercial airplanes. The marketing staff has proposed that SEC develop some prototypes and conduct test marketing of the engine. A corporate planning group, including representatives from production, marketing, and engineering, estimates that this preliminary phase will take a year and will cost \$100 million. Furthermore, the group believes there is a 75 percent chance that the marketing tests will prove successful.

If the initial marketing tests are *successful*, SEC can go ahead with full-scale production. This investment phase will cost \$1,500 million. Production and sales will occur over the next five years. The preliminary cash flow projection appears in Table 9.1. Should SEC

**TABLE 9.1**  
Cash Flow Forecasts  
for Solar Electronics  
Corporation's Jet Engine  
Base Case (millions)\*

INVESTMENT	YEAR 1	YEARS 2-6
Revenues		\$6,000
Variable costs		3,000
Fixed costs		1,791
Depreciation		300
Pretax profit		\$ 909
Tax ( $t_c = .34$ )		309
Net profit		\$ 600
Cash flow		\$ 900
Initial investment costs	-\$1,500	

\*Assumptions: (1) Investment is depreciated in years 2 through 6 using the straight-line method; (2) tax rate is 34 percent; (3) the company receives no tax benefits on initial development costs.

go ahead with investment and production on the jet engine, the NPV at a discount rate of 15 percent (in millions) is:

$$\begin{aligned}
 \text{NPV} &= -\$1,500 + \sum_{t=1}^5 \frac{\$900}{(1.15)^t} \\
 &= -\$1,500 + \$900 \times \text{PVIFA}_{15\%,5} \\
 &= \$1,517
 \end{aligned}$$

Note that the NPV is calculated as of date 1, the date at which the investment of \$1,500 million is made. Later, we bring this number back to date 0.

If the initial marketing tests are *unsuccessful*, SEC's \$1,500 million investment has an NPV of -\$3,611 million. This figure is also calculated as of date 1. (To save space, we will not provide the raw numbers leading to this calculation.)

Figure 9.1 displays the problem concerning the jet engine as a decision tree. If SEC decides to conduct test marketing, there is a 75 percent probability that the test marketing will be successful. If the tests are successful, the firm faces a second decision: whether to invest \$1,500 million in a project that yields \$1,517 million NPV or to stop. If the tests are unsuccessful, the firm faces a different decision: whether to invest \$1,500 million in a project that yields -\$3,611 million NPV or to stop.

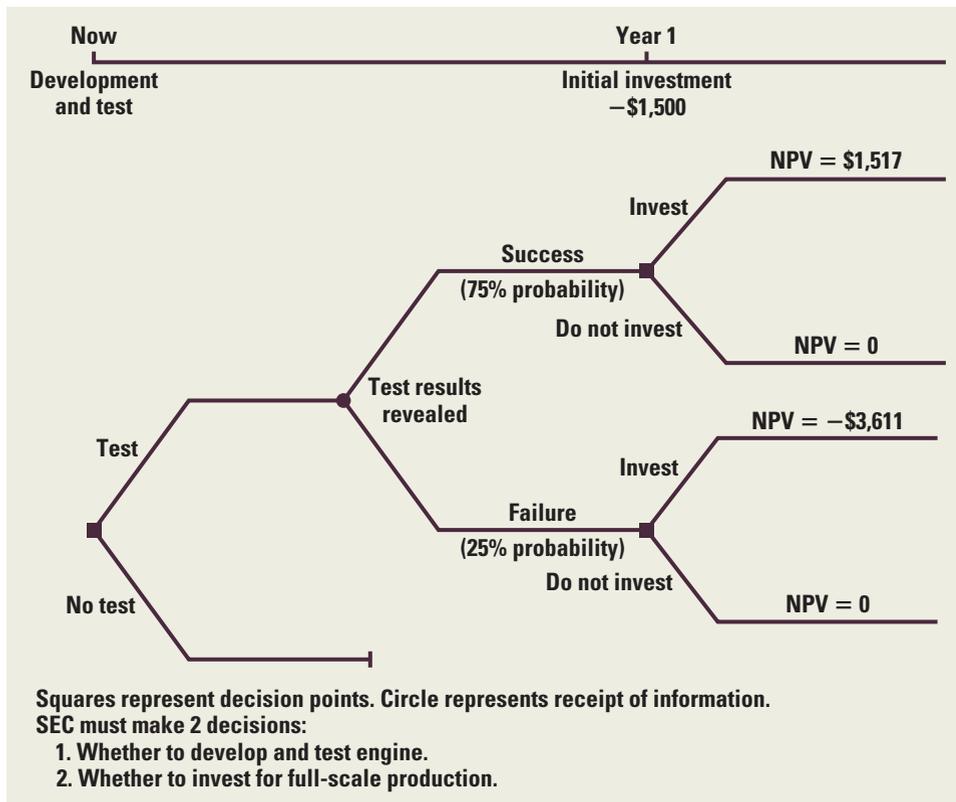
To review, SEC has the following two decisions to make:

1. Whether to develop and test the solar-powered jet engine.
2. Whether to invest for full-scale production following the results of the test.

One makes decisions in reverse order with decision trees. Thus we analyze the second-stage investment of \$1,500 million first. If the tests are successful should SEC make the second-stage investment? The answer is obviously yes, since \$1,517 million is greater than zero. If the tests are unsuccessful, should the second-stage investment be made? Just as obviously, the answer is no, since -\$3,611 million is below zero.

Now we move back to the first stage, where the decision boils down to the question: Should SEC invest \$100 million now to obtain a 75 percent chance of \$1,517 million one year later? The expected payoff evaluated at date 1 (in millions) is:

$$\begin{aligned}
 \text{Expected payoff} &= \left( \begin{array}{cc} \text{Probability} & \text{Payoff} \\ \text{of} & \text{if} \\ \text{success} & \text{successful} \end{array} \right) \times \left( \begin{array}{cc} \text{Probability} & \text{Payoff} \\ \text{of} & \text{if} \\ \text{failure} & \text{failure} \end{array} \right) \\
 &= (.75 \times \$1,517) + (.25 \times \$0) \\
 &= \$1,138
 \end{aligned}$$



**FIGURE 9.1**  
Decision Tree (\$ millions)  
for SEC

The NPV of testing computed at date 0 (in millions) is:

$$\begin{aligned} \text{NPV} &= -\$100 + \frac{\$1,138}{1.15} \\ &= \$890 \end{aligned}$$

Since the NPV is a positive number, the firm should test the market for solar-powered jet engines.

**WARNING** We have used a discount rate of 15 percent for both the testing and the investment decisions. Perhaps a higher discount rate should have been used for the initial test-marketing decision, which is likely to be riskier than the investment decision.

## 9.2 SENSITIVITY ANALYSIS, SCENARIO ANALYSIS, AND BREAK-EVEN ANALYSIS

One thrust of this book is that NPV analysis is a superior capital budgeting technique. In fact, because the NPV approach uses cash flows rather than profits, uses all the cash flows, and discounts the cash flows properly, it is hard to find any theoretical fault with it. However, in our conversations with practical businesspeople, we hear the phrase “a false sense of security” frequently. These people point out that the documentation for capital budgeting proposals is often quite impressive. Cash flows are projected down to the last thousand dollars (or even the last dollar) for each year (or even each month). Opportunity costs and side effects are handled quite properly. Sunk costs are ignored—also quite properly. When a high net present value appears at the bottom, one’s temptation is to say yes immediately. Nevertheless, the projected cash flow often goes unmet in practice, and the firm ends up with a money loser. A nearby *The Real World* box discusses some recent cases of plans gone awry.



## WHEN THINGS GO WRONG...

If you think about it, the decision by a company to acquire another company is a capital budgeting decision. One important difference, however, is that an acquisition may be more expensive than a typical project, and possibly much more expensive. Of course, as with any other project, acquisitions can fail. When they do, the losses can be huge.

In 2008, Bank of America (BOA) appeared to have made two such financial mistakes. In July, BOA acquired Countrywide Financial for \$4 billion. Countrywide became the symbol for loose lending and risky mortgages when the housing market began to falter in 2007. These practices affected the ability of Countrywide to continue as a stand-alone business. At that point, BOA stepped in with the purchase, evidently believing there was still value in the company. But was there? BOA was expected to ultimately absorb about \$30 billion in losses related to the purchase. And given the damage done to Countrywide's reputation, it wasn't surprising that BOA changed the Countrywide name to Bank of America Home Loans in April 2009.

The other BOA acquisition that appears to have been problematic was the \$50 billion purchase of struggling brokerage giant Merrill Lynch. When BOA shareholders voted in December 2008 to do the deal, Merrill Lynch had lost about \$13 billion in October and November of that year. By the time the merger took place in January 2009, the final total for the fourth quarter amounted to about \$16 billion. BOA had to request an additional \$20 billion in government assistance to deal with the unanticipated losses (on top of the \$25 billion the company had received in 2008). Even with this money, S&P lowered BOA's credit rating to A, with indications that the rating could be lowered even further. Further controversy erupted in 2009 over whether BOA's management had adequately informed shareholders of the potential risks associated with the acquisition.

One of the largest acquisitions in U.S. history was America Online's (AOL's) purchase of Time Warner in 2001. AOL purchased Time Warner under the assumption that AOL was part of the "new economy" and primed for fast growth. Time Warner was the "old" communications company, owning cable stations and a music label, among other things. But things didn't work as well as planned. Infighting among employees from the two companies hurt production and morale. In 2002, accounting irregularities were uncovered at AOL, and, as a result of the acquisition costs, the company was straddled with massive debt. To make matters worse, AOL began to lose customers and money. Although AOL was the acquirer, and once dominant partner, things got so bad at AOL that the company changed its name back to Time Warner. To cap things off, in 2002, Time Warner wrote off a stunning \$54 billion in assets associated with the acquisition, which was, at the time, the largest such write-off in history.

## Sensitivity Analysis and Scenario Analysis

How can the firm get the net present value technique to live up to its potential? One approach is **sensitivity analysis** (a.k.a. *what-if analysis* and *bop analysis*<sup>1</sup>), which examines how sensitive a particular NPV calculation is to changes in underlying assumptions. We illustrate the technique with Solar Electronics's solar-powered jet engine from the previous section. As pointed out earlier, the cash flow forecasts for this project appear in Table 9.1. We begin by considering the assumptions underlying revenues, costs, and aftertax cash flows shown in the table.

**REVENUES** Sales projections for the proposed jet engine have been estimated by the marketing department as:

$$\begin{array}{rcl}
 \text{Number of jet engines sold} & = & \text{Market share} \times \text{Size of jet engine market} \\
 3,000 & = & .30 \times 10,000 \\
 \text{Sales revenues} & = & \text{Number of jet engines sold} \times \text{Price per engine} \\
 \$6,000 \text{ million} & = & 3,000 \times \$2 \text{ million}
 \end{array}$$

<sup>1</sup>Bop stands for best, optimistic, pessimistic

Thus, it turns out that the revenue estimates depend on three assumptions.

1. Market share.
2. Size of jet engine market.
3. Price per engine.

**COSTS** Financial analysts frequently divide costs into two types: variable costs and fixed costs. **Variable costs** change as the output changes, and they are zero when production is zero. Costs of direct labor and raw materials are usually variable. It is common to assume that a variable cost is constant per unit of output, implying that total variable costs are proportional to the level of production. For example, if direct labor is variable and one unit of final output requires \$10 of direct labor, then 100 units of final output should require \$1,000 of direct labor.

**Fixed costs** are not dependent on the amount of goods or services produced during the period. Fixed costs are usually measured as costs per unit of time, such as rent per month or salaries per year. Naturally, fixed costs are not fixed forever. They are only fixed over a predetermined time period.

The engineering department has estimated variable costs to be \$1 million per engine. Fixed costs are \$1,791 million per year. The cost breakdowns are:

$$\begin{aligned}
 \text{Variable cost} &= \text{Variable cost per unit} \times \text{Number of jet engines sold} \\
 \mathbf{\$3,000 \text{ million}} &= \mathbf{\$1 \text{ million}} \times \mathbf{3,000} \\
 \text{Total cost before taxes} &= \text{Variable cost} + \text{Fixed cost} \\
 \mathbf{\$4,791 \text{ million}} &= \mathbf{\$3,000 \text{ million}} + \mathbf{\$1,791 \text{ million}}
 \end{aligned}$$

The above estimates for market size, market share, price, variable cost, and fixed cost, as well as the estimate of initial investment, are presented in the middle column of Table 9.2. These figures represent the firm's expectations or best estimates of the different parameters. For purposes of comparison, the firm's analysts prepared both optimistic and pessimistic forecasts for the different variables. These are also provided in the table.

Standard sensitivity analysis calls for an NPV calculation for all three possibilities of a single variable, along with the expected forecast for all other variables. This procedure is illustrated in Table 9.3. For example, consider the NPV calculation of \$8,154 million provided in the upper right-hand corner of this table. This occurs when the optimistic forecast of 20,000 units per year is used for market size. However, the expected forecasts from Table 9.2 are employed for all other variables when the \$8,154 million figure is generated. Note that the same number of \$1,517 million appears in each row of the middle column of Table 9.3. This occurs because the expected forecast is used for the variable that was singled out, as well as for all other variables.

VARIABLE	PESSIMISTIC	EXPECTED OR BEST	OPTIMISTIC
Market size (per year)	5,000	10,000	20,000
Market share	20%	30%	50%
Price	\$1.9 million	\$2 million	\$2.2 million
Variable cost (per engine)	\$1.2 million	\$1 million	\$0.8 million
Fixed cost (per year)	\$1,891 million	\$1,791 million	\$1,741 million
Investment	\$1,900 million	\$1,500 million	\$1,000 million

**TABLE 9.2**

Different Estimates for Solar Electronics's Solar Jet Engine

**TABLE 9.3**

NPV Calculations as of Date 1 (in \$ millions) for the Solar Jet Engine Using Sensitivity Analysis

	PESSIMISTIC	EXPECTED OR BEST	OPTIMISTIC
Market size	−\$1,802*	\$1,517	\$8,154
Market share	− 696*	1,517	5,942
Price	853	1,517	2,844
Variable cost	189	1,517	2,844
Fixed cost	1,295	1,517	1,627
Investment	1,208	1,517	1,903

Under sensitivity analysis, one input is varied while all other inputs are assumed to meet expectation. For example, an NPV of −\$1,802 occurs when the pessimistic forecast of 5,000 is used for market size. However, the expected forecasts from Table 9.2 are used for all other variables when −\$1,802 is generated.

\*We assume that the other divisions of the firm are profitable, implying that a loss on this project can offset income elsewhere in the firm, thereby reducing the overall taxes of the firm.

Table 9.3 can be used for a number of purposes. First, taken as a whole, the table can indicate whether NPV analysis should be trusted. In other words, it reduces the false sense of security we spoke of earlier. Suppose that NPV is positive when the expected forecast for each variable is used. However, further suppose that every number in the pessimistic column is highly negative and every number in the optimistic column is highly positive. Even a single error in this forecast greatly alters the estimate, making one leery of the net present value approach. A conservative manager might well scrap the entire NPV analysis in this situation. Fortunately, this does not seem to be the case in Table 9.3, because all but two of the numbers are positive. Managers viewing the table will likely consider NPV analysis to be useful for the solar-powered jet engine.

Second, sensitivity analysis shows where more information is needed. For example, an error in the estimate of investment appears to be relatively unimportant because, even under the pessimistic scenario, the NPV of \$1,208 million is still highly positive. By contrast, the pessimistic forecast for market share leads to a negative NPV of −\$696 million, and a pessimistic forecast for market size leads to a substantially negative NPV of −\$1,802 million. Since the effect of incorrect estimates on revenues is so much greater than the effect of incorrect estimates on costs, more information on the factors determining revenues might be needed.

Because of these advantages, sensitivity analysis is widely used in practice. Graham and Harvey<sup>2</sup> report that slightly over 50 percent of the 392 firms in their sample subject their capital budgeting calculations to sensitivity analysis. This number is particularly large when one considers that only about 75 percent of the firms in their sample use NPV analysis.

Unfortunately, sensitivity analysis also suffers from some drawbacks. For example, sensitivity analysis may unwittingly *increase* the false sense of security among managers. Suppose all pessimistic forecasts yield positive NPVs. A manager might feel that there is no way the project can lose money. Of course, the forecasters may simply have an optimistic view of a pessimistic forecast. To combat this, some companies do not treat optimistic and pessimistic forecasts subjectively. Rather, their pessimistic forecasts are always, say, 20 percent less than expected. Unfortunately, the cure in this case may be worse than the disease, because a deviation of a fixed percentage ignores the fact that some variables are easier to forecast than others.

In addition, sensitivity analysis treats each variable in isolation when, in reality, the different variables are likely to be related. For example, if ineffective management allows costs to get out of control, it is likely that variable costs, fixed costs, and investment will all rise above expectation at the same time. If the market is not receptive to a solar plane, both market share and price should decline together.

<sup>2</sup>See Figure 2 of John Graham and Campbell Harvey, "The Theory and Practice of Corporate Finance: Evidence from the Field," *Journal of Financial Economics* (May/June 2001).

	YEAR 1	YEARS 2-6
Revenues		\$2,800
Variable costs		– 1,400
Fixed costs		– 1,791
Depreciation		– 300
Pretax profit		–\$ 691
Tax ( $t_c = .34$ ) <sup>†</sup>		235
Net profit		–\$ 456
Cash flow		– 156
Initial investment cost	–\$1,500	

**TABLE 9.4**

Cash Flow Forecast (in \$ millions) under the Scenario of a Plane Crash\*

\*Assumptions are

Market size	7,000 (70 percent of expectation)
Market share	20% (2/3 of expectation)

Forecasts for all other variables are the expected forecasts as given in Table 9.2.

<sup>†</sup>Tax loss offsets income elsewhere in firm.

Managers frequently perform **scenario analysis**, a variant of sensitivity analysis, to minimize this problem. Simply put, this approach examines a number of different likely scenarios, where each scenario involves a confluence of factors. As a simple example, consider the effect of a few airline crashes. These crashes are likely to reduce flying in total, thereby limiting the demand for any new engines. Furthermore, even if the crashes did not involve solar-powered aircraft, the public could become more averse to any innovative and controversial technologies. Hence, SEC's market share might fall as well. Perhaps the cash flow calculations would look like those in Table 9.4 under the scenario of a plane crash. Given the calculations in the table, the NPV (in millions) would be:

$$-\$2,023 = -\$1,500 - \$156 \times \text{PVIFA}_{15\%,5}$$

A series of scenarios like this might illuminate issues concerning the project better than the standard application of sensitivity analysis would.

## Break-Even Analysis

Our discussion of sensitivity analysis and scenario analysis suggests that there are many ways to examine variability in forecasts. We now present another approach, **break-even analysis**. As its name implies, this approach determines the sales needed to break even. The approach is a useful complement to sensitivity analysis, because it also sheds light on the severity of incorrect forecasts. We calculate the break-even point in terms of both accounting profit and present value.

**ACCOUNTING PROFIT** Net profit under four different sales forecasts is:

UNIT SALES	NET PROFIT (\$ MILLIONS)
0	–\$1,380
1,000	– 720
3,000	600
10,000	5,220

A more complete presentation of costs and revenues appears in Table 9.5.

We plot the revenues, costs, and profits under the different assumptions about sales in Figure 9.2. The revenue and cost curves cross at 2,091 jet engines. This is the break-even

**TABLE 9.5**

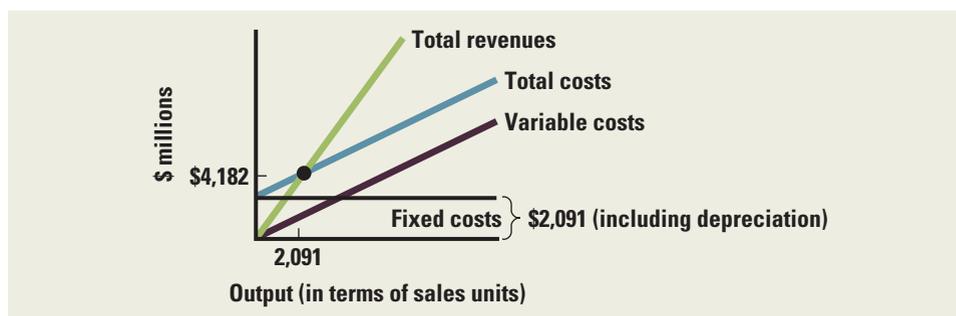
Revenues and Costs of Project under Different Sales Assumptions (in \$ millions, except unit sales)

YEAR 1	YEARS 2-6								NPV (EVALUATED DATE 1)
INITIAL INVESTMENT	ANNUAL UNIT SALES	REVENUES	VARIABLE COSTS	FIXED COSTS	DEPRECIATION	TAXES* ( $t_c = .34$ )	NET PROFIT	OPERATING CASH FLOWS	
\$1,500	0	\$ 0	\$ 0	-\$1,791	-\$300	\$ 711	-\$1,380	-\$1,080	-\$5,120
1,500	1,000	2,000	- 1,000	- 1,791	- 300	371	- 720	- 420	- 2,908
1,500	3,000	6,000	- 3,000	- 1,791	- 300	- 309	600	900	1,517
1,500	10,000	20,000	- 10,000	- 1,791	- 300	- 2,689	5,220	5,520	17,004

\*Loss is incurred in the first two rows. For tax purposes, this loss offsets income elsewhere in the firm.

**FIGURE 9.2**

Break-Even Point Using Accounting Numbers



point, that is, the point where the project generates no profits or losses. As long as sales are above 2,091 jet engines, the project will make a profit.

This break-even point can be calculated very easily. Because the sales price is \$2 million per engine and the variable cost is \$1 million per engine,<sup>3</sup> the aftertax difference per engine is:

$$(\text{Sales price} - \text{Variable cost}) \times (1 - t_c) = (\$2 \text{ million} - \$1 \text{ million}) \times (1 - .34) = \$0.66 \text{ million}$$

where  $t_c$  is the corporate tax rate of 34 percent. This aftertax difference is called the **contribution margin** because each additional engine contributes this amount to after-tax profit.

Fixed costs are \$1,791 million and depreciation is \$300 million, implying that the after-tax sum of these costs is:

$$(\text{Fixed costs} + \text{Depreciation}) \times (1 - t_c) = (\$1,791 \text{ million} + \$300 \text{ million}) \times (1 - .34) = \$1,380 \text{ million}$$

That is, the firm incurs costs of \$1,380 million, regardless of the number of sales. Because each engine contributes \$.66 million, sales must reach the following level to offset the above costs:

**Accounting Profit Break-Even Point:**

$$\frac{(\text{Fixed costs} + \text{Depreciation}) \times (1 - t_c)}{(\text{Sales price} - \text{Variable costs}) \times (1 - t_c)} = \frac{\$1,380 \text{ million}}{\$.66 \text{ million}} = 2,091$$

Thus, 2,091 engines is the break-even point required for an accounting profit.

<sup>3</sup>Though the previous section considered both optimistic and pessimistic forecasts for sales price and variable cost, break-even analysis uses just the expected or best estimates of these variables.

**PRESENT VALUE** As we have stated many times in the text, we are more interested in present value than we are in net profits. Therefore, we must calculate the present value of the cash flows. Given a discount rate of 15 percent, we have:

UNIT SALES	NPV (\$ MILLIONS)
0	-\$ 5,120
1,000	- 2,908
3,000	1,517
10,000	17,004

These NPV calculations are reproduced from the last column of Table 9.5. We can see that the NPV is negative if SEC produces 1,000 jet engines and positive if it produces 3,000 jet engines. Obviously, the zero NPV point occurs between 1,000 and 3,000 jet engines.

The present value break-even point can be calculated very easily. The firm originally invested \$1,500 million. This initial investment can be expressed as a five-year equivalent annual cost (EAC), determined by dividing the initial investment by the appropriate five-year annuity factor:

$$\begin{aligned} \text{EAC} &= \frac{\text{Initial investment}}{\text{5-year annuity factor at 15\%}} = \frac{\text{Initial investment}}{\text{PVIFA}_{15\%,5}} \\ &= \frac{\$1,500 \text{ million}}{3.3522} = \$447.5 \text{ million} \end{aligned}$$

Note that the EAC of \$447.5 million is greater than the yearly depreciation of \$300 million. This must occur since the calculation of EAC implicitly assumes that the \$1,500 million investment could have been invested at 15 percent.

Aftertax costs, regardless of output, can be viewed as:

$$\begin{aligned} \$1,528 \text{ million} &= \text{EAC} + \text{Fixed costs} \times (1 - t_c) - \text{Depreciation} \times t_c \\ &= \$447.5 \text{ million} + \$1,791 \text{ million} \times .66 - \$300 \text{ million} \times .34 \end{aligned}$$

That is, in addition to the initial investment's equivalent annual cost of \$447.5 million, the firm pays fixed costs each year and receives a depreciation tax shield each year. The depreciation tax shield is written as a negative number since it offsets the costs in the equation. Because each engine contributes \$.66 million to aftertax profit, it will take the following sales to offset the above costs:

**Present Value Break-Even Point:**

$$\frac{\text{EAC} + \text{Fixed costs} \times (1 - t_c) - \text{Depreciation} \times t_c}{(\text{Sales price} - \text{Variable costs}) \times (1 - t_c)} = \frac{\$1,528 \text{ million}}{\$.66 \text{ million}} = 2,315$$

Thus, 2,315 engines is the break-even point from the perspective of present value.

Why is the accounting break-even point different from the financial break-even point? When we use accounting profit as the basis for the break-even calculation, we subtract depreciation. Depreciation for the solar jet engines project is \$300 million. If 2,091 solar jet engines are sold, SEC will generate sufficient revenues to cover the \$300 million depreciation expense plus other costs. Unfortunately, at this level of sales SEC will not cover the economic opportunity costs of the \$1,500 million laid out for the investment. If we take into account that the \$1,500 million could have been invested at 15 percent, the true annual cost of the investment is \$447.5 million and not \$300 million. Depreciation understates the true costs of recovering the initial investment. Thus, companies that break even on an accounting basis are really losing money. They are losing the opportunity cost of the initial investment.

### 9.3 MONTE CARLO SIMULATION

Both sensitivity analysis and scenario analysis attempt to answer the question, “What if?” However, while both analyses are frequently used in the real world, each has its own limitations. Sensitivity analysis allows only one variable to change at a time. By contrast, many variables are likely to move at the same time in the real world. Scenario analysis follows specific scenarios, such as changes in inflation, government regulation, or the number of competitors. While this methodology is often quite helpful, it cannot cover all sources of variability. In fact, projects are likely to exhibit a lot of variability under just one economic scenario.

For a free demonstration of a spreadsheet application of Monte Carlo analysis, go to [www.crystalball.com](http://www.crystalball.com).

**Monte Carlo simulation** is a further attempt to model real-world uncertainty. This approach takes its name from the famous European casino, because it analyzes projects the way one might analyze gambling strategies. Imagine a serious blackjack player who wonders if he should take a third card whenever his first two cards total 16. Most likely, a formal mathematical model would be too complex to be practical here. However, he could play thousands of hands in a casino, sometimes drawing a third card when his first two cards add to 16 and sometimes not drawing that third card. He could compare his winnings (or losings) under the two strategies in order to determine which was better. Of course, since he would probably lose a lot of money performing this test in a real casino, simulating the results from the two strategies on a computer might be cheaper. Monte Carlo simulation of capital budgeting projects is in this spirit.

Imagine that Backyard Barbeques, Inc. (BBI), a manufacturer of both charcoal and gas grills, has the blueprint for a new grill that cooks with compressed hydrogen. The CFO, Edward H. Comiskey, being dissatisfied with simpler capital budgeting techniques, wants a Monte Carlo simulation for this new grill. A consultant specializing in the Monte Carlo approach, Les Mauney, takes him through the five basic steps of the method.

**STEP 1: SPECIFY THE BASIC MODEL** Les Mauney breaks up cash flow into three components: annual revenue, annual costs, and initial investment. The revenue in any year is viewed as:

$$\text{Number of grills sold by entire industry} \times \text{Market share of BBI's hydrogen grill (in percent)} \times \text{Price per hydrogen grill}$$

The cost in any year is viewed as:

$$\text{Fixed manufacturing costs} + \text{Variable manufacturing costs} + \text{Marketing costs} + \text{Selling costs}$$

Initial investment is viewed as:

$$\text{Cost of patent} + \text{Test-marketing costs} + \text{Cost of production facility}$$

**STEP 2: SPECIFY A DISTRIBUTION FOR EACH VARIABLE IN THE MODEL** Here comes the hard part. Let’s start with revenue, which has three components in the equation above. The consultant first models overall market size, that is, the number of grills sold by the entire industry. The trade publication, *Outdoor Food (OF)*, reported that 10 million grills of all types were sold in the continental United States last year and it forecasts sales of 10.5 million next year. Mr. Mauney, using *OF*’s forecast and his own intuition, creates the following distribution for next year’s sales of grills by the entire industry:

<b>PROBABILITY</b>	20%	60%	20%
<b>NEXT YEAR'S INDUSTRYWIDE UNIT SALES</b>	10 million	10.5 million	11 million

The tight distribution here reflects the slow but steady historical growth in the grill market.

Les Mauney realizes that estimating the market share of BBI's hydrogen grill is more difficult. Nevertheless, after a great deal of analysis, he determines the distribution of next year's market share to be:

<b>PROBABILITY</b>	10%	20%	30%	25%	10%	5%
<b>MARKET SHARE OF BBI'S HYDROGEN GRILL NEXT YEAR</b>	1%	2%	3%	4%	5%	8%

While the consultant assumed a symmetrical distribution for industrywide unit sales, he believes a skewed distribution makes more sense for the project's market share. In his mind, there is always the small possibility that sales of the hydrogen grill will really take off.

The above forecasts assume that unit sales for the overall industry are unrelated to the project's market share. In other words, the two variables are *independent* of each other. Mr. Mauney reasons that, while an economic boom might increase industrywide grill sales and a recession might decrease them, the project's market share is unlikely to be related to economic conditions.

Now Mr. Mauney must determine the distribution of price per grill. Mr. Comiskey, the CFO, informs him that the price will be in the area of \$200 per grill, given what other competitors are charging. However, the consultant believes that the price per hydrogen grill will almost certainly depend on the size of the overall market for grills. As in any business, you can usually charge more if demand is high.

After rejecting a number of complex models for price, Mr. Mauney settles on the following specification:

$$\text{Next year's price per hydrogen grill} = \$190 + \$1 \times \text{Industrywide unit sales (in millions)} \pm \$3$$

The grill price in the above equation is dependent on the unit sales of the industry. In addition, random variation is modeled via the term " $\pm \$3$ ," where a drawing of  $+\$3$  and a drawing of  $-\$3$  each occur 50 percent of the time. For example, if industrywide unit sales are 11 million, the price per grill would be either:

$$\$190 + \$11 + \$3 = \$204 \quad (50\% \text{ probability})$$

$$\$190 + \$11 - \$3 = \$198 \quad (50\% \text{ probability})$$

The consultant now has distributions for each of the three components of next year's revenue. However, he needs distributions for future years as well. Using forecasts from *Outdoor Food* and other publications, Mr. Mauney forecasts the distribution of growth rates for the entire industry over the second year to be:

<b>PROBABILITY</b>	20%	60%	20%
<b>GROWTH RATE OF INDUSTRYWIDE UNIT SALES IN SECOND YEAR</b>	1%	3%	5%

Given both the distribution of next year's industrywide unit sales and the distribution of growth rates for this variable over the second year, we can generate the distribution of industrywide unit sales for the second year. A similar extension should give Mr. Mauney a distribution for later years as well, though we won't go into the details here. And, just as the consultant extended the first component of revenue (industrywide unit sales) to later years, he would want to do the same thing for market share and unit price.

The above discussion shows how the three components of revenue can be modeled. Step 2 would be complete once the components of cost and of investment are modeled

in a similar way. Special attention must be paid to the interactions between variables here, since ineffective management will likely allow the different cost components to rise together. However, since you are probably getting the idea now, we will skip the rest of this step.

**STEP 3: THE COMPUTER DRAWS ONE OUTCOME** As we said above, next year's revenue in our model is the product of three components. Imagine that the computer randomly picks industrywide unit sales of 10 million, a market share for BBI's hydrogen grill of 2 percent, and a +\$3 random price variation. Given these drawings, next year's price per hydrogen grill will be:

$$\mathbf{\$190 + \$10 + \$3 = \$203}$$

and next year's revenue for BBI's hydrogen grill will be:

$$\mathbf{10 \text{ million} \times .02 \times \$203 = \$40.6 \text{ million}}$$

Of course, we are not done with the entire outcome yet. We would have to perform drawings for revenue in each future year. In addition, we would perform drawings for costs in each future year. Finally, a drawing for initial investment would have to be made as well. In this way, a single outcome would generate a cash flow from the project in each future year.

How likely is it that the specific outcome above would be drawn? We can answer this because we know the probability of each component. Since industry sales of 10 million units has a 20 percent probability, a market share of 2 percent also has a 20 percent probability, and a random price variation of +\$3 has a 50 percent probability, the probability of these three drawings together in the same outcome is:

$$\mathbf{.02 = .20 \times .20 \times .50}$$

Of course, the probability would get even smaller once drawings for future revenues, future costs, and the initial investment are included in the outcome.

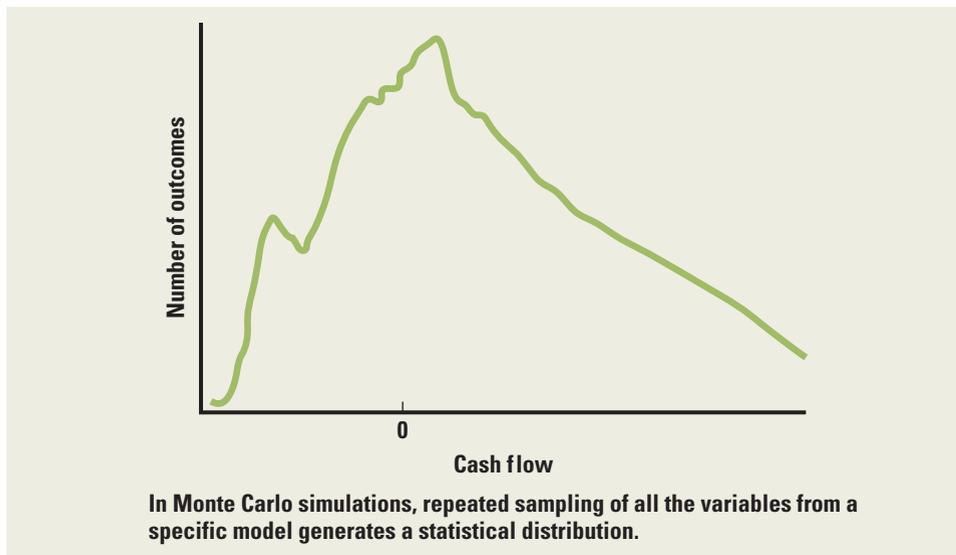
This step generates the cash flow for each year from a single outcome. What we are ultimately interested in is the *distribution* of cash flow each year across many outcomes. We ask the computer to randomly draw over and over again to give us this distribution, which is just what is done in the next step.

**STEP 4: REPEAT THE PROCEDURE** While the above three steps generate one outcome, the essence of Monte Carlo simulation is repeated outcomes. Depending on the situation, the computer may be called on to generate thousands or even millions of outcomes. The result of all these drawings is a distribution of cash flow for each future year. This distribution is the basic output of Monte Carlo simulation.

Consider Figure 9.3. Here, repeated drawings have produced the simulated distribution of the third year's cash flow. There would be, of course, a distribution like the one in this figure for each future year. This leaves us with just one more step.

**STEP 5: CALCULATE NPV** Given the distribution of cash flow for the third year in Figure 9.3, one can determine the expected cash flow for this year. In a similar manner, one can also determine the expected cash flow for each future year and can then calculate the net present value of the project by discounting these expected cash flows at an appropriate rate.

Monte Carlo simulation is often viewed as a step beyond either sensitivity analysis or scenario analysis. Interactions between the variables are explicitly specified in Monte Carlo so, at least in theory, this methodology provides a more complete analysis. And, as a by-product, having to build a precise model deepens the forecaster's understanding of the project.



**FIGURE 9.3**  
 Simulated Distribution of  
 the Third Year's Cash Flow  
 for BBI's New Hydrogen  
 Grill

Since Monte Carlo simulations have been around for at least 35 years, you might think that most firms would be performing them by now. Surprisingly, this does not seem to be the case. In our experience, executives are frequently skeptical of all the complexity. It is difficult to model either the distributions of each variable or the interactions between variables. In addition, the computer output is often devoid of economic intuition. Thus, while Monte Carlo simulations are used in certain real-world situations, the approach is not likely to be “the wave of the future.” In fact, Graham and Harvey<sup>4</sup> report that only about 15 percent of the firms in their sample use capital budgeting simulations.

## 9.4 REAL OPTIONS

In Chapter 7, we stressed the superiority of net present value (NPV) analysis over other approaches when valuing capital budgeting projects. However, both scholars and practitioners have pointed out problems with NPV. The basic idea here is that NPV analysis, as well as all the other approaches in Chapter 7, ignores the adjustments that a firm can make after a project is accepted. These adjustments are called **real options**. In this respect, NPV underestimates the true value of a project. NPV's conservatism here is best explained through a series of examples.

### The Option to Expand

Conrad Willig, an entrepreneur, recently learned of a chemical treatment that causes water to freeze at 100 degrees Fahrenheit, rather than 32 degrees. Of all the many practical applications for this treatment, Mr. Willig liked the idea of hotels made of ice more than anything else. Conrad estimated the annual cash flows from a single ice hotel to be \$2 million, based on an initial investment of \$12 million. He felt that 20 percent was an appropriate discount rate, given the risk of this new venture. Assuming that the cash flows were perpetual, Mr. Willig determined the NPV of the project to be:

$$-\$12,000,000 + \$2,000,000/.20 = -\$2 \text{ million}$$

Most entrepreneurs would have rejected this venture, given its negative NPV. But Conrad was not your typical entrepreneur. He reasoned that NPV analysis missed a hidden source

<sup>4</sup>See Figure 2 of Graham and Harvey, *op. cit.*

of value. While he was pretty sure that the initial investment would cost \$12 million, there was some uncertainty concerning annual cash flows. His cash flow estimate of \$2 million per year actually reflected his belief that there was a 50 percent probability that annual cash flows would be \$3 million and a 50 percent probability that annual cash flows would be \$1 million.

The NPV calculations for the two forecasts are:

**Optimistic forecast:  $-\$12 \text{ million} + \$3 \text{ million}/.20 = \$3 \text{ million}$**

**Pessimistic forecast:  $-\$12 \text{ million} + \$1 \text{ million}/.20 = -\$7 \text{ million}$**

On the surface, this new calculation doesn't seem to help Mr. Willig very much since an average of the two forecasts yields an NPV for the project of:

**$.50 \times \$3 \text{ million} + .50 \times (-\$7 \text{ million}) = -\$2 \text{ million}$**

which is just the value he calculated in the first place.

However, if the optimistic forecast turns out to be correct, Mr. Willig would want to *expand*. If he believes that there are, say, 10 locations in the country that can support an ice hotel, the true NPV of the venture would be:

**$.50 \times 10 \times \$3 \text{ million} + .50 \times (-\$7 \text{ million}) = \$11.5 \text{ million}$**

The idea here, which is represented in Figure 9.4, is both basic and universal. The entrepreneur has the option to expand if the pilot location is successful. For example, think of all the people that start restaurants, most of them ultimately failing. These individuals are not necessarily overly optimistic. They may realize the likelihood of failure but go ahead anyway because of the small chance of starting the next McDonald's or Burger King.

### The Option to Abandon

Managers also have the option to abandon existing projects. While abandonment may seem cowardly, it can often save companies a great deal of money. Because of this, the option to abandon increases the value of any potential project.

The above example on ice hotels, which illustrated the option to expand, can also illustrate the option to abandon. To see this, imagine that Mr. Willig now believes that there is a 50 percent probability that annual cash flows will be \$6 million and a 50 percent probability that annual cash flows will be  $-\$2$  million. The NPV calculations under the two forecasts become:

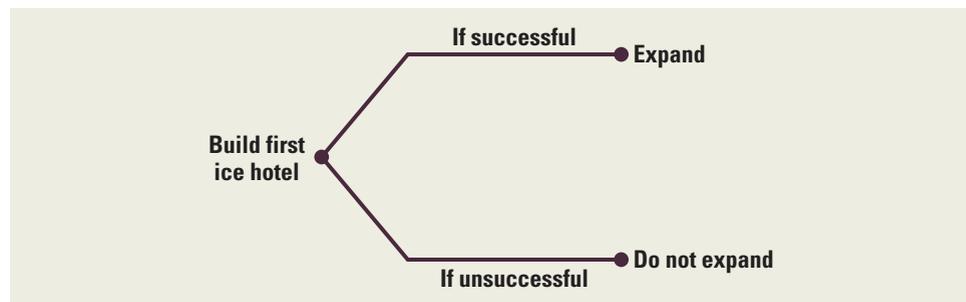
**Optimistic forecast:  $-\$12 \text{ million} + \$6 \text{ million}/.2 = \$18 \text{ million}$**

**Pessimistic forecast:  $-\$12 \text{ million} - \$2 \text{ million}/.2 = -\$22 \text{ million}$**

yielding an NPV for the project of:

**$.50 \times \$18 \text{ million} + .50 \times (-\$22 \text{ million}) = -\$2 \text{ million}$**

**FIGURE 9.4**  
Decision Tree for Ice Hotel



Furthermore, now imagine that Mr. Willig wants to own, at most, just one ice hotel, implying that there is no option to expand. Since the NPV here is negative, it looks as if he will not build the hotel.

But things change when we consider the abandonment option. As of date 1, the entrepreneur will know which forecast has come true. If cash flows equal those under the optimistic forecast, Conrad will keep the project alive. If, however, cash flows equal those under the pessimistic forecast, he will abandon the hotel. Knowing these possibilities ahead of time, the NPV of the project becomes:

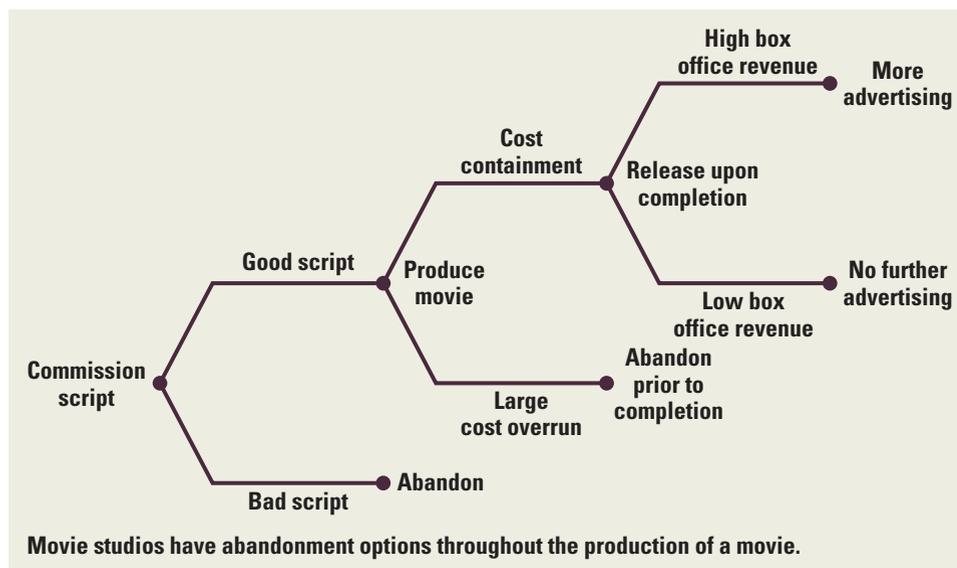
$$.50 \times \$18 \text{ million} + .50 \times (-\$12 \text{ million} - \$2 \text{ million}/1.20) = \$2.17 \text{ million}$$

Since Conrad abandons after experiencing the cash flow of  $-\$2$  million at date 1, he does not have to endure this outflow in any of the later years. Because the NPV is now positive, Conrad will accept the project.

The example here is clearly a stylized one. While many years may pass before a project is abandoned in the real world, our ice hotel was abandoned after just one year. And, while salvage values generally accompany abandonment, we assumed no salvage value for the ice hotel. Nevertheless, abandonment options are pervasive in the real world.

For example, consider the moviemaking industry, which we discussed to open the chapter. As shown in Figure 9.5, movies begin with either the purchase or development of a script. A completed script might cost a movie studio a few million dollars and potentially lead to actual production. However, the great majority of scripts (perhaps well in excess of 80 percent) are abandoned. Why would studios abandon scripts that they had commissioned in the first place? While the studios know ahead of time that only a few scripts will be promising, they don't know which ones. Thus, they cast a wide net, commissioning many scripts to get a few good ones. And the studios must be ruthless with the bad scripts, since the expenditure on a script pales in comparison to the huge losses from producing a bad movie.

The few lucky scripts will then move into production, where costs might be budgeted in the tens of millions of dollars, if not much more. At this stage, the dreaded phrase is that on-location production gets "bogged down," creating cost overruns. But the studios are equally ruthless here. Should these overruns become excessive, production is likely to be abandoned in midstream. Interestingly, abandonment almost always



**FIGURE 9.5**

The Abandonment Option in the Movie Industry

occurs due to high costs, not due to the fear that the movie won't be able to find an audience. Little information on that score will be obtained until the movie is actually released.

Release of the movie is accompanied by significant advertising expenditures, perhaps in the range of \$10 to \$20 million. Box office success in the first few weeks is likely to lead to further advertising expenditures. Again, the studio has the option, but not the obligation, to increase advertising here.

Moviemaking is one of the riskiest businesses around, with studios receiving hundreds of millions of dollars in a matter of weeks from a blockbuster while receiving practically nothing during this period from a flop. The above abandonment options contain costs that might otherwise bankrupt the industry.

To illustrate some of these ideas, consider the case of Euro Disney. The deal to open Euro Disney occurred in 1987, and the park opened its doors outside of Paris in 1992. Disney's management thought Europeans would go goofy over the new park, but trouble soon began. The number of visitors never met expectations, in part because the company priced tickets too high. Disney also decided not to serve alcohol in a country that was accustomed to wine with meals. French labor inspectors fought Disney's strict dress codes, and so on.

After several years of operations, the park began serving wine in its restaurants, lowered ticket prices, and made other adjustments. In other words, management exercised its option to reformulate the product. The park began to make a small profit. Then, the company exercised the option to expand by adding a "second gate," which was another theme park next to Euro Disney named Walt Disney Studios. The second gate was intended to encourage visitors to extend their stays. But the new park flopped. The reasons ranged from high ticket prices, attractions geared toward Hollywood rather than European filmmaking, labor strikes in Paris, and a summer heat wave.

By the summer of 2003, Euro Disney was close to bankruptcy again. Executives discussed a range of options. These options ranged from letting the company go broke (the option to abandon) to pulling the Disney name from the park. In 2005, the company finally agreed to a restructuring with the help of the French government.

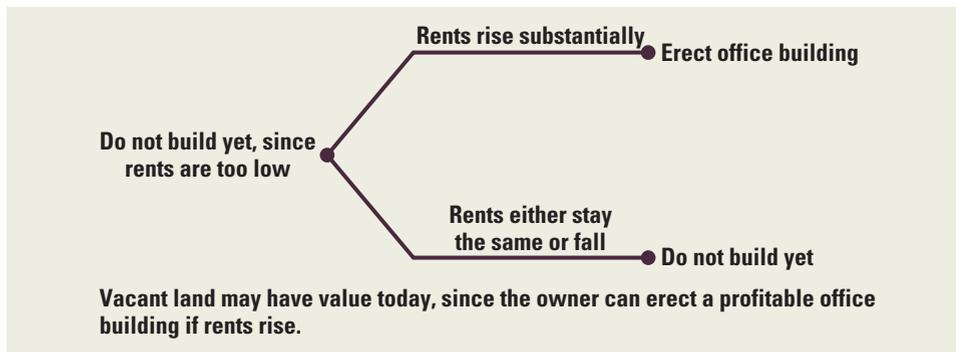
The whole idea of managerial options was summed up aptly by Jay Rasulo, the overseer of Disney's theme parks, when he said, "One thing we know for sure is that you never get it 100 percent right the first time. We open every one of our parks with the notion that we're going to add content." After all the changes made at Euro Disney, the economic environment in 2009 was still troubling. During 2009, the park had a record 15.4 million visitors, but its revenue fell about 7 percent because visitors spent less. The park's loss for the year was \$93.5 million, a substantial increase over its 2008 loss of \$3.7 million. Of course, there were still more options available. A company spokesperson said that if the park did not meet its goals in 2010, it would reduce operating costs, curtail a portion of planned capital expenditures, and possibly seek assistance from its American parent.

A recent example of the option to abandon occurred in 2009 when GM announced that it would phase out the storied Pontiac brand by the end of 2010. Originally the Oakland Motor Company, Pontiac was started in 1907 and had been a major contributor to GM's success. However, declining sales for Pontiac as well as GM as a whole made the decision to drop this Pontiac brand an economic necessity.

## Timing Options

One often finds urban land that has been vacant for many years. Yet this land is bought and sold from time to time. Why would anyone pay a positive price for land that has no source of revenue? Certainly one could not arrive at this positive value through NPV analysis. However, the paradox can easily be explained in terms of real options.

Suppose that the land's highest and best use is as an office building. Total construction costs for the building are estimated to be \$1 million. Currently, net rents (after all costs) are



**FIGURE 9.6**  
Decision Tree for Vacant Land

estimated to be \$90,000 per year in perpetuity and the discount rate is 10 percent. The NPV of this proposed building would be:

$$-\$1 \text{ million} + \$90,000/.10 = -\$100,000$$

Since this NPV is negative, one would not currently want to build. In addition, it appears as if the land is worthless. However, suppose that the federal government is planning various urban revitalization programs for the city. Office rents will likely increase if the programs succeed. In this case, the property's owner might want to erect the office building after all. Conversely, office rents will remain the same, or even fall, if the programs fail. The owner will not build in this case.

We say that the property owner has a *timing option*. While he does not currently want to build, he will want to build in the future should rents in the area rise substantially. This timing option explains why vacant land often has value. While there are costs, such as taxes, from holding raw land, the value of an office building after a substantial rise in rents may more than offset these holding costs. Of course, the exact value of the vacant land depends on both the probability of success in the revitalization program and the extent of the rent increase. Figure 9.6 illustrates this timing option.

Mining operations almost always provide timing options as well. Suppose you own a copper mine where the cost of mining each ton of copper exceeds the sales revenue. It's a no-brainer to say that you would not want to mine the copper currently. And since there are costs of ownership such as property taxes, insurance, and security, you might actually want to pay someone to take the mine off your hands. However, we would caution you not to do so hastily. Copper prices in the future might very well increase enough so that production is profitable. Given that possibility, you could likely find someone to pay a positive price for the property today.

## SUMMARY AND CONCLUSIONS

This chapter discusses a number of practical applications of capital budgeting.

1. Though NPV is the best capital budgeting approach conceptually, it has been criticized in practice for providing managers with a false sense of security. Sensitivity analysis shows NPV under varying assumptions, giving managers a better feel for the project's risks. Unfortunately, sensitivity analysis modifies only one variable at a time, while many variables are likely to vary together in the real world. Scenario analysis examines a project's performance under different

scenarios (e.g., war breaking out or oil prices skyrocketing). Finally, managers want to know how bad forecasts must be before a project loses money. Break-even analysis calculates the sales figure at which the project breaks even. Though break-even analysis is frequently performed on an accounting profit basis, we suggest that a net present value basis is more appropriate.

2. Monte Carlo simulation begins with a model of the firm's cash flows, based on both the interactions between different variables and the movement of each individual variable over time. Random sampling generates a distribution of these cash flows for each period, leading to a net present value calculation.
3. We analyze the hidden options in capital budgeting, such as the option to expand, the option to abandon, and timing options.

## CONCEPT QUESTIONS

1. **Forecasting Risk** What is forecasting risk? In general, would the degree of forecasting risk be greater for a new product or a cost-cutting proposal? Why?
2. **Sensitivity Analysis and Scenario Analysis** What is the essential difference between sensitivity analysis and scenario analysis?
3. **Marginal Cash Flows** A co-worker claims that looking at all this marginal this and incremental that is just a bunch of nonsense, and states: "Listen, if our average revenue doesn't exceed our average cost, then we will have a negative cash flow, and we will go broke!" How do you respond?
4. **Break-Even Point** As a shareholder of a firm that is contemplating a new project, would you be more concerned with the accounting break-even point, the cash break-even point (i.e., the point at which operating cash flow is zero), or the financial break-even point? Why?
5. **Break-Even Point** Assume a firm is considering a new project that requires an initial investment and has equal sales and costs over its life. Will the project reach the accounting, cash, or financial break-even point first? Which will it reach next? Last? Will this ordering always apply?
6. **Real Options** Why does traditional NPV analysis tend to underestimate the true value of a capital budgeting project?
7. **Real Options** The Mango Republic has just liberalized its markets and is now permitting foreign investors. Tesla Manufacturing has analyzed starting a project in the country and has determined that the project has a negative NPV. Why might the company go ahead with the project? What type of option is most likely to add value to this project?
8. **Sensitivity Analysis and Breakeven** How does sensitivity analysis interact with break-even analysis?
9. **Option to Wait** An option can often have more than one source of value. Consider a logging company. The company can log the timber today, or wait another year (or more) to log the timber. What advantages would waiting one year potentially have?
10. **Project Analysis** You are discussing a project analysis with a co-worker. The project involves real options, such as expanding the project if successful, or abandoning the project if it fails. Your co-worker makes the following statement: "This analysis is ridiculous. We looked at expanding or abandoning the project in two years, but there are many other options we should consider. For example, we could expand in one year, and expand further in two years. Or we could expand in one year, and abandon the project in two years. There are too many options for us to examine. Because of this, anything this analysis would give us is worthless." How would you evaluate this statement? Considering that with any capital budgeting project there are an infinite number of real options, when do you stop the option analysis on an individual project?

## QUESTIONS AND PROBLEMS

- 1. Sensitivity Analysis and Break-Even Point** We are evaluating a project that costs \$804,000, has an eight-year life, and has no salvage value. Assume that depreciation is straight-line to zero over the life of the project. Sales are projected at 95,000 units per year. Price per unit is \$41, variable cost per unit is \$27, and fixed costs are \$925,000 per year. The tax rate is 35 percent, and we require a 15 percent return on this project.
- Calculate the accounting break-even point.
  - Calculate the base-case cash flow and NPV. What is the sensitivity of NPV to changes in the sales figure? Explain what your answer tells you about a 500-unit decrease in projected sales.
  - What is the sensitivity of OCF to changes in the variable cost figure? Explain what your answer tells you about a \$1 decrease in estimated variable costs.
- 2. Scenario Analysis** In the previous problem, suppose the projections given for price, quantity, variable costs, and fixed costs are all accurate to within  $\pm 10$  percent. Calculate the best-case and worst-case NPV figures.
- 3. Calculating Breakeven** In each of the following cases, find the unknown variable. Ignore taxes.

ACCOUNTING BREAK-EVEN	UNIT PRICE	UNIT VARIABLE COST	FIXED COSTS	DEPRECIATION
125,800	\$ 37	\$27	\$740,000	?
12,800	?	55	516,000	\$725,000
7,483	140	?	160,000	143,000

- 4. Financial Breakeven** Shane's Toys Inc. just purchased a \$325,000 machine to produce toy cars. The machine will be fully depreciated by the straight-line method over its five-year economic life. Each toy sells for \$32. The variable cost per toy is \$11, and the firm incurs fixed costs of \$385,000 each year. The corporate tax rate for the company is 35 percent. The appropriate discount rate is 10 percent. What is the financial break-even point for the project?
- 5. Option to Wait** Your company is deciding whether to invest in a new machine. The new machine will increase cash flow by \$425,000 per year. You believe the technology used in the machine has a 10-year life; in other words, no matter when you purchase the machine, it will be obsolete 10 years from today. The machine is currently priced at \$2,600,000. The cost of the machine will decline by \$230,000 per year until it reaches \$1,450,000, where it will remain. If your required return is 12 percent, should you purchase the machine? If so, when should you purchase it?
- 6. Decision Trees** Ang Electronics, Inc., has developed a new HD DVD. If the HD DVD is successful, the present value of the payoff (at the time the product is brought to market) is \$30 million. If the HD DVD fails, the present value of the payoff is \$8 million. If the product goes directly to market, there is a 50 percent chance of success. Alternatively, Ang can delay the launch by one year and spend \$1.5 million to test market the HD DVD. Test marketing would allow the firm to improve the product and increase the probability of success to 75 percent. The appropriate discount rate is 11 percent. Should the firm conduct test marketing?
- 7. Decision Trees** The manager for a growing firm is considering the launch of a new product. If the product goes directly to market, there is a 40 percent chance of success. For \$85,000, the manager can conduct a focus group that will increase the product's chance of success



Basic  
(Questions 1–10)



to 60 percent. Alternatively, the manager has the option to pay a consulting firm \$310,000 to research the market and refine the product. The consulting firm successfully launches new products 85 percent of the time. If the firm successfully launches the product, the payoff will be \$1,650,000. If the product is a failure, the NPV is \$0. Which action will result in the highest expected payoff to the firm?

- 8. Decision Trees** B&B has a new baby powder ready to market. If the firm goes directly to the market with the product, there is only a 60 percent chance of success. However, the firm can conduct customer segment research, which will take a year and cost \$800,000. By going through research, B&B will be able to better target potential customers and will increase the probability of success to 75 percent. If successful, the baby powder will bring a present value profit (at time of initial selling) of \$29 million. If unsuccessful, the present value profit is only \$6 million. Should the firm conduct customer segment research or go directly to market? The appropriate discount rate is 14 percent.
- 9. Financial Break-Even Analysis** You are considering investing in a company that cultivates abalone for sale to local restaurants. Use the following information:

Sales price per abalone	= \$8.75
Variable costs per abalone	= \$1.23
Fixed costs per year	= \$430,000
Depreciation per year	= \$55,000
Tax rate	= 35%

The discount rate for the company is 13 percent, the initial investment in equipment is \$385,000, and the project's economic life is seven years. Assume the equipment is depreciated on a straight-line basis over the project's life.

- What is the accounting break-even level for the project?
- What is the financial break-even level for the project?

- 10. Financial Breakeven** Niko has purchased a brand new machine to produce its High Flight line of shoes. The machine has an economic life of six years. The depreciation schedule for the machine is straight-line with no salvage value. The machine costs \$474,000. The sales price per pair of shoes is \$75, while the variable cost is \$31. \$280,000 of fixed costs per year are attributed to the machine. Assume that the corporate tax rate is 34 percent and the appropriate discount rate is 12 percent. What is the financial break-even point?

**Intermediate**  
(Questions 11–25)

- 11. Break-Even Intuition** Consider a project with a required return of  $R$  percent that costs  $\$/$  and will last for  $N$  years. The project uses straight-line depreciation to zero over the  $N$ -year life; there are neither salvage value nor net working capital requirements.
- At the accounting break-even level of output, what is the IRR of this project? The payback period? The NPV?
  - At the cash break-even level of output, what is the IRR of this project? The payback period? The NPV?
  - At the financial break-even level of output, what is the IRR of this project? The payback period? The NPV?
- 12. Sensitivity Analysis** Consider a four-year project with the following information: initial fixed asset investment = \$430,000; straight-line depreciation to zero over the four-year life; zero salvage value; price = \$29; variable costs = \$18; fixed costs = \$320,000; quantity sold = 91,000 units; tax rate = 34 percent. How sensitive is OCF to changes in quantity sold?

- 13. Project Analysis** You are considering a new product launch. The project will cost \$720,000, have a four-year life, and have no salvage value; depreciation is straight-line to zero. Sales are projected at 180 units per year; price per unit will be \$17,400, variable cost per unit will be \$13,200, and fixed costs will be \$320,000 per year. The required return on the project is 15 percent, and the relevant tax rate is 35 percent.
- Based on your experience, you think the unit sales, variable cost, and fixed cost projections given here are probably accurate to within  $\pm 10$  percent. What are the upper and lower bounds for these projections? What is the base-case NPV? What are the best-case and worst-case scenarios?
  - Evaluate the sensitivity of your base-case NPV to changes in fixed costs.
  - What is the accounting break-even level of output for this project?
- 14. Project Analysis** McGilla Golf has decided to sell a new line of golf clubs. The clubs will sell for \$700 per set and have a variable cost of \$310 per set. The company has spent \$150,000 for a marketing study that determined the company will sell 39,000 sets per year for seven years. The marketing study also determined that the company will lose sales of 12,000 sets of its high-priced clubs. The high-priced clubs sell at \$1,100 and have variable costs of \$630. The company will also increase sales of its cheap clubs by 10,000 sets. The cheap clubs sell for \$390 and have variable costs of \$195 per set. The fixed costs each year will be \$6,400,000. The company has also spent \$1,000,000 on research and development for the new clubs. The plant and equipment required will cost \$13,300,000 and will be depreciated on a straight-line basis. The new clubs will also require an increase in net working capital of \$1,700,000 that will be returned at the end of the project. The tax rate is 40 percent, and the cost of capital is 14 percent. Calculate the payback period, the NPV, and the IRR.
- 15. Scenario Analysis** In the previous problem, you feel that the units sold, variable costs, and fixed costs are accurate to within only  $\pm 10$  percent. What are the best-case and worst-case NPVs? (Hint: The price and variable costs for the two existing sets of clubs are known with certainty; only the sales gained or lost are uncertain.)
- 16. Sensitivity Analysis** McGilla Golf (see Problem 14) would like to know the sensitivity of NPV to changes in the price of the new clubs and the quantity of new clubs sold. What is the sensitivity of the NPV to each of these variables?
- 17. Abandonment Value** We are examining a new project. We expect to sell 13,000 units per year at \$70 net cash flow apiece for the next 10 years. In other words, the annual operating cash flow is projected to be  $\$70 \times 13,000 = \$910,000$ . The relevant discount rate is 11 percent, and the initial investment required is \$4,500,000.
- What is the base-case NPV?
  - After the first year, the project can be dismantled and sold for \$1,800,000. If expected sales are revised based on the first year's performance, when would it make sense to abandon the investment? In other words, at what level of expected sales would it make sense to abandon the project?
  - Explain how the \$1,800,000 abandonment value can be viewed as the opportunity cost of keeping the project in one year.
- 18. Abandonment** In the previous problem, suppose you think it is likely that expected sales will be revised upwards to 17,000 units if the first year is a success and revised downward to 3,400 units if the first year is not a success.
- If success and failure are equally likely, what is the NPV of the project? Consider the possibility of abandonment in answering.
  - What is the value of the option to abandon?



- 19. Abandonment and Expansion** In the previous problem, suppose the scale of the project can be doubled in one year in the sense that twice as many units can be produced and sold. Naturally, expansion would only be desirable if the project were a success. This implies that if the project is a success, projected sales after expansion will be 26,000. Again assuming that success and failure are equally likely, what is the NPV of the project? Note that abandonment is still an option if the project is a failure. What is the value of the option to expand?
- 20. Break-Even Analysis** Your buddy comes to you with a sure fire way to make some quick money and help pay off your student loans. His idea is to sell T-shirts with the words “I get” on them. “You get it?” He says, “You see all those bumper stickers and T-shirts that say, ‘got milk’ or ‘got surf.’ So this says, ‘I get.’ It’s funny! All we have to do is buy a used silk screen press for \$3,500 and we are in business!” Assume there are no fixed costs, and you depreciate the \$3,500 in the first period. Further, taxes are 30 percent.
- a. What is the accounting break-even point if each shirt costs \$6.50 to make and you can sell them for \$13 apiece?
- Now assume one year has passed and you have sold 5,000 shirts! You find out that the Dairy Farmers of America have copyrighted the “got milk” slogan and are requiring you to pay \$15,000 to continue operations. You expect this craze will last for another three years and that your discount rate is 12 percent.
- b. What is the financial break-even point for your enterprise now?
- 21. Decision Trees** Young screenwriter Carl Draper has just finished his first script. It has action, drama, humor, and he thinks it will be a blockbuster. He takes the script to every motion picture studio in town and tries to sell it but to no avail. Finally, ACME studios offers to buy the script, for either (a) \$25,000 or (b) 1 percent of the movie’s profits. There are two decisions the studio will have to make. First is to decide if the script is good or bad, and second if the movie is good or bad. First, there is a 90 percent chance that the script is bad. If it is bad, the studio does nothing more and throws the script out. If the script is good, it will shoot the movie. After the movie is shot, the studio will review it and there is a 70 percent chance that the movie is bad. If the movie is bad, the movie will not be promoted and will not turn a profit. If the movie is good, the studio will promote heavily and the average profit for this type of movie is \$100 million. Carl rejects the \$25,000 and says he wants the 1 percent of profits. Was this a good decision by Carl?
- 22. Accounting Breakeven** Samuelson, Inc., has just purchased a \$675,000 machine to produce calculators. The machine will be fully depreciated by the straight-line method over its economic life of five years and will produce 21,000 calculators each year. The variable production cost per calculator is \$17 and total fixed costs are \$910,000 per year. The corporate tax rate for the company is 30 percent. For the firm to break even in terms of accounting profit, how much should the firm charge per calculator?
- 23. Abandonment Decisions** Tidwell Products, Inc., is considering a new product launch. The firm expects to have an annual operating cash flow of \$13 million for the next 10 years. Tidwell Products uses a discount rate of 14 percent for new product launches. The initial investment is \$55 million. Assume that the project has no salvage value at the end of its economic life.
- a. What is the NPV of the new product?
- b. After the first year, the project can be dismantled and sold for \$38 million. If the estimates of remaining cash flows are revised based on the first year’s experience, at what level of expected cash flows does it make sense to abandon the project?

- 24. Expansion Decisions** Applied Nanotech is thinking about introducing a new surface cleaning machine. The marketing department has come up with the estimate that Applied Nanotech can sell 10 units per year at \$185,000 net cash flow per unit for the next five years. The engineering department has come up with the estimate that developing the machine will take a \$7 million initial investment. The finance department has estimated that a 13 percent discount rate should be used.
- What is the base-case NPV?
  - If unsuccessful, after the first year the project can be dismantled and will have an aftertax salvage value of \$3.2 million. Also, after the first year, expected cash flows will be revised up to 20 units per year or to 0 units, with equal probability. What is the revised NPV?
- 25. Scenario Analysis** You are the financial analyst for a tennis racket manufacturer. The company is considering using a graphite-like material in its tennis rackets. The company has estimated the information in the table below about the market for a racket with the new material. The company expects to sell the racket for five years. The equipment required for the project has no salvage value. The required return for projects of this type is 13 percent, and the company has a 40 percent tax rate. Should you recommend the project?

	PESSIMISTIC	EXPECTED	OPTIMISTIC
Market size	126,000	140,000	150,000
Market share	15%	19%	23%
Selling price	\$ 106	\$ 115	\$ 124
Variable costs per year	\$ 50	\$ 47	\$ 43
Fixed costs per year	\$ 975,000	\$ 925,000	\$ 870,000
Initial investment	\$2,200,000	\$2,200,000	\$2,200,000

- 26. Scenario Analysis** Consider a project to supply Detroit with 60,000 tons of machine screws annually for automobile production. You will need an initial \$3,250,000 investment in threading equipment to get the project started; the project will last for five years. The accounting department estimates that annual fixed costs will be \$230,000 and that variable costs should be \$208 per ton; accounting will depreciate the initial fixed asset investment straight-line to zero over the five-year project life. It also estimates a salvage value of \$500,000 after dismantling costs. The marketing department estimates that the automakers will let the contract at a selling price of \$234 per ton. The engineering department estimates you will need an initial net working capital investment of \$450,000. You require a 13 percent return and face a marginal tax rate of 38 percent on this project.
- What is the estimated OCF for this project? The NPV? Should you pursue this project?
  - Suppose you believe that the accounting department's initial cost and salvage value projections are accurate only to within  $\pm 15$  percent; the marketing department's price estimate is accurate only to within  $\pm 10$  percent; and the engineering department's net working capital estimate is accurate only to within  $\pm 5$  percent. What is your worst-case scenario for this project? Your best-case scenario? Do you still want to pursue the project?
- 27. Sensitivity Analysis** In Problem 26, suppose you're confident about your own projections, but you're a little unsure about Detroit's actual machine screw requirement. What is the sensitivity of the project OCF to changes in the quantity supplied? What about the sensitivity of NPV to changes in quantity supplied? Given the sensitivity number you calculated, is there some minimum level of output below which you wouldn't want to operate? Why?

**Challenge**

(Questions 26–30)

**28. Abandonment Decisions** Consider the following project for Hand Clapper, Inc. The company is considering a four-year project to manufacture clap-command garage door openers. This project requires an initial investment of \$8.2 million that will be depreciated straight-line to zero over the project's life. An initial investment in net working capital of \$1.3 million is required to support spare parts inventory; this cost is fully recoverable whenever the project ends. The company believes it can generate \$7.05 million in pretax revenues with \$2.9 million in total pretax operating costs. The tax rate is 38 percent and the discount rate is 16 percent. The market value of the equipment over the life of the project is as follows:

YEAR	MARKET VALUE (\$ MILLIONS)
1	\$5.7
2	5.1
3	3.4
4	0.0

- a. Assuming Hand Clapper operates this project for four years, what is the NPV?
  - b. Now compute the project NPVs assuming the project is abandoned after only one year, after two years, and after three years. What economic life for this project maximizes its value to the firm? What does this problem tell you about not considering abandonment possibilities when evaluating projects?
- 29. Abandonment Decisions** M.V.P. Games, Inc., has hired you to perform a feasibility study of a new video game that requires an \$8 million initial investment. M.V.P. expects a total annual operating cash flow of \$1.3 million for the next 10 years. The relevant discount rate is 11 percent. Cash flows occur at year-end.
- a. What is the NPV of the new video game?
  - b. After one year, the estimate of remaining annual cash flows will either be revised upward to \$2.1 million or revised downward to \$600,000. Each revision has an equal probability of occurring. At that time, the video game project can be sold for \$4.1 million. What is the revised NPV given that the firm can abandon the project after one year?
- 30. Financial Breakeven** The Cornchopper Company is considering the purchase of a new harvester. Cornchopper has hired you to determine the break-even purchase price in terms of present value of the harvester. This break-even purchase price is the price at which the project's NPV is zero. Base your analysis on the following facts:
- The new harvester is not expected to affect revenues, but pretax operating expenses will be reduced by \$9,000 per year for 10 years.
  - The old harvester is now 5 years old, with 10 years of its scheduled life remaining. It was originally purchased for \$67,000 and has been depreciated by the straight-line method.
  - The old harvester can be sold for \$21,000 today.
  - The new harvester will be depreciated by the straight-line method over its 10-year life.
  - The corporate tax rate is 34 percent.
  - The firm's required rate of return is 13 percent.
  - The initial investment, the proceeds from selling the old harvester, and any resulting tax effects occur immediately.
  - All other cash flows occur at year-end.
  - The market value of each harvester at the end of its economic life is zero.



## BUNYAN LUMBER, LLC

Bunyan Lumber, LLC, harvests timber and delivers logs to timber mills for sale. The company was founded 70 years ago by Pete Bunyan. The current CEO is Paula Bunyan, the granddaughter of the founder. The company is currently evaluating a 7,500-acre forest it owns in Oregon. Paula has asked Steve Boles, the company's finance officer, to evaluate the project. Paula's concern is when the company should harvest the timber.

Lumber is sold by the company for its "pond value." Pond value is the amount a mill will pay for a log delivered to the mill location. The price paid for logs delivered to a mill is quoted in dollars per thousands of board feet (MBF), and the price depends on the grade of the logs. The forest Bunyan Lumber is evaluating was planted by the company 20 years ago and is made up entirely of Douglas fir trees. The table below shows the current price per MBF for the three grades of timber the company feels will come from the stand:

TIMBER GRADE	PRICE PER MBF
1P	\$575
2P	555
3P	530

Steve believes that the pond value of lumber will increase at the inflation rate. The company is planning to thin the forest today, and it expects to realize a positive cash flow of \$450 per acre from thinning. The thinning is done to increase the growth rate of the remaining trees, and it is always done 20 years following a planting.

The major decision the company faces is when to log the forest. When the company logs the forest, it will immediately replant saplings, which will allow for a future harvest. The longer the forest is allowed to grow, the larger the harvest becomes per acre. Additionally, an older forest has a higher grade of timber. Steve has compiled the following table with the expected harvest per acre in thousands of board feet, along with the breakdown of the timber grade.

YEARS FROM TODAY TO BEGIN HARVEST	HARVEST (MBF) PER ACRE	TIMBER GRADE		
		1P	2P	3P
20	7.2	15%	42%	43%
25	9.4	18	49	33
30	11.3	20	51	29
35	12.2	22	53	25

The company expects to lose 5 percent of the timber it cuts due to defects and breakage.

The forest will be clear-cut when the company harvests the timber. This method of harvesting allows for faster growth of replanted trees. All of the harvesting, processing, replanting, and transportation are to be handled by subcontractors hired by Bunyan Lumber. The cost of the logging is expected to be \$155 per MBF. A road system has to be constructed and is expected to cost \$60 per MBF on average. Sales preparation and administrative costs, excluding office overhead costs, are expected to be \$21 per MBF.

As soon as the harvesting is complete, the company will reforest the land. Reforesting costs include the following:

	PER ACRE COST
Excavator piling	\$160
Broadcast burning	280
Site preparation	140
Planting costs	270

All costs are expected to increase at the inflation rate.

Assume all cash flows occur at the year of harvest. For example, if the company begins harvesting the timber 20 years from today, the cash flow from the harvest will be received 20 years from today. When the company logs the land, it will immediately replant the land with new saplings. The harvest period chosen will be repeated for the foreseeable future. The company's nominal required return is 10 percent, and the inflation rate is expected to be 3.7 percent per year. Bunyan Lumber has a 35 percent tax rate.

Clear-cutting is a controversial method of forest management. To obtain the necessary permits, Bunyan Lumber has agreed to contribute to a conservation fund every time it harvests the lumber. If the company harvested the forest today, the required contribution would be \$300,000. The company has agreed that the required contribution will grow by 3.2 percent per year. When should the company harvest the forest?