Risk Analysis, Real Options, and Capital Budgeting 9

OPENING CASE

In 2015, the Universal Studios movie *Blackhat* debuted in theaters. While the movie had poor reviews, it had an even worse box office as audiences stayed away in droves, making the film one of 2015's biggest box office flops.

Looking at the numbers, Universal Studios spent about $90 million making the movie, plus millions more for marketing and distribution. However, based on the film's performance, Universal only pulled in about $20 million worldwide, a huge write-off. 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 2015, the Lucasfilm movie *Star Wars: The Force Awakens* raked in about $2.03 billion worldwide at a production cost of $200 million.

Obviously, Universal Studios didn't *plan* to lose $70 or so million on *Blackhat,* but it happened. As the money poured into *Blackhat* 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.

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9.1 DECISION TREES

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

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

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	

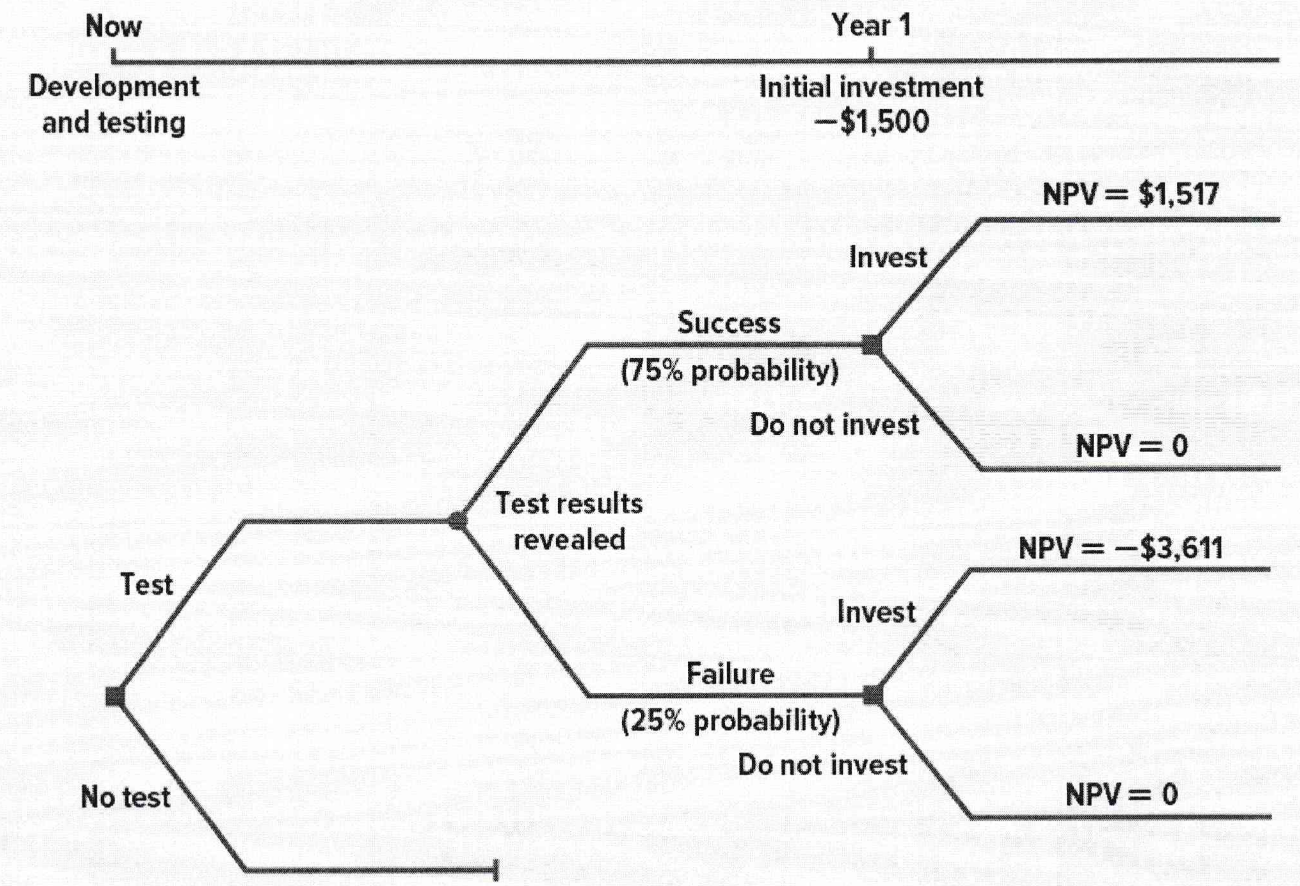
* Assumptions: (1) Investment is depreciated in Years 2 through 6 using the straight-line method; (2) tax rate is 34 percent; (3) the company receives no tax benefits on initial development costs.

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.

FIGURE 9.1
Decision Tree ($ millions) for SEC



Squares represent decision points. Circle represents receipt of information.
SEC must make two decisions:

1. Whether to develop and test engine.
2. Whether to invest for full-scale production.

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:

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

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

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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 *Finance Matters* box discusses some recent cases of plans gone awry.

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*[1]), 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.

FINANCE MATTERS

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 2015, Microsoft admitted to such a mistake. In 2014, Microsoft acquired mobile phone manufacturer Nokia for $7.2 billion in cash in order to have a standalone phone system for the company's mobile operating system. Unfortunately, the acquisition was not profitable for Microsoft. In July 2015, Microsoft wrote off $7.6 billion in charges related to the Nokia acquisition, more than the original purchase price.

Deutsche Bank announced a $7 billion write-off in October 2015 related to the company's acquisition of Bankers Trust. Deutsche Bank had acquired Bankers Trust for $10.1 billion in 1999 in an effort to increase its investment banking and proprietary trading revenue. As the write-off shows, the acquisition was unsuccessful. Of course, these write-offs took several years to occur. In October 2012, FarmVille creator Zynga announced that it was writing off about $90 million related to the company's acquisition of OMGPOP. While this is a rather small write-off, Zynga had paid $180 million for OMGPOP just 197 days earlier!

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 saddled 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.

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

$$\text{Number of jet engines sold} = \text{Market share} \times \text{Size of jet engine market}$$

$$3{,}000 = .30 \times 10{,}000$$

$$\text{Sales revenues} = \text{Number of jet engines sold} \times \text{Price per engine}$$

$$\$6{,}000 \text{ million} = 3{,}000 \times \$2 \text{ million}$$

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:

Variable cost	=	**Variable cost per unit**	×	**Number of jet engines sold**
$3,000 million	=	**$1 million**	×	**3,000**
Total cost before taxes	=	**Variable cost**	+	**Fixed cost**
$4,791 million	=	**$3,000 million**	+	**$1,791 million**

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.

TABLE 9.2 Different Estimates for Solar Electronics's Solar Jet Engine

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	$.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 9.3 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.

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

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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.

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[2] 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.

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:

TABLE 9.4 Cash Flow Forecast (in $ millions) under the Scenario of a Plane Crash*

	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)†		235
Net profit		−$ 456
Cash flow		−$ 156
Initial investment cost	−$1,500	

* 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.

† Tax loss offsets income elsewhere in firm.

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

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 net 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.

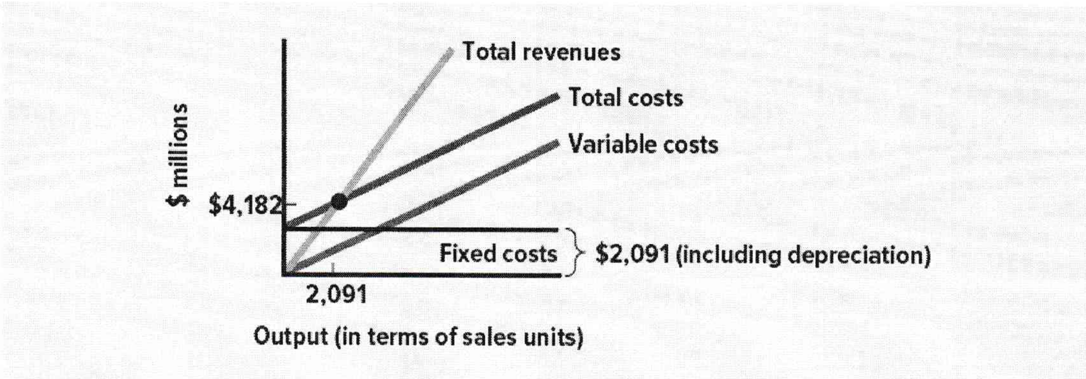
We plot the revenues, costs, and profits under the different assumptions about sales in Figure 9.2. The revenue and cost curves cross at 2,091 jet engines. This is the break-even point, that is, the point where the project generates no profits or losses. As long as sales are above 2,091 jet engines, the project will make a profit.

TABLE 9.5 Revenues and Costs of Project under Different Sales Assumptions (in $ millions, except unit sales)

YEAR 1	YEAR 2–6								
INITIAL INVEST-MENT	ANNUAL UNIT SALES	REVENUES	VARIABLE COSTS	FIXED COSTS	DEPRECI-ATION	TAXES* (tc = .34)	NET PROFIT	OPERATING CASH FLOWS	NPV (EVALUATED DATE 1)
$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	− 0,000	− 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



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,[3] the aftertax difference per engine is

$$\begin{aligned}\text{(Sales price} - \text{Variable cost)} \times (1 - t_c) &= (\$2 \text{ million} - \$1 \text{ million}) \times (1 - .34) \\ &= \$.66 \text{ million}\end{aligned}$$

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 aftertax profit.

Fixed costs are $1,791 million and depreciation is $300 million, implying that the aftertax sum of these costs is:

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

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.

FINANCIAL BREAK-EVEN 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 financial 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:

$$\text{EAC} = \frac{\text{Initial investment}}{\text{5 – year annuity factor at 15\%}} = \frac{\text{Initial investment}}{\text{PVIFA}_{15\%,5}}$$

$$= \frac{\$1{,}500 \text{ million}}{3.3522} = \$447.5 \text{ million}$$

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:

$$\underset{\text{million}}{\$1{,}528} = \text{EAC} + \underset{\text{costs}}{\text{Fixed}} \times (1 - t_c) - \text{Depreciation} \times t_c$$

$$= \underset{\text{million}}{\$447.5} + \underset{\text{million}}{\$1{,}791} \times .66 - \underset{\text{million}}{\$300} \times .34$$

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:

Financial 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 engine 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

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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.

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.

> For a free demonstration of a spreadsheet application of Monte Carlo analysis, go to www.crystalball.com.

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:

Fixed manufacturing costs + Variable manufacturing costs
+ Marketing costs + Selling costs

Initial investment is viewed as:

Cost of patent + Test-marketing costs + 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:

PROBABILITY	20%	60%	20%
NEXT YEAR'S INDUSTRYWIDE UNIT SALES	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:

PROBABILITY	10%	20%	30%	25%	10%	5%
MARKET SHARE OF BBI'S HYDROGEN GRILL NEXT YEAR	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:

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

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 "+/−$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:

PROBABILITY	20%	60%	20%
GROWTH RATE OF INDUSTRYWIDE UNIT SALES IN SECOND YEAR	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:

$$\$190 + 10 + 3 = \$203$$

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

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

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:

$$.02 = .02 \times .02 \times .50$$

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.

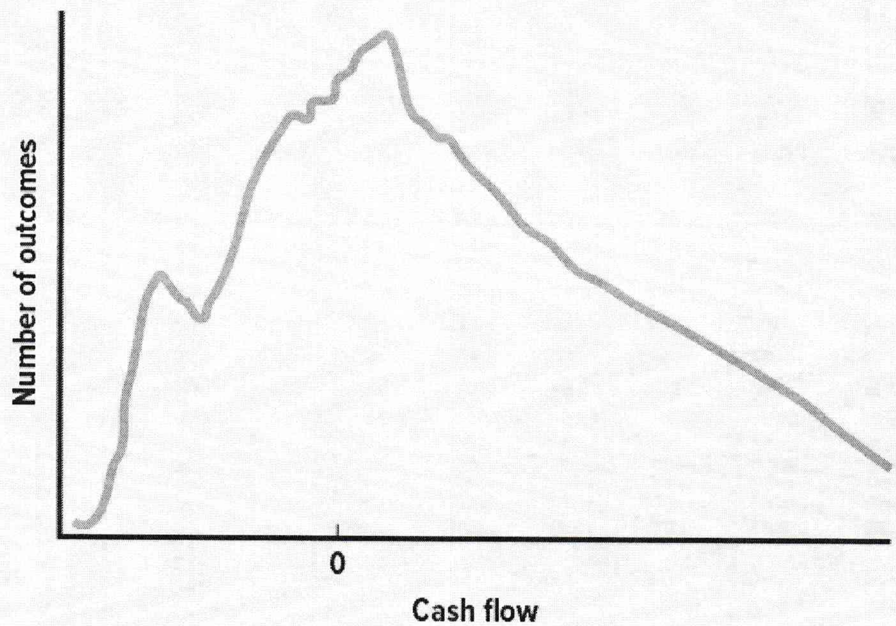
STEP 4: REPEAT THE PROCEDURE While the above three steps generate one outcome, the essence of Monte Carlo simulation is repeated outcomes. Depending on the situation, the computer may be called on to generate thousands or even millions of outcomes. The result of all these drawings is a distribution of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



In Monte Carlo simulations, repeated sampling of all the variables from a specific model generates a statistical distribution.

Because Monte Carlo simulations have been around since at least the 1940s, 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[4] 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 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.

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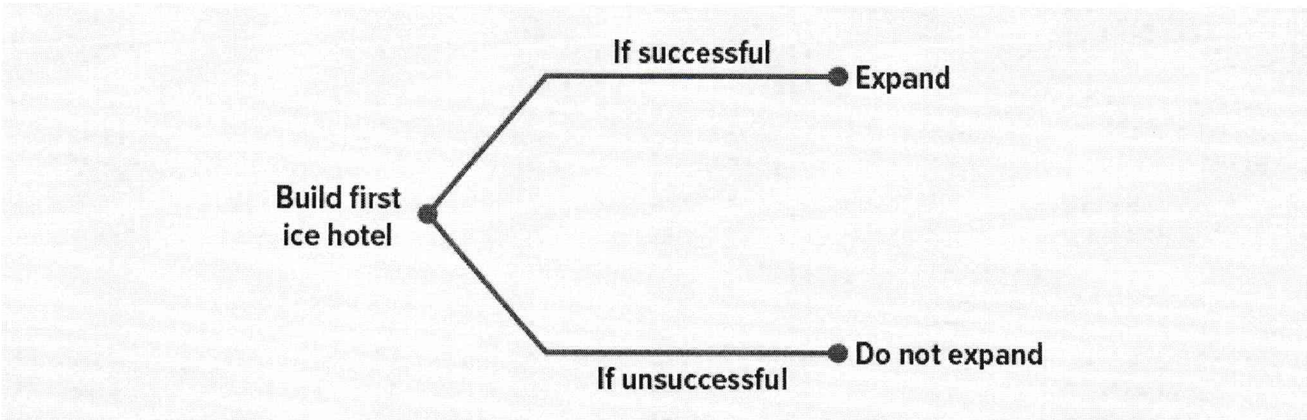
FIGURE 9.4
Decision Tree for Ice Hotel



The NPV calculations for the two forecasts are:

Optimistic forecast: − $12 million + $3 million/.20 = $3 million
Pessimistic forecast: − $12 million + $1 million/.20 = − $7 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 × $3 million + .50 × (−$7 million) = − $2 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 × 10 × $3 million + .50 × (−$7 million) = $11.5 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 of 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 million + \$6 million/.2 = \$18 million

Pessimistic forecast: − \$12 million − \$2 million/.2 = − \$22 million

yielding an NPV for the project of:

.50 × \$18 million + .50 × (−\$22 million) = − \$2 million

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:

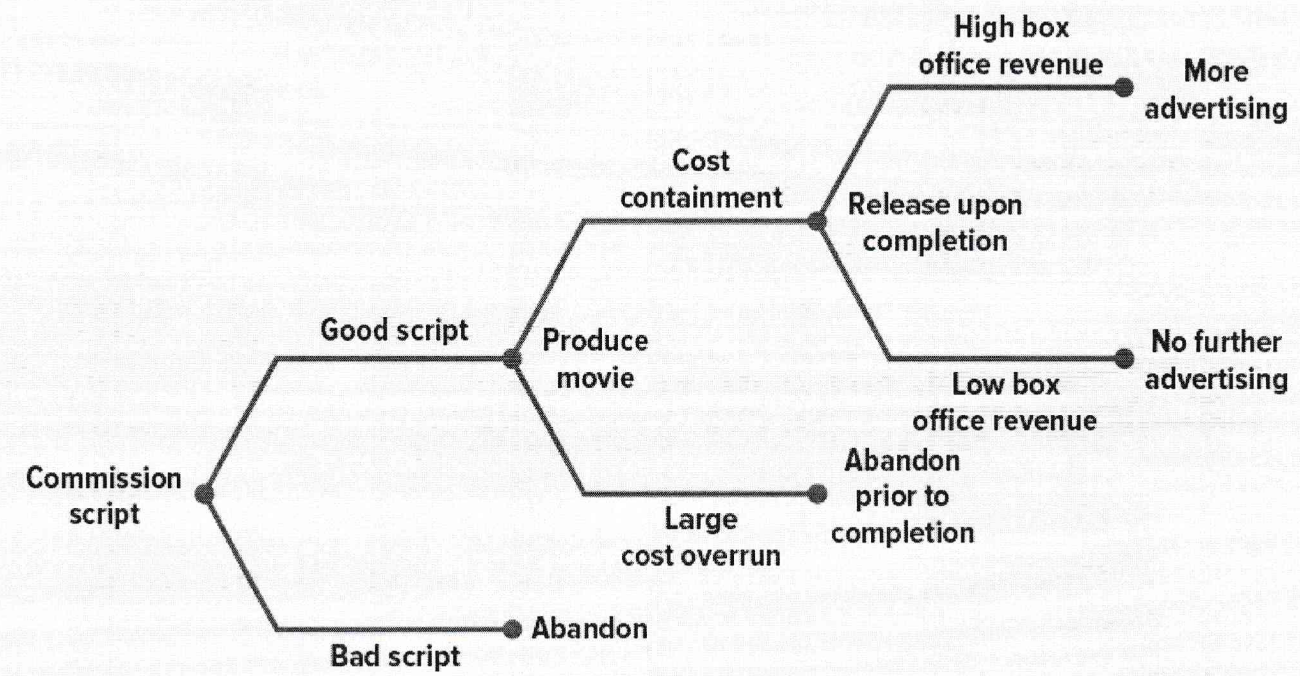
$$.50 \times \$18 \text{ million} + .50 \times (-\$12 \text{ million} - \$2 \text{ million}/1.20) = \$2.17 \text{ million}$$

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.

FIGURE 9.5
The Abandonment Option in the Movie Industry



Movie studios have abandonment options throughout the production of a 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 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 park's performance was still troubling. During 2015, the park had a record 14.8 million visitors, but the company lost €84.2 million ($94 million).

A recent example of the option to abandon occurred in 2015 when Apple announced that it would shut down Beats Music, which it had purchased for $3 billion the previous year. With the shuttering of Beats, Apple believed that most subscribers would move to Apple Music.

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 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.