Chapter NINETEEN

Introduction to Decision Analysis

CHAPTER OUTCOMES

After studying the material in Chapter 19, you should be able to:

1. Describe the decision-making environments of certainty and uncertainty.
2. Construct both a payoff table and an opportunity-loss table.
3. Define the expected value criterion.
4. Apply the expected value criterion in decision situations.
5. Compute the cost of uncertainty and value of perfect information.
6. Develop a decision tree and explain how it can aid decision making in an uncertain environment.

PREPARING FOR CHAPTER NINETEEN

- Review how to construct tree diagrams, covered in Section 4.1.
- Make sure you are familiar with how to determine expected values introduced in Section 4.2.

Why You Need to Know

Although this text is devoted to discussing statistical techniques managers can use to help analyze decisions, the term *decision analysis* has a specialized meaning. It applies to the set of tools, some of which are covered in this chapter, that have been developed to help managers analyze multistage decisions that must be made in an uncertain environment.

Putting together this set of tools has been a relatively recent development, starting in the late 1950s, initially by faculty at the Harvard Business School. The individual tools themselves are considerably older than decision analysis, however, and come from three theoretical areas of thought: (1) Bayesian statistics, (2) game theory, and (3) risk-preference analysis.

The bedrock of decision analysis was formed by the eighteenth-century work of the Reverend Thomas Bayes, one of the most enigmatic figures in scientific history. He is credited with being the first person to give a rational account of how statistical inference can be used as a process for understanding situations in the real world. But his pioneering work was not published until after his death in 1761, and during his lifetime he was a scientific unknown. Now, however, he has become so popular that a whole group of decision analysts refer to themselves as "Bayesians."

A second contribution to modern decision analysis is the game-theory approach of John Von Neumann and Oskar Morgenstern. They demonstrated that the "correct" decision in any situation depends on the objectives of the decision maker and the actions that are likely to be taken by competitors.

The third area is the work of such economists as Milton Friedman and L. J. Savage. They showed that a person's attitude toward risk depends on the person's circumstances; and therefore, different decision makers, when facing the same decision, may make different choices because of their differing risk attitudes.

Since its introduction in the late 1950s, decision analysis has become a common feature in MBA programs and has influenced thousands of decision makers in government and industry.

This chapter introduces the fundamentals of decision analysis and shows, through examples, how several basic decision analysis tools are used in the decision-making process.

19.1 Decision-Making Environments and Decision Criteria

In business, you will encounter a wide variety of decision situations. The analytic methods you use to deal with each situation will depend largely on the decision environment. The two primary decision environments are certainty and uncertainty.

CHAPTER OUTCOME #1

Certainty

Sometimes you will encounter a decision situation in which you can be certain of the outcome for each alternative. This type of decision environment, in which the results of each alternative are known before the decision is made, is termed a **certainty** environment.

Certainty
A decision environment in which the results of selecting each alternative are known before the decision is made.

Business Application

ECONOPRINT COMPANY Consider a decision faced by the Econoprint Company, which makes replacement cartridges for laser printers. The national sales manager has just received a message from a regional sales representative indicating that she has negotiated a deal with a new distributor for 1 million cartridges at $5.00 each. However, the customer wants the cartridges to be packaged in groups of 6, rather than the usual 24 per package. The sales representative points out that the company can modify its packaging equipment "quite easily" to accommodate this change. She urges a quick decision, because a delay is likely to force the customer to go elsewhere, and the efforts to attract this new business will be lost.

Needing information on which to base his decision, the national sales manager contacts the industrial engineering and accounting staffs. He is told that the total production costs for the product grouped 6 to a package will be $4.50 per cartridge. Selling costs and overhead costs are 5% and 1% of sales, respectively.

Table 19.1 shows the projected profits and losses for the two decision alternatives: accept the offer or reject the offer. Because all costs and revenues are known for each

TABLE 19.1 Econoprint Company: Profits and Losses for Two Alternatives

	Alternatives	
Revenues and Expenses	Accept Offer	Reject Offer
Revenues		
Sales (1 million × $5.00)	$5,000,000	0
Costs		
Production (1 million × $4.50)	$4,500,000	0
Selling (5% of sales)	250,000	0
Overhead (1% of sales)	50,000	0
Profit	$ 200,000	0

alternative, the decision is straightforward: The $200,000 profit associated with accepting the offer exceeds the $0 profit associated with not accepting the offer; therefore, the offer should be accepted.

As this example shows, once a certainty model has been specified, the best decision is evident. By "best decision," we mean the alternative course of action, using all available information, that best satisfies the decision criterion. In the Econoprint Company example, the decision criterion was highest profit. Given that the decision model displayed in Table 19.1 utilized all available information, the best decision was to accept the offer. Because this is a certainty environment, the decision will result in an outcome of $200,000 profit. Thus, in a certainty environment, the best decision will always be associated with the best outcome.

CHAPTER OUTCOME #1

Uncertainty

If business decisions were always made in a certainty environment, you would probably not need the academic training you are now receiving to be successful. How many of us would have chosen to reject the offer in the Econoprint Company example if Table 19.1 reflected the total decision picture? In reality, the typical business decision-making environment is not one of certainty but, rather, **uncertainty**.

Uncertainty
A decision environment in which the decision maker does not know what outcome will occur when an alternative is selected.

The certainty environment is predicated on the fact that the outcome from each alternative course of action is known. If we choose alternative A, outcome Y will occur. If alternative B is selected, outcome *Z* will occur. This makes choosing between the alternatives straightforward. However, in most business situations, although we may be able to specify the possible outcomes for each alternative, we will be uncertain about which outcome will occur. Consider the real estate speculator who is trying to decide whether to purchase land outside of Las Vegas, one of the fastest-growing cities in the country, hoping to resell the land to a developer. If the speculator elects not to purchase the property, the net change in his financial position will be zero. He knows this for sure. However, if he chooses to buy the land, what will the outcome be? Will he make $10,000,000, or $20,000,000, or will he lose $5,000,000? Identifying the possible outcomes is difficult enough, but knowing for certain what outcome definitely will occur is impossible in a competitive real estate market. Thus, the speculator must decide whether to buy in an environment of uncertainty.

Business Application

EAGLE LUMBER COMPANY Consider the Eagle Lumber Company in Glenns Ferry, Wisconsin. About 3 weeks ago, the manager received 4,000 board feet of 2-inch-by-6-inch tongue-and-groove knotty pine, which is used primarily for walls and ceilings. The product is hard to get because the supplier makes only a limited quantity each month. The wholesale price for the recent shipment was $360 per 1,000 board feet. Two days after receiving the material, a customer came in and bought the entire shipment for $450 per 1,000 board feet. However, the customer wanted Eagle Lumber to store the material for 8 weeks.

Two weeks later, another customer arrived and wanted to purchase as much 2-inch-by-6-inch tongue-and-groove knotty pine as possible for immediate use. The only stock on hand at the lumber company at the time was the 4,000 board feet, which had already been sold. After seeing the paid-for knotty pine, the new customer asked whether the manager would consider selling him the 4,000 board feet now and replacing the material before the previous customer returned to pick it up in about 7 weeks.

In a certain environment, the decision would be relatively easy. If the lumber could be replaced at a known price before the first customer returned, the manager could resell the material and both customers would be happy. If the lumber could not be replaced before the first customer returned, the second customer would be turned away. Unfortunately, the decision environment facing Eagle's manager is not one of certainty. For one thing, he does not know whether he will be able to replace the stock within 7 weeks. Furthermore, if he is able to replace the material, he does not know exactly what the cost will be. Therefore, he is uncertain about what price to charge the second customer. He is also uncertain about whether the first customer will arrive early to take his material. As you can see, a seemingly simple situation is actually quite complex due to the uncertainties involved.

The decision analysis techniques presented in this chapter do not eliminate the uncertainty associated with a decision, but they do provide a framework for dealing with the uncertainty. These techniques help you make good decisions under certain conditions, but good decisions don't necessarily result in good outcomes. For instance, suppose after considering all available information that the best decision is not to sell to the new customer. Then, a week later, the original customer calls to say he will be 6 weeks late picking up the material. If the manager had known this, he could have sold the materials to the new customer and received the additional profit. Thus, the best decision at the time did not result in a good outcome.

This concept of decision analysis is contrary to how many people view situations. The tendency is to look at the outcome and, if it is not good, we second-guess our decision. However, if we have properly used all available information in making the decision, it was a good decision. Decision makers must realize that in an uncertain environment, in which they don't have total control over the outcomes of their decisions, bad outcomes will sometimes occur. Decision makers must also continually remind themselves that there is a difference between a good decision and a good outcome. *The goal of decision analysis is to focus on making good decisions, which in the long run should result in an increased number of good outcomes*.

Not all decisions require the use of decision analysis; the complexity of the decision situation usually determines the usefulness of decision analysis. The more complex the decision, the greater the potential benefit from decision analysis. Several factors affect the complexity of a decision, including the number of alternatives available to the decision maker, the number of possible outcomes associated with each alternative, and the general level of uncertainty associated with the decision. For example, marketing decisions regarding product design, product pricing, and distribution are very complex, and decision analysis tools can be helpful to the decision maker. Of course, any decision involving product design or pricing also involves other areas in an organization, including production and finance.

Another characteristic of situations in which decisions can be aided by decision analysis is that they often extend to multiple functional areas of an organization. Production decisions, including process design, aggregate planning, and facilities planning, all lend themselves to decision analysis because of their complexity and long-term importance to the organization. Such financial decision areas as capital budgeting, project financing, and pension investing clearly can benefit from the application of decision analysis.

The types of decisions mentioned here are only a few of those in which decision analysis can be effectively applied. Throughout the remainder of this chapter, we will present further examples in which decision analysis can be used to aid business decision making.

Decision Criteria

When you are faced with choices between two or more options in a business situation, you are required to make a decision. Unless you are willing to flip a coin, "draw straws," or use some other random method, you will need to establish some basis for making the decision. The criteria on which the decision is to be made need to be established. Then, ideally, you will perform an analysis of the decision situation and make the "best" choice by weighing each decision option against the criteria you have established.

Business Application

FISHER FABRICATION Fisher Fabrication has been in business for 10 years in eastern Tennessee. The company was started by two brothers who had worked in the electronics industry in Texas and California. They wanted to get back to where they grew up, and they saw that many electronics companies were beginning to subcontract their assembly work, particularly on small-volume items. They saw an opportunity to get into the subcontracting business and decided to move back home. They found a dedicated workforce and soon employed 150 people.

The brothers concentrated on manual assembly of limited-volume items such as special equipment for oil exploration, vehicles, and military contracts. Business had been extremely good until 2 years ago, when revenues began to decline slightly. By contacting past customers, the brothers determined the drop in sales was due to the increasing use companies were making of surface-mounted components, something the Fishers were not able to do by hand.

This finding made the brothers realize their company must invest in a surface-mount machine, but they were uncertain about the extent of the investment needed. Initial research led them to identify three potential courses of action (alternatives):

A_1: A large investment, which would involve purchasing a full-scale surface-mount system, including robotics, thus allowing them to bid on the majority of current manufacturing contracts. This equipment would give them greater capability.

A_2: A medium investment, which would give them the same general capability as alternative A, but the equipment would operate at a much lower speed. This would prevent them from bidding on large contracts.

A_3: A small investment, which would limit them to bidding on less than half of the potential contracts.

Obviously, the alternative the Fishers should select depended on the future revenues generated by the new equipment. Consequently, the Fishers identified three potential directions that they believed the demand for surface-mounted components could take. In decision analysis terminology, these three demand levels are referred to as **states of nature**. For the Fishers, the states of nature were

States of Nature
The possible outcomes in a decision situation over which the decision maker has no control.

S_1: Rapidly increasing demand due to the capability of the surface-mount equipment

S_2: Moderately increasing demand

S_3: Slight increase in demand as more businesses added their own surface-mount capability

CHAPTER OUTCOME #2

Payoff
The outcome (profit or loss) for any combination of alternative and state of nature. The payoffs associated with all possible combinations of alternatives and states of nature constitute a *payoff table*.

The Fishers wanted to base their investment decision on yearly profit values, but as we can see, there were three potential profit levels, due to the three states of nature, for each alternative. The outcome that is associated with any combination of a particular state of nature and an alternative is called a **payoff**. Because the brothers' decision involved three alternatives and three states of nature, they had nine possible payoffs to consider, as shown in the payoff table (Table 19.2).

In order to decide among the three alternatives, the Fishers had to have some basis for comparison, so they established decision criteria. There are two main categories of decision criteria: *nonprobabilistic* and *probabilistic*. Nonprobabilistic criteria are used when either the probabilities associated with the possible payoffs are unknown or the decision

TABLE 19.2 Fisher Fabrication Payoff Table

	Demand (States of Nature)		
Alternative	S_1 Large Increase	S_2 Moderate Increase	S_3 Small Increase
A_1 Large Investment	$6,000,000	$4,000,000	−$2,600,000
A_2 Medium Investment	2,500,000	5,000,000	−1,000,000
A_3 Small Investment	2,000,000	1,500,000	1,200,000

Note: These values are the Fishers' estimates of the profit associated with each combination of alternative and state of nature.

maker lacks confidence and/or information with which to assess probabilities for the various payoffs. Probabilistic criteria incorporate the decision maker's assessment of the probability of each state of nature occurring.

Maximax Criterion
An optimistic decision criterion for dealing with uncertainty without using probability. For each option, the decision maker finds the maximum possible payoff and then selects the option with the greatest maximum payoff.

Maximin Criterion
A pessimistic (conservative) decision criterion for dealing with uncertainty without using probability. For each option, the decision maker finds the minimum possible payoff and selects the option with the greatest minimum payoff.

Nonprobabilistic Decision Criteria

Several specific decision criteria fall into the nonprobabilistic category. One of these is the **maximax criterion**. For the Fisher brothers, using this criterion would mean making a major investment in surface-mount equipment, because that was the alternative with the highest possible payoff, $6,000,000 per year (Table 19.2). The maximax criterion might be chosen by optimistic decision makers.

If we are not optimistic, we might select the alternative whose worst possible outcome is better than the worst possible outcome from any other alternative. This pessimistic (or conservative) criterion is called the **maximin criterion**. For the Fishers, using the maximin criterion would mean selecting the small-investment alternative, because its worst outcome, $1,200,000 was better than any other alternative's worst outcome.

CHAPTER OUTCOME #2

A disadvantage of the maximax and maximin criteria is that they use only one value from the payoff table to make a decision. In analyzing the decision situation, the brothers may have been interested in determining how much damage making the wrong choice would cause. For instance, suppose they decided on the medium-investment alternative and later found that the market for surface-mount capability had expanded greatly. The medium-investment decision led to a $2,500,000 yearly profit, but given perfect hindsight, the best decision of making a large investment would have earned $6,000,000. The difference between the actual payoff and the optimal payoff for a given state of nature is an **opportunity loss**; in this case, it is $3,500,000. If the Fishers decided to use the **minimax regret criterion**, they would need to know the value of the opportunity loss.

Opportunity Loss
The difference between the actual payoff that occurs for a decision and the optimal payoff for the same state of nature.

Minimax Regret Criterion
A decision criterion that considers the results of selecting the "wrong" alternative. For each state of nature, the decision maker finds the difference between the best payoff and each other alternative and uses these values to construct an opportunity-loss table. The decision maker then identifies the maximum opportunity loss for each alternative and selects the alternative with the minimum of these maximum values.

The minimax regret criterion considers the results of selecting the "wrong" alternative. The first step is to construct an opportunity-loss, or regret, table by finding, for each state of nature, the differences between the payoff for the best decision and the payoffs for all the other alternatives. Table 19.3 shows how this is done. The next step is to find the

TABLE 19.3 Fisher Fabrication: Opportunity-Loss Table

	Demand (States of Nature)		
Alternative	S_1 Large Increase	S_2 Moderate Increase	S_3 Small Increase
A_1 Large Investment	$ 0	$1,000,000	$3,800,000
A_2 Medium Investment	3,500,000	0	2,200,000
A_3 Small Investment	4,000,000	3,500,000	0

Note: The values in this table were found by subtracting each column value in Table 19.2 from the largest value in that column.

TABLE 19.4 Fisher Fabrication Maximum Regret Table

Alternative	Maximum Opportunity Loss, or Regret	
A_1 Large Investment	\$3,800,000	
A_2 Medium Investment	\$3,500,000	(smallest regret)
A_3 Small Investment	\$4,000,000	

maximum regret for each alternative. These values are shown in Table 19.4. The minimax regret criterion now requires selecting the minimum of these maximum regret values. Using this criterion, we would choose the medium-investment decision, because the maximum opportunity loss of \$3,500,000 is lower than the maximum opportunity loss for either of the other two alternatives.

Observe that all three criteria lead to different decisions; therefore, the brothers would determine which criterion best described their decision-making philosophy and use it to help them decide on their level of investment.

The maximax, maximin, and minimax regret decision criteria are examples of nonprobabilistic decision criteria. Nonprobabilistic criteria do not take into account the probability associated with the outcomes for each alternative; they merely focus on the dollar value of the outcomes. The criticism of nonprobabilistic decision criteria is aimed at their failure to include important information about the chances of each outcome occurring. Decision analysts argue that if the payoff probabilities are known or can be assessed, a probabilistic decision criterion should be employed.

CHAPTER OUTCOME #3

Probabilistic Decision Criteria

Some decision criteria take into account the probabilities associated with each outcome. One of these is the **expected-value criterion**.

Expected-Value Criterion
A decision criterion that employs probability to select the alternative that will produce the greatest average payoff or minimum average loss.

Expected-Value Criterion The term *expected value* is often used in statistics to refer to the long-run average outcome for a given alternative. In order to determine an expected value, we must have probabilities for each possible outcome. The expected value for a discrete variable is computed as follows:

Expected Value

$$E(x) = \sum_{i=1}^{k} x_i P(x_i) \tag{19.1}$$

where:

x_i = The ith outcome of the specified alternative measured in some units, such as dollars

$P(x_i)$ = The probability of outcome x_i occurring

k = Number of potential outcomes

and:

$$\sum_{i=1}^{k} P(x_i) = 1 \tag{19.2}$$

$$0 \le P(x_i) \le 1 \tag{19.3}$$

Equation 19.1 shows that the expected value is the sum of the weighted outcomes for a specified alternative. This means that if the alternative is repeatedly selected, over the long run the average outcome will equal $E(x)$, the expected value.

TRY PROBLEM 19.10

CHAPTER OUTCOME #4

EXAMPLE 19-1 Employing the Expected-Value Criterion

Xircom, Inc. Consider the following simple decision situation, which involves Xircom, Inc., a mobile connectivity leader. Its products provide notebook PC users the ability to access their corporate networks. Recently, its stock has been trading at $36.50 a share. There has been a rumor of a merger between Xircom and one of its major competitors. The expected-value criterion can be used to determine whether to invest in Xircom using the following steps:

Step 1 **Define the decision alternatives.**
The alternatives are to invest or don't invest.

Step 2 **Define the possible outcomes (states of nature) associated with each alternative.**
If the decision is not to invest in Xircom, then the resulting payoff is zero. That is, you are in the same position as you were before making the decision. However, for the do invest alternative, two possible outcomes are thought possible:

1. The merger will occur and the stock price will increase $10 per share.
2. The merger will not occur and the stock price will drop $5 per share.

Step 3 **Assign probabilities to the possible outcomes associated with each alternative.**
For the don't-invest option, there is 1.0 probability of a zero payoff. For the invest option, analysts believe there is a 0.50 chance of the merger (and likewise a 0.50 chance of no merger).

Step 4 **Compute the expected value for each decision alternative.**
For the don't-invest option, the expected value (payoff) is $0 because there is 1.0 chance of that outcome occurring. For the buy alternative, we can let x_1 = $10 (merger occurs) and $x_2 = -\$5$ (merger fails). Then, using the analysts' probability assessments, the following probability distribution exists:

x	$P(x)$
$10	0.50
−$5	0.50
	1.00

The expected value is computed using Equation 19.1.

$$E(x) = \sum_{i=1}^{k} x_i P(x_i)$$

$$E(x) = (\$10)(0.50) + (-\$5)(0.50) = \$2.50$$

This means that over the long run you would have an expected $2.50 gain per share if you elected to purchase the stock. If you don't purchase the stock, the expected gain is $0. Thus, the *best* decision, based on expected value, is to buy the Xircom stock.

When applying the expected-value criterion, the best decision is to select the alternative with the highest average payoff or the lowest average loss. In Example 19-1, the stock purchase example, the best decision, using the expected-value criterion, is to purchase the stock, because $2.50 > $0. The advantage of the expected-value criterion is that it takes into account the information contained in the probabilities.

Expected value is the decision criterion around which the techniques of decision analysis are built and is the one emphasized throughout this chapter. The disadvantage of the expected-value criterion is that it does not take into account the decision maker's attitude toward risk. For instance, in the first case for the stock purchase example, the expected value was \$2.50. Clearly, on the basis of expected value we buy the stock, because \$2.50 > \$0. However, if we purchase stock under these same conditions, we could lose \$5. Depending on how averse we are to this outcome, we might decide not to participate after all.

19-1: Exercises

Skill Development

19-1. In decision analysis, what is the difference between a good decision and a good outcome? Do good decisions always produce the "best" outcome? Why or why not?

19-2. What is the goal of decision analysis?

19-3. Varsity Contracting has recently started negotiating to provide custodial service for a local manufacturer at several facilities in the area. The manufacturer has offered to contract for Varsity's services at the rate of \$0.10 per square foot per month. To provide nightly custodial service for the 100,000-square-foot plant, Varsity would have to hire two more workers at \$8.00 per hour. The new service would require 8 hours per night, 5 nights a week. Supplies would cost \$200 per week, and overhead would be charged at 20% of the labor cost.

Given the information presented here, what decision environment exists? Why do you think so? Would you recommend that Varsity sign this contract? Explain your reasoning?

19-4. Given the following decision table:

		States of Nature		
		S_1	S_2	S_3
Alternatives	A_1	150	80	−20
	A_2	60	40	45
	A_3	240	70	−10

a. Use the maximax criterion to determine which decision alternative to select.
b. Use the maximin criterion to determine which decision alternative to select.
c. Use the minimax regret criterion to determine which decision alternative to select.

19-5. The probabilities assessed with the states of nature in the previous exercise are

$$P(S_1) = 0.3, \quad P(S_2) = 0.2, \quad P(S_3) = 0.5$$

Using these probabilities, determine which alternative to select using the expected-value criterion.

19-6. Given the following decision table:

		States of Nature			
		S_1	S_2	S_3	S_4
Alternatives	A_1	170	45	−60	100
	A_2	30	190	175	−65
	A_3	145	−50	120	110
	A_4	−40	80	10	70

a. Use the maximax criterion to determine which decision alternative to select.
b. Use the maximin criterion to determine which decision alternative to select.
c. Use the minimax regret criterion to determine which decision alternative to select.

19-7. The probabilities assessed with the states of nature in the previous problem are

$$P(S_1) = 0.1, \quad P(S_2) = 0.2, \quad P(S_3) = 0.4, \quad P(S_4) = 0.3$$

Using these probabilities, determine which alternative to select using the expected-value criterion.

Business Applications

19-8. Larry Jacava is considering producing a novelty item for golfers that will be sold through pro shops. Larry has decided on a selling price of \$3.50 for the item. The item's variable cost of production is \$2.00 per unit, with fixed costs of \$3,750. Larry has marketed his product to local pro shops and believes the demand for the item will be either 2,000 units, 3,000 units, 4,000 units, or 5,000 units.

a. Set up the payoff table for Larry's decision.
b. Determine the number of units that Larry should produce using each of the following criteria:
   1. maximax criterion
   2. maximin criterion
   3. minimax regret criterion

19-9. Sal De Carlo is the manager for food sales for Coyote Stadium. For each home game, Sal must decide how many hot dogs to have available for sale. The number of hot dogs sold depends on the game's attendance. Sal pays \$0.75 for each hot dog and \$0.15 for each hot dog bun. Hot dogs are sold to fans during the game for \$1.75. Any leftover hot dogs are sold to the mens' dorms for $0.25 a piece. Sal estimates that demand for hot dogs for next week's game will be either 10,000, 15,000, 20,000, or 25,000.

a. Set up the payoff table for Sal's decision.
b. How many hot dogs would Sal order if he used each of the following criteria?
   1. maximax criterion
   2. maximin criterion
   3. minimax regret criterion

19-10. A real estate investor in a medium-sized western city is considering three investments: an apartment building, a strip mall, and an office building. Returns from each investment alternative depend on future population growth. The investor has developed three growth scenarios showing the revenue from each investment alternative along with their probabilities of occurrence. This information is shown in the following table:

Population Growth	Probability	Apartment	Mall	Office
Slow	0.20	−$75,000	$15,000	−$200,000
Average	0.30	10,000	30,000	50,000
High	0.50	150,000	75,000	100,000

For the given payoff matrix, what is the best decision and its associated payoff using each of the following?

a. the maximax criterion
b. the maximin criterion
c. the minimax regret criterion
d. the expected-value criterion

19-11. Cooke Collectibles produces fine porcelain miniatures representing famous people and historical events. To avoid production and scheduling problems, Cooke's policy is to make all copies of a figure in one production run. In the event that the demand for any figure exceeds the number produced, each customer's money is returned along with a coupon good for $10.00 toward the purchase of another Cooke miniature. If the company makes too many figures, the extras are sold to a discount outlet, which agrees to hold them for 6 months, for $50 each. This price is half the variable production cost of a figure.

Cooke Collectibles has recently agreed to pay $200,000 for the rights to produce a miniature representing a famous singer. The company plans to sell the figures for $250 each. The marketing department predicts that actual demand will equal one of these possible demand levels: 20,000; 40,000; 60,000; or 80,000.

a. Set up a table showing the payoffs for all combinations of production and demand.
b. Use the maximin criterion to arrive at the appropriate decision and the associated payoff. Contrast this decision with one made using the maximax criterion instead.

19-12. Referring to the previous exercise, suppose the marketing manager at Cooke Collectibles has analyzed the possible demand levels and subjectively assessed the following probabilities for them:

Demand Level	Probability
20,000	0.10
40,000	0.30
60,000	0.40
80,000	0.20
	1.00

Use the expected-value criterion to arrive at the best decision for Cooke and the associated expected value.

19-13. The Special Occasions Company, a nationwide distributor of flowers and greeting cards, has just contracted with Global Floral to purchase up to 500,000 dozen red and yellow roses for sale in the week before Valentine's Day. Special Occasions supplies flower shops and other retail outlets from regional distribution centers throughout the country. The problem now facing the company is how many dozen roses to buy. If the company doesn't buy enough, it loses potential business; if it buys more than are demanded, it loses the costs of purchasing and shipping these unsold roses. Any unsold roses are given to local hospitals and retirement homes or are disposed of at the area landfill.

The contract calls for a basic payment of $150,000 plus $5 per each dozen roses bought by Special Occasions. The company's accounting department has determined that the cost of shipping the roses from Global Floral's greenhouses averages $1.50 per dozen. The marketing department has estimated the demand (in dozens) for roses, and its probability distribution, as follows:

Demand Level	Probability
100,000	0.10
150,000	0.40
200,000	0.20
225,000	0.20
250,000	0.10
	1.00

Assuming the roses sell for an average of $18 per dozen, set up the payoff table and use the expected-value criterion to find how many dozen roses should be purchased for the next Valentine's Day sales and the associated expected profit.

Exercises 19-14, 19-15, and 19-16 refer to Baker Enterprises, a produce wholesaler that supplies fruits and vegetables to local grocery stores and restaurants, which has just received notice that a frost in Florida will have a serious impact on this winter's orange harvest. If Baker's buyer waits until the time he normally buys Florida oranges, the price could be very high. Consequently, Sara Baker, the owner, has decided to enter into a contract now. The Florida supplier will guarantee any quantity of oranges this winter, but only on the following terms:

Fixed finder's fee	$10,000
Fewer than 1,001 boxes	$3.00 per box
1,001 to 5,000 boxes	$2.80 per box
More than 5,000 boxes	$2.50 per box

The sales manager has identified the following possible demand levels for boxes of oranges this winter: 500, 1,000, 2,000, 4,000, and 7,000. The expected selling price will be $9.00 per box, and unsold boxes will be given away.

19-14. Set up a payoff table for this decision problem and use the minimax regret decision criterion to determine how many boxes of oranges Baker Enterprises should buy and the accompanying profit.

19-15. The managers at Baker Enterprises have discussed the situation and, on the basis of their past experience with orange sales, have assessed the following probabilities for each possible demand level:

Demand	Probability
500	0.15
1,000	0.20
2,000	0.20
4,000	0.30
7,000	0.15
	1.00

Incorporate these probabilities into your analysis and determine the "best decision" for Baker Enterprises, as well as the expected profit for this decision, using the expected-value criterion.

19-16. Sara Baker has found an alternative supplier of Florida oranges. The new supplier will not charge a finder's fee but will charge $4.50 per box regardless of the quantity purchased. If Sara Baker decides to buy from the new supplier, how many boxes of oranges should she buy in order to maximize expected profit? Which supplier should she choose? Explain.

19-17. Duckland Enterprises is considering bidding on one or all of the first five franchises offered by a popular Japanese fast-food operation. Each franchise requires a yearly $100,000 payment and the construction of a building at an average cost of $250,000. Duckland plans to keep the franchises for a year and, if the businesses are successful, it should be able to sell them for $600,000 each, including the buildings. If the operations are not successful, Duckland will close them down and sell the buildings for $150,000.

a. Use the maximax decision criterion to determine how many franchises Duckland should purchase and the associated profit.

b. How many franchises should Duckland purchase if the maximin decision criterion is used? Determine the accompanying profit for this decision criterion as well.

c. Suppose Duckland Enterprises has three options for constructing the buildings for its franchises. One option is to construct the buildings as originally planned, at a cost of $250,000 each. A second option is to build smaller facilities in established malls, with building expenses totaling $150,000 each. If the mall operations are not successful, Duckland can recover $100,000 of the $150,000 building cost; and if they are successful, they can be sold for $500,000 each. A third option is to construct larger buildings, at a cost of $400,000 each. If successful, these operations can be sold for $1,000,000 each; and if they are not successful, the buildings can be sold for $200,000 each. Construct a payoff table describing these new alternatives for Duckland Enterprises.

d. Determine how many franchises Duckland should acquire under each building-cost option described in part c, and determine the associated profit. Provide separate answers using the maximin and maximax decision criteria.

e. Referring to part c, suppose Duckland Enterprises assesses the following probability distributions for the number of successful franchises at each building-cost level:

$150,000		$250,000		$400,000	
Number	***P*(Success)**	**Number**	***P*(Success)**	**Number**	***P*(Success)**
0	0.05	0	0.06	0	0.09
1	0.10	1	0.10	1	0.15
2	0.15	2	0.20	2	0.25
3	0.25	3	0.40	3	0.40
4	0.30	4	0.12	4	0.07
5	0.15	5	0.12	5	0.04

For each building alternative, use the expected-payoff criterion to determine the optimal number of franchises to purchase and the expected payoff. Then determine which building-cost level Duckland should use for its franchises.

19.2 Cost of Uncertainty

The advantage of making decisions in a certain environment is that the best decision always yields the best outcome. In an uncertain environment, the best decision might not result in the best outcome. Thus, there is a cost of uncertainty associated with not knowing in advance which outcome will occur. An example will show what we mean.

EXAMPLE 19-2 Computing the Cost of Uncertainty

TRY PROBLEMS 19.23

CHAPTER OUTCOME #5

Haroldson's In the United States, more money is now being spent on take-out and restaurant food than is spent buying groceries. Many grocery chains, in an effort to keep up with this trend, have added extensive deli and take-out sections. Haroldson's is a regional chain that has joined the movement. A popular packaged meal is made up of broiled chicken, potato salad, and a green salad. However, because of several television news specials about potentially spoiled food, Haroldson's has a company policy of giving all unsold food to a local homeless shelter at the end of each day. Although the company doesn't mind giving the food away, it would rather sell all the meals it prepares. Therefore, the question that deli managers face each day is how many meals to make. To answer this question and to compute the cost of uncertainty in this situation, you can use the following steps:

Step 1 **Determine the possible outcomes (states of nature).**
A deli manager feels that on any weekday, the minimum demand for the broiled-chicken meal will be 50 and the maximum demand will be 90. To simplify the analysis, the following five demand levels are considered possible:

Demand = x = 50	60	70	80	90

Step 2 **Assess the probability for each possible outcome.**
Based on historical data, the probabilities for each demand level are

Demand = x =	50	60	70	80	90
$P(x)$ =	0.05	0.10	0.20	0.40	0.25

Step 3 **Assign appropriate revenue and cost values and establish the payoff function.**
The fixed cost of setting up to cook the meals is \$120, variable costs amount to \$1.50 per meal, and the selling price is \$3.70 each. With this information, we find the payoffs associated with different production levels by using the following equation:

$$\text{Payoff} = \$3.70(s) - \$120 - \$1.50(p)$$

where:

s = number of units sold
p = number of units produced

Step 4 **Construct the payoff table.**
The payoff when production is 50 and demand is 50 is

$$\text{Payoff} = \$3.70(50) - \$120 - \$1.50(50) = -\$10.00$$

Likewise, if 70 meals are prepared and 90 are demanded, the payoff is

$$\text{Payoff} = \$3.70(70) - \$120 - \$1.50(70) = \$34.00$$

(Notice that even though demand is 90, sales are limited to 70 because only 70 were produced.) The payoffs associated with all combinations of production and demand are displayed in the following payoff table. The demand levels are labeled "states of nature," because demand is outside the control of the decision maker.

Payoff Table

	Demand (States of Nature)				
Production	50	60	70	80	90
50	−$10	−$10	−$10	−$10	−$10
60	−25	12	12	12	12
70	−40	−3	34	34	34
80	−55	−18	19	56	56
90	−70	−33	4	41	78

Step 5 **Add the probabilities to the payoff table and compute the expected value for each production decision using Equation 19.1.**
The expected values are computed by summing the payoffs times the probabilities. For example, the expected payoff for a production level of 80 meals is

$$\begin{aligned} E(\text{payoff}) &= -\$55(0.05) + -\$18(0.10) + \$19(0.20) \\ &\quad + \$56(0.40) + \$56(0.25) \\ &= \$35.65 \end{aligned}$$

Therefore, in the long run, the deli manager can expect to make $35.65 if she prepares 80 meals of broiled chicken and potato salad. The other expected values are computed in a similar manner.

Haroldson's Expected Values

	Demand (States of Nature)					
Production	50 $p = 0.05$	60 $p = 0.1$	70 $p = 0.2$	80 $p = 0.4$	90 $p = 0.25$	E(Payoff)
50	−$10	−$10	−$10	−$10	−$10	−$10.00
60	−25	12	12	12	12	10.15
70	−40	−3	34	34	34	26.60
80	−55	−18	19	56	56	35.65
90	−70	−33	4	41	78	29.90

Step 6 **Determine the best decision using the expected-value decision criterion.**
From Step 5 we see that if the decision criterion of highest expected payoff is used, the best decision is to prepare 80 meals. This production level has a higher expected payoff than any other alternative at $35.65. However, on any single day, the actual payoff from this level could be either −$55, −$18, $19, or $56. This means that for any single situation, the best decision might not give the best outcome. Thus, there is a cost of being uncertain about which demand level will occur.

Step 7 **Compute the expected value under certainty.**
If the deli manager could obtain perfect information about the demand level, her decision environment would change to one of certainty. If she

knew in advance how many meals would be demanded, she could select the production level that would maximize the payoff in each case. For example, if she knew the demand was going to be 70, she would decide to prepare 70 meals, for a profit of $34.00. If she knew demand would be 90, she would decide to prepare 90, for a profit of $78.00.

To compute the *expected value under certainty (EVUC)*, we first assume we know what the demand will be for each day. Therefore, we are able to achieve the optimal decision each time. To determine our overall expected profit, we multiply the probability of each demand level times the payoff associated with the *best* decision *given* that demand level occurs. Therefore, if the deli manager had perfect information (certainty) about what the demand was going to be for each day, her expected payoff would be computed as follows:

$$\begin{aligned} EVUC &= -\$10(0.05) + \$12(0.10) + \$34(0.20) \\ &\quad + \$56(0.40) + \$78(0.25) \\ &= \$49.40 \end{aligned}$$

With perfect information, the deli would make, on average, a profit of $49.40 per day.

Step 8 Compute the cost of uncertainty.

We determined in Step 6 that the expected payoff for the best decision under uncertainty was $35.65. The expected cost of uncertainty is the difference between the expected payoff given perfect information and the expected payoff under uncertainty. This is

$$\text{Expected Cost of Uncertainty} = \$49.40 - \$35.65 = \$13.75$$

The expected cost of not having perfect information for this decision situation is $13.75.

Another term for the cost of uncertainty is the *expected value of perfect information (EVPI)*. For Example 19-2, the EVPI is $13.75. This is the most the manager would be willing to pay for perfect information about the meal demand on any weekday. Any information that is not perfect would be worth less than $13.75 per day.

19-2: Exercises

Skill Development

19-18. Consider the following payoff table, in which the probabilities associated with each state of nature are in parentheses:

		States of Nature			
		$S_1(0.2)$	$S_2(0.1)$	$S_3(0.4)$	$S_4(0.3)$
Alternatives	A_1	170	45	−60	100
	A_2	30	190	175	−65
	A_3	145	−50	120	110
	A_4	−40	80	10	70

a. Convert the payoff table to an opportunity-loss table.

b. Find the expected value of perfect information for these alternatives.

19-19. Consider the following payoff table, in which the probabilities associated with each state of nature are shown:

		States of Nature		
		S_1	S_2	S_3
	Probabilities	0.5	0.2	0.3
Alternatives	A_1	145	55	80
	A_2	130	65	100
	A_3	110	80	120

a. Convert the payoff table to an opportunity-loss table.

b. Find the expected value of perfect information for these alternatives.

Business Applications

19-20. Refer to Exercise 19-9 in Section 19.1 concerning the number of hot dogs that Sal De Carlo should order for next week's football game. Suppose that Sal has assigned the probabilities shown here for the different demand levels:

Demand	Probability
10,000	0.20
15,000	0.25
20,000	0.30
25,000	0.25

a. Set up the payoff table for Sal's decision concerning the number of hot dogs to order.
b. What are the expected values for each decision that Sal can make?
c. How much would Sal be willing to pay for perfect information about the number of hot dogs that will be demanded during next week's game?

19-21. Refer to the Cooke Collectibles exercise (Exercise 19-11) in Section 19.1. How much would Cooke be willing to pay for perfect information about the number of miniatures representing a famous singer that it should produce?

19-22. Refer to the Special Occasions Company exercise (Exercise 19-13) in Section 19.1. How much should the company be willing to pay for perfect information in order to determine how many dozen roses it should order for the next Valentine's Day sales?

19-23. Refer to the Baker Enterprises exercise (Exercises 19-14 to 19-16) in Section 19.1. What is the maximum amount that Baker should pay for perfect information to help it determine how many boxes of oranges to order?

CHAPTER OUTCOME #6

19.3 Decision-Tree Analysis

Decision Tree
A diagram that illustrates the correct ordering of actions and events in a decision analysis problem. Each act or event is represented by a branch on the decision tree.

When decision analysis is applied to a real business problem, the process can become quite complex. The decision maker must identify the outcomes for each decision alternative, assess probabilities associated with each outcome, assign cash flows in the form of payoffs or opportunity costs, and somehow keep the sequence of decisions and outcomes in the proper order. Decision-tree analysis is very helpful in dealing with these complex decisions in an orderly manner. A **decision tree** provides a "road map" of the decision problem. In this section, we illustrate the steps involved in using decision trees to help with the decision process.

EXAMPLE 19-3 Decision-Tree Analysis

TRY PROBLEM 19.24

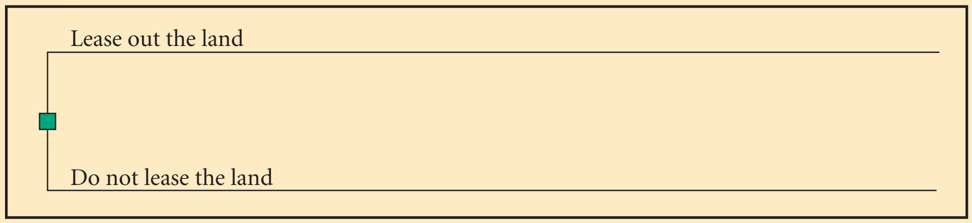
Bighorn Oil Company Bighorn Oil Company has leased the drilling rights on a large parcel of land in Wyoming that may or may not contain an oil reserve. A competitor has offered to lease the land for \$200,000 cash in return for drilling rights and all rights to any oil that might be found. The offer will expire in 3 days. If Bighorn does not take the deal, it will be faced with the decision of whether to drill for oil on its own. Drilling costs are projected to be \$400,000. The company feels that there are four possible outcomes from drilling:

1. dry hole (no oil or natural gas)
2. natural gas
3. natural gas and some oil
4. oil only

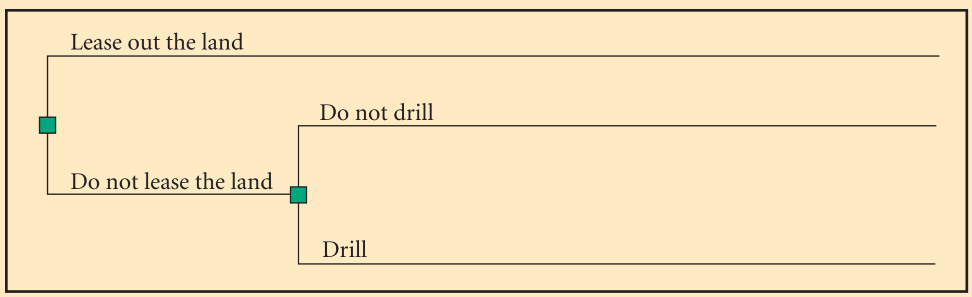
If drilling yields a dry hole, the land will be basically worthless, because it is located in the badlands of Wyoming. If natural gas is discovered, Bighorn will recover only its drilling costs. If natural gas and some oil is discovered, revenue is projected to be $800,000. Finally, if only oil is discovered, revenues will be $1,600,000.

Decision-tree analysis can be used to help make the decision using the following steps:

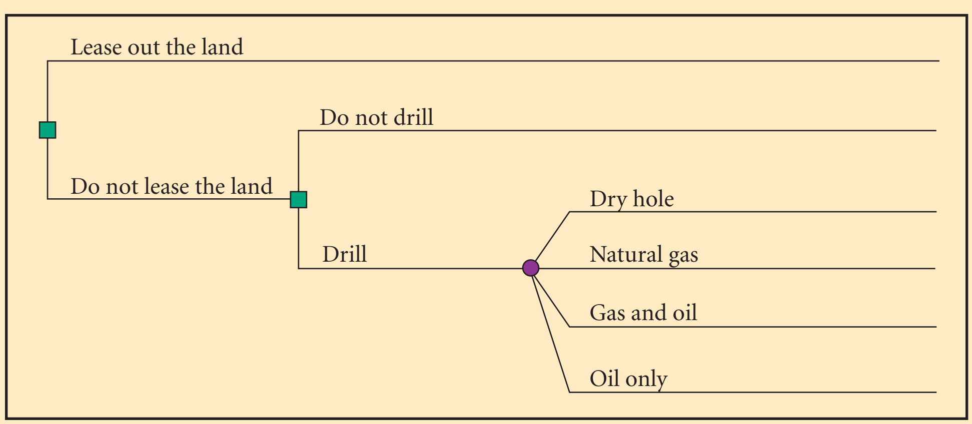
Step 1 **Grow the decision tree.**
The decision tree is developed by organizing the decisions and events in chronological order. In this example, the initial decision to be made is whether to accept the lease. The tree is started as



If the land is leased, no further decisions are required. However, if the land is not leased, Bighorn faces the decision of whether to drill on the property. The tree then grows to



Now, if Bighorn decides to drill, there are four possible events that could occur. These are shown on the decision tree.

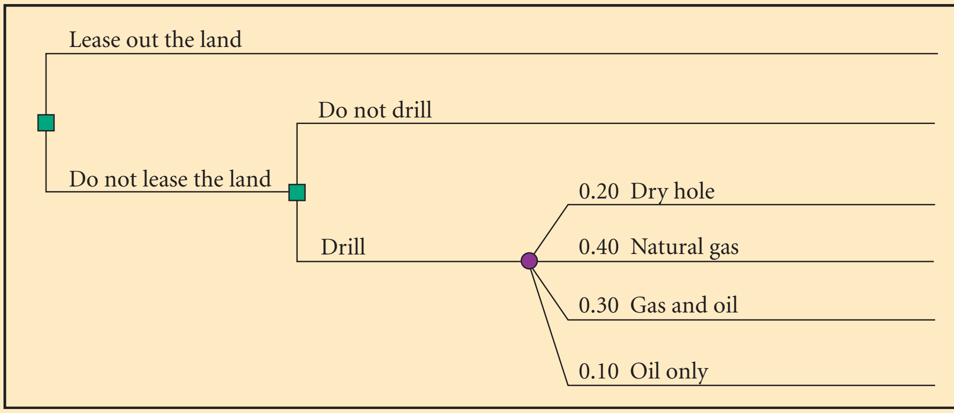


When finished, the decision tree should show all the decisions and events.

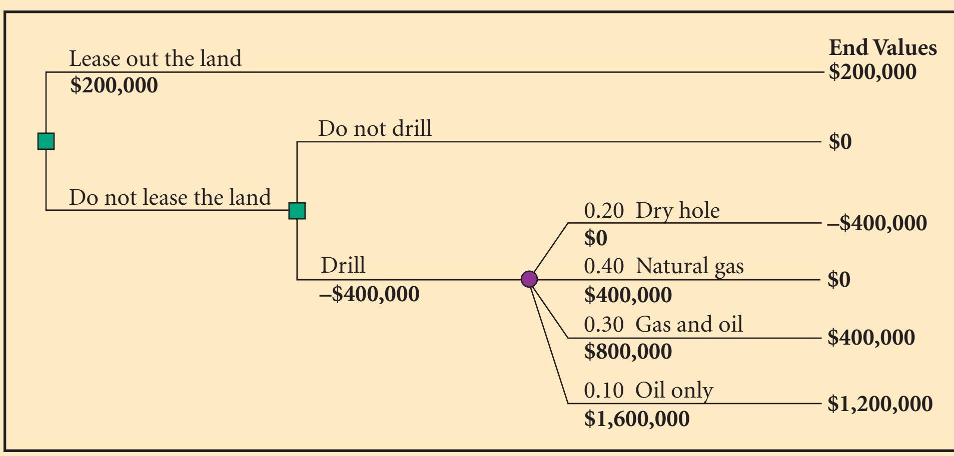
Step 2 **Assign probabilities to the event outcomes on the tree.**
In this example, the only event deals with the production result if Bighorn decides to drill. The company has subjectively assessed the probability of each of the four possible outcomes as follows:

Outcome	Probability
Dry hole	0.20
Natural gas	0.40
Gas and oil	0.30
Oil only	0.10

The revised decision tree reflects these probabilities and becomes



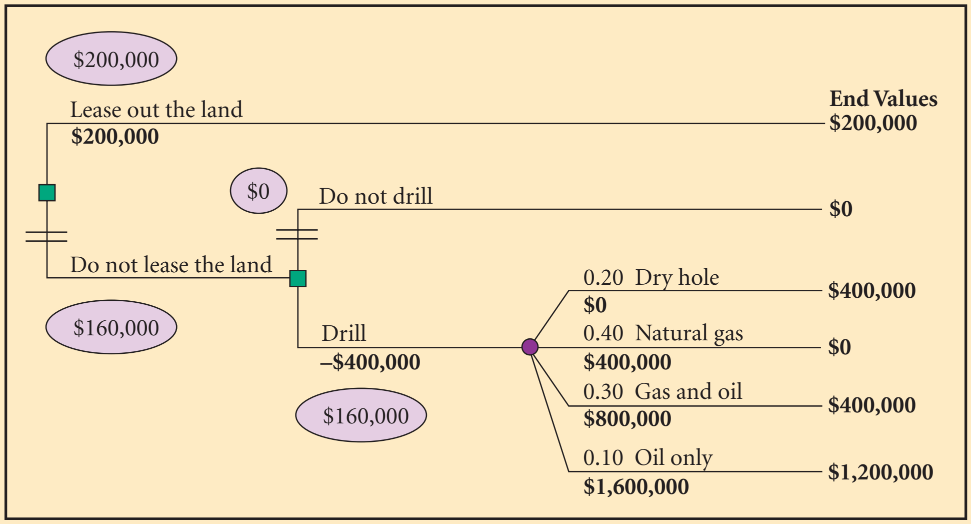
Step 3 **Assign the cash flows to the tree.**
At each branch of the tree at which a revenue or a cost occurs, show the dollar value. These revenues and costs are then totaled across the tree, and the end values for each branch are determined. These cash flows are placed on the tree as follows:



Step 4 **Fold back the decision tree and compute the expected values for each decision.**
We need to compute the expected value for each decision alternative. This is done starting from the right side of the tree and working back to the left. We first determine the expected value for the *Drill* branch as follows:

$$\begin{aligned} E[\text{Drill}] &= -\$400{,}000(0.20) + \$0(0.40) + \$400{,}000(0.30) \\ &\quad + \$1{,}200{,}000(0.10) \\ &= \$160{,}000 \end{aligned}$$

As we fold back the tree, we block all decision alternatives that do not have the highest expected value. This is shown in the decision tree as follows:



Note that we always select the decision with the highest expected payoff. In this example, the *best decision* is to lease the land and accept the $200,000 payment because it exceeds the $160,000 expected value of the not-lease option.

The value of decision-tree analysis is that a tree helps you to visually structure the decision problem and to systematically analyze the decision alternatives. Decision-tree analysis also provides a way for you to take into account future decisions when making the most current decision. The Bighorn example was a very simple one that could have easily been handled without a decision tree. The following application is a little more complicated, and you should see the advantage of using decision-tree analysis.

Harris Publishing Company

Business Application

Consider the decision facing the Harris Publishing Company, which recently received a manuscript written by a former government official about the private life of a very influential member of the United States government. The author will grant Harris full rights to the book for a guaranteed up-front payment of $400,000 plus a per copy royalty if the book is published. The basic question facing Harris's management is whether to sign the contract with this author or risk losing the book to another publisher. Even if it signs, Harris will publish the book only if the manuscript receives a favorable review from the editorial board. However, several uncertainties make this decision difficult. The executive editor, who is the person ultimately responsible for making the decision, has outlined the following items for consideration:

1. There is an 80% (0.80) chance that the content of the book is accurate. If the content is accurate, the author will be paid $2.00 per copy for each hardcover book sold and $0.80 per copy for each paperback. No royalties will be paid if the manuscript is not accurate.
2. If the content is not accurate, there is a 0.90 chance that a libel suit will be filed; and if so, experience indicates the publisher will settle out of court for $1,800,000.
3. For hardcover publication, the following demand distribution has been assessed:

Demand	Probability
100,000 copies	0.40
1,000,000 copies	0.60

4. The fixed production costs for the hardcover book will be $700,000 before any copies are printed, and the cost of printing and binding is $16.00 per copy. The number of copies to be printed can match any projected demand. The wholesale selling price of the hardcover book will be $24.00.
5. For paperback publication, the following demand distribution has been assessed:

Demand	Probability
50,000 copies	0.30
1,500,000 copies	0.70

6. The fixed costs for paperback publication are $400,000, the printing and binding costs are $2.00 per copy, and the wholesale selling price is $8.00 each.
7. The accuracy of the book's content will be known only after the book has been published and sold.
8. The editor has assessed the probability that the manuscript will get a favorable review from the editorial board as 0.80.

The decision in this case is complicated by the many uncertainties involved. In situations such as these, a decision tree can be used to provide a framework to help make the decision. The following steps are used to develop and apply a decision tree to a decision problem such as the one the Harris Publishing Company is facing.

Step 1 Growing the Tree

The decision tree is developed by starting with the initial decision facing the publisher: Sign the contract or don't sign the contract. Figure 19.1 shows the beginnings of the decision tree. The box represents a *decision fork*, the point at which a decision must be made.

If the publisher does not sign the contract, the issue is settled. There are no further branches on that side of the tree. However, if the contract is signed, other branches are needed. Keep in mind that the decision tree is a model of the decision in which alternatives (decisions) are followed by the outcomes (events) that they influence. Usually, but not always, the ordering of alternatives and outcomes follows a chronological sequence. Thus, if the contract is signed, the next step is the review by the editorial board. The outcome of this review is considered an event and is not within control of the company, because it is determined by how well the book is written. A small circle is used to designate an event fork on the decision tree, as is shown in Figure 19.2.

FIGURE 19.1

Harris Publishing Decision Tree: Phase 1

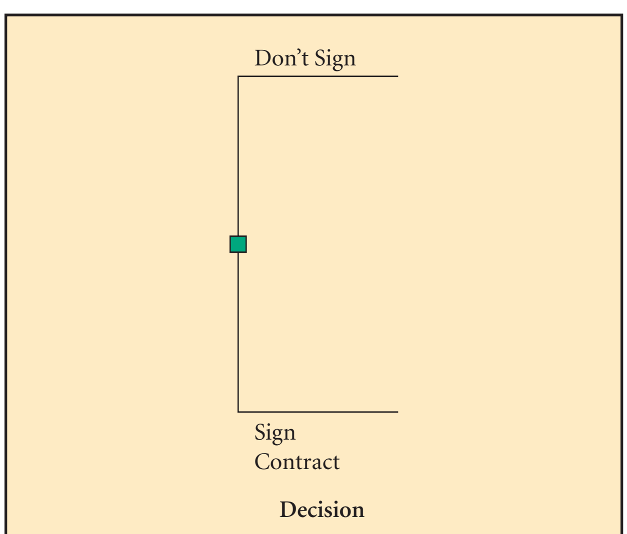


FIGURE 19.2

Harris Publishing Decision Tree: Phase 2

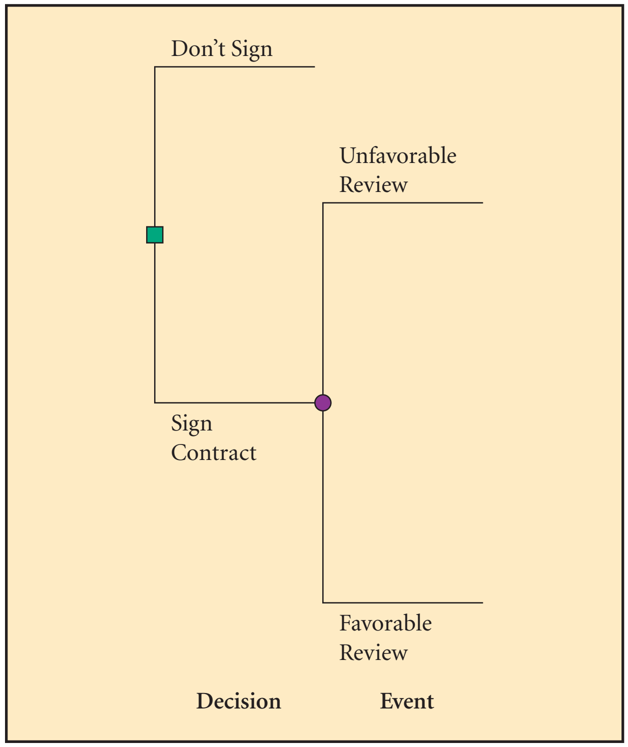


FIGURE 19.3

Harris Publishing Decision Tree: Phase 3

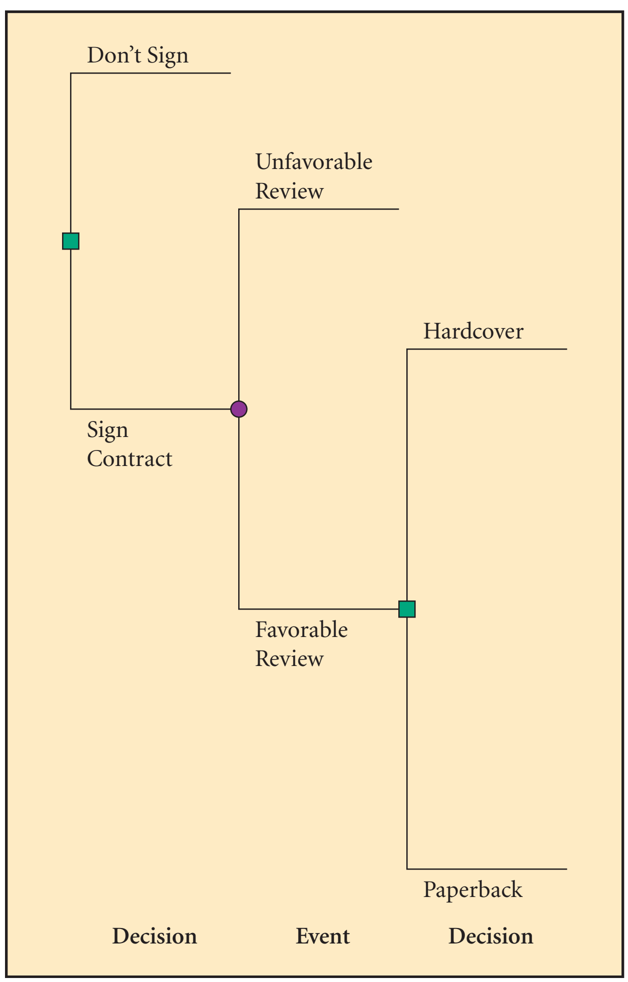
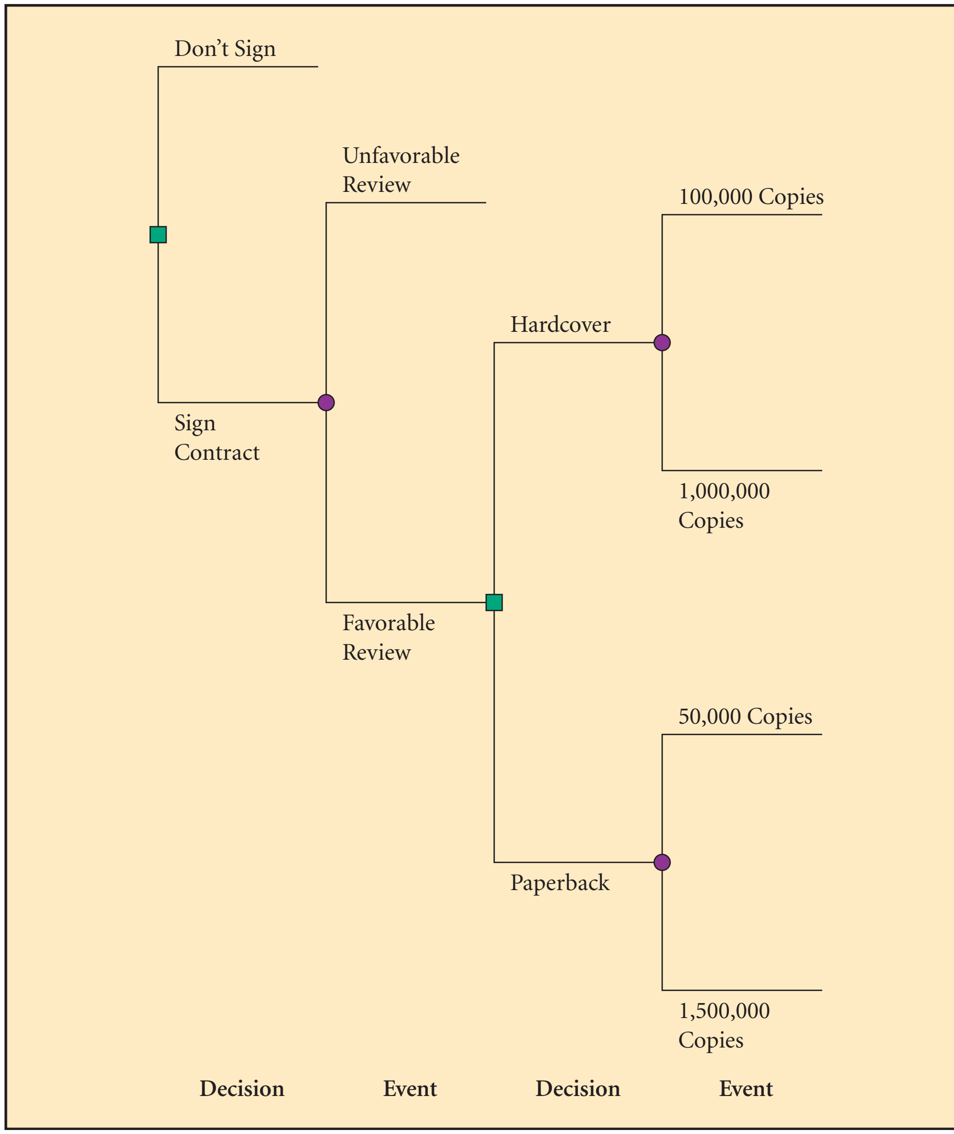


FIGURE 19.4

Harris Publishing Decision Tree: Phase 4



If the editorial review is unfavorable, the book will not be published. If the manuscript review is favorable, the book will be published. Then the company must decide between hardcover or paperback books. This decision fork is shown in Figure 19.3.

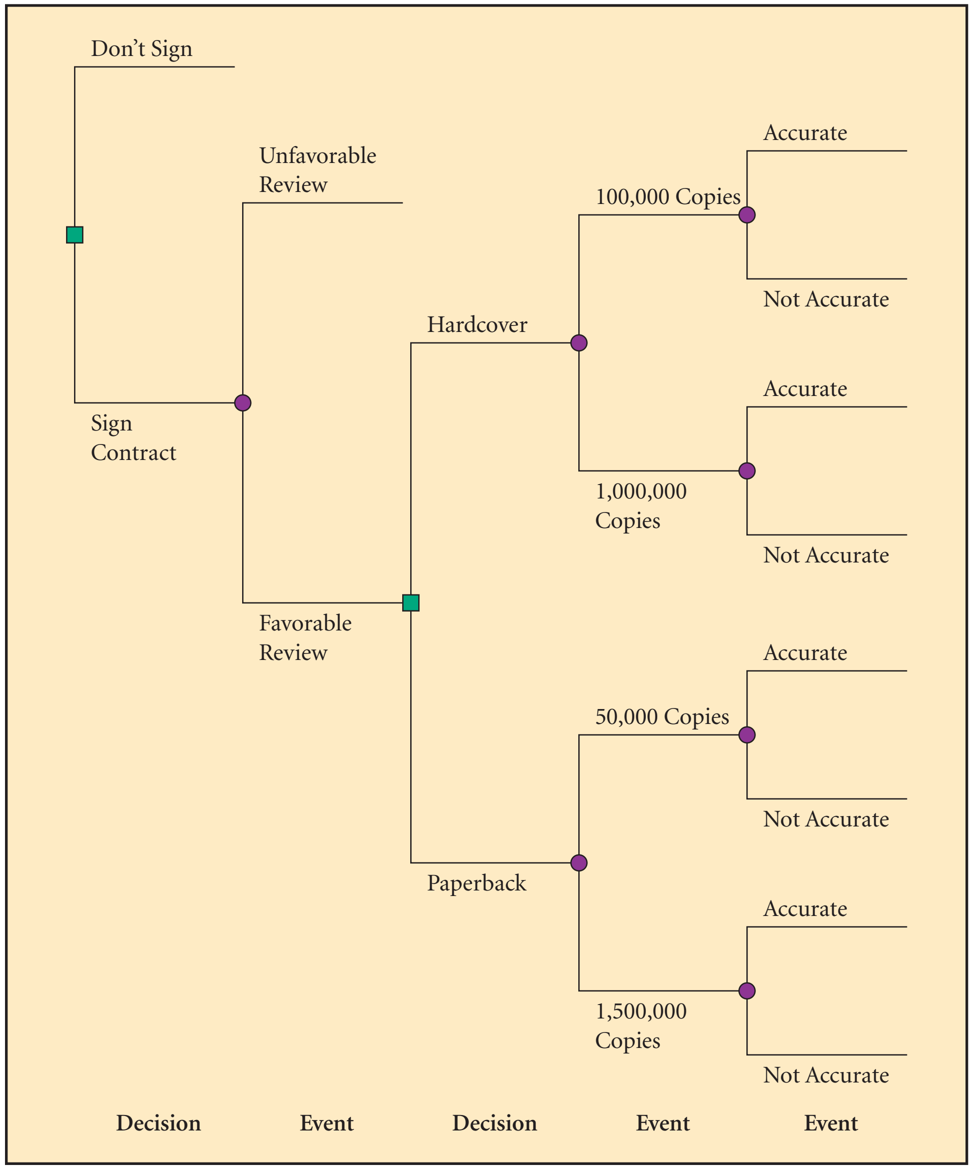
Following the hardcover/paperback decision, the book will go on sale and the true demand will be known. (Recall that we assumed production can be set to match demand.) The level of demand is an event and is not controlled by the company. Figure 19.4 shows the event forks and branches associated with demand.

After the book goes on sale, the company will find out whether the content is accurate. This is an event beyond the decision maker's control. Figure 19.5 shows these event branches. As you can see, the tree is growing.

Figure 19.6 shows the final set of branches, which relate to the possibility of a libel suit. If we have correctly described the decision problem, this tree is a model of the decision facing the Harris Publishing Company. After reaching the point at which you think the tree is complete, conferring with someone who has not been involved in developing the tree can be helpful. A fresh perspective is often useful in finding oversights and inconsistencies in a

FIGURE 19.5

Harris Publishing Decision Tree: Phase 5



decision tree. *The decision tree should reflect the decision problem as accurately as possible before any further analysis is performed using the tree.*

Step 2 Assigning the Probabilities

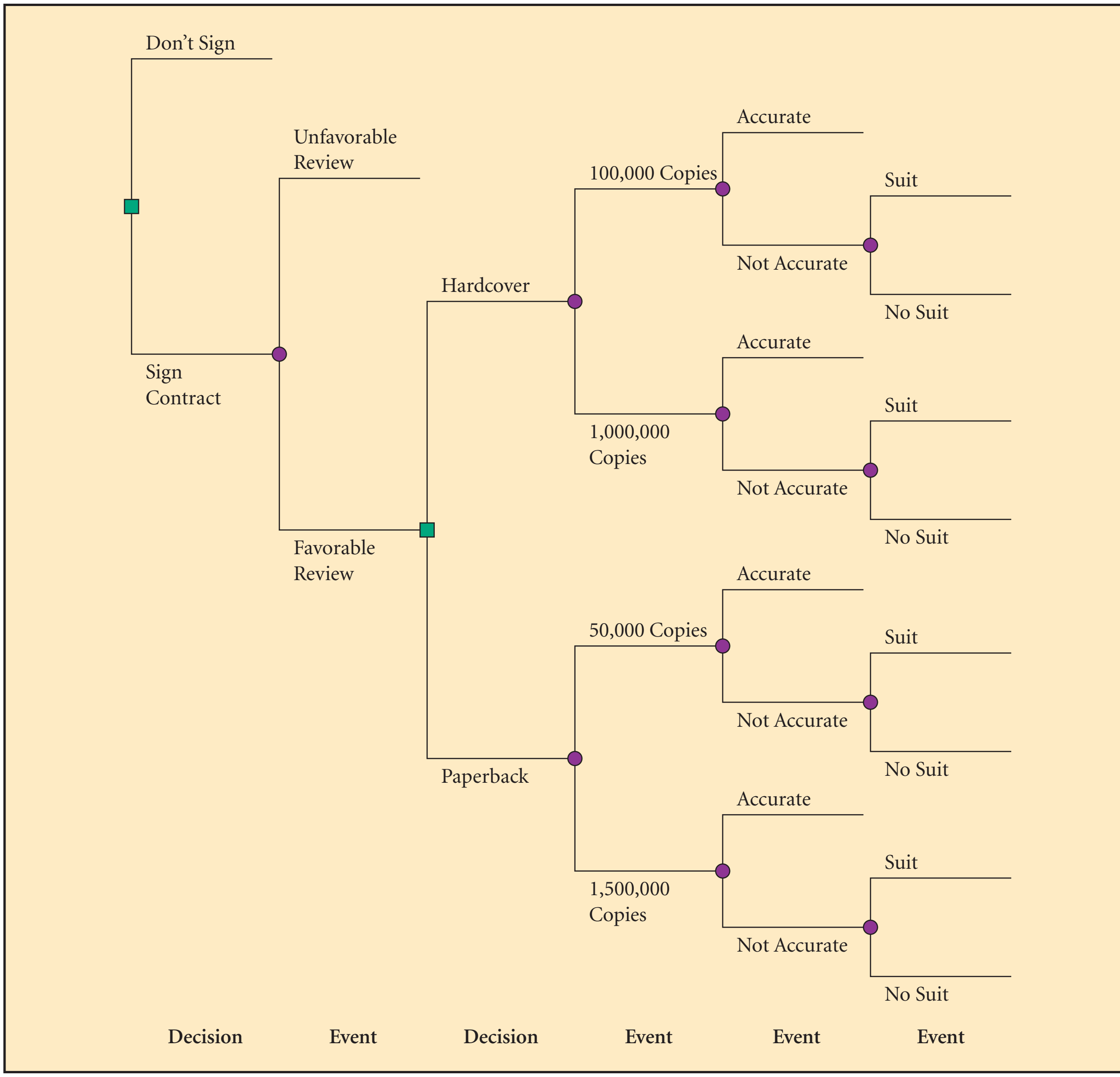
The decision tree contains a number of *event forks*, represented by small circles. The branches leaving these event forks represent possible outcomes from an uncertain event. To make full use of decision-tree analysis, probabilities must be assigned to each of these event branches. These probabilities can come from classical assessment, relative frequency of occurrence or, most likely, subjective assessment.

In the Harris Publishing Company example, the probabilities were subjective assessments by the executive editor, based on her experience and the available information. We can summarize these as follows:

1. The probability that a manuscript review will be favorable is 0.80; unfavorable, 0.20.
2. If a hardcover edition is printed, there is a 0.40 chance that demand will be 100,000 copies and a 0.60 chance that demand will be 1 million copies.

FIGURE 19.6

Harris Publishing Decision Tree: Phase 6, Final Tree



3. If a paperback edition is printed, there is a 0.30 chance that 50,000 copies will be sold and a 0.70 chance that 1.5 million copies will be sold.
4. There is an 0.80 chance that the content of the book will prove accurate.
5. There is a 0.90 chance the publisher will be sued for libel if the book turns out to be inaccurate.

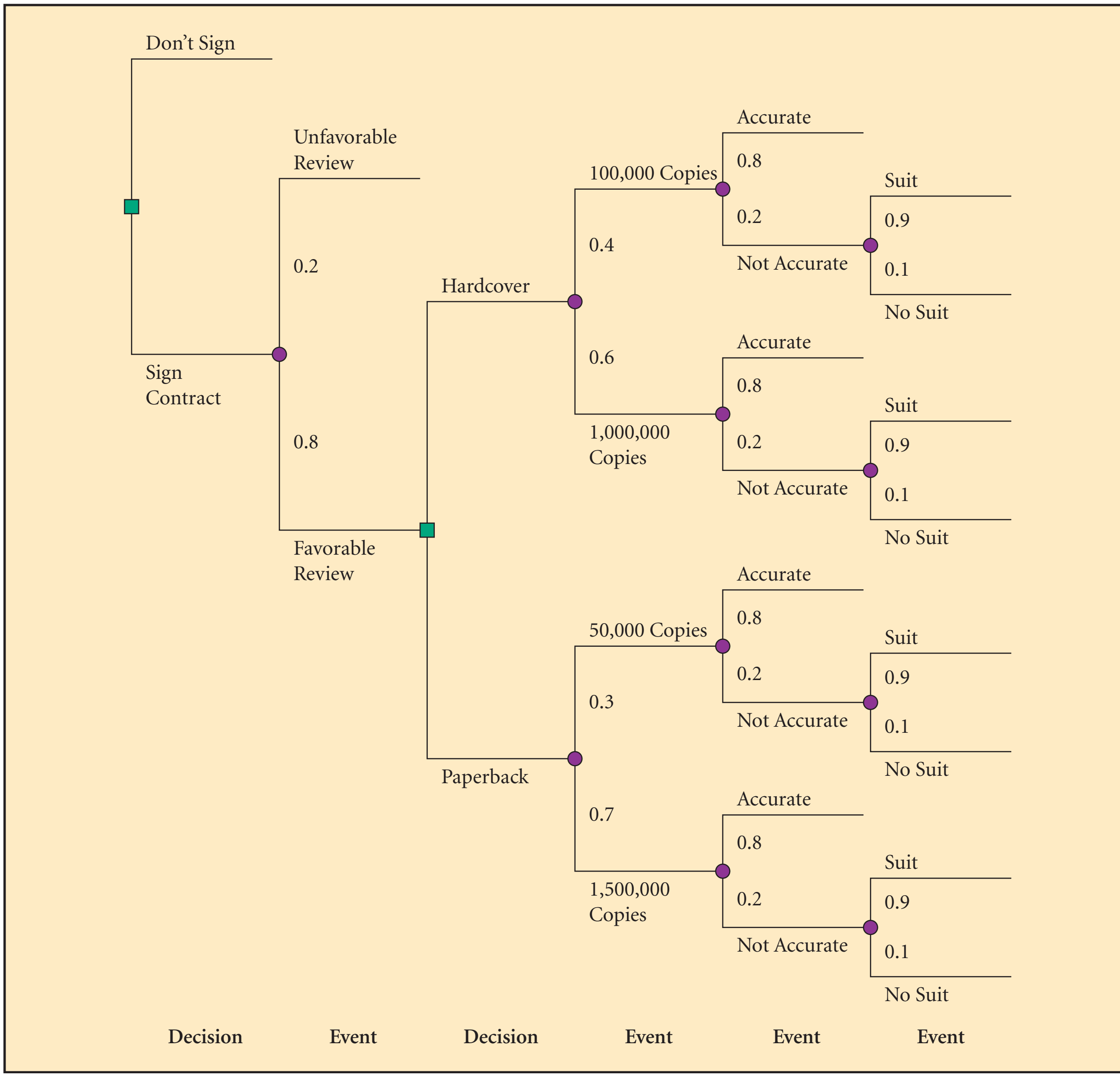
Figure 19.7 shows the decision tree with the probabilities assigned. Remember, probabilities must be assigned to every event branch. The sum of the probabilities for each event fork must be 1.

Step 3 Assigning the Cash Flows

Once probabilities have been assigned to each event, the next step is to assign the cash flows. A *cash flow* is defined here as any dollar change in the decision maker's asset position. For instance, any income or expense that is expressed in dollar terms is considered a cash flow. (In some applications, the "cash flows" might be expressed in something other than dollars,

FIGURE 19.7

Harris Publishing Co.—Assigning Probabilities

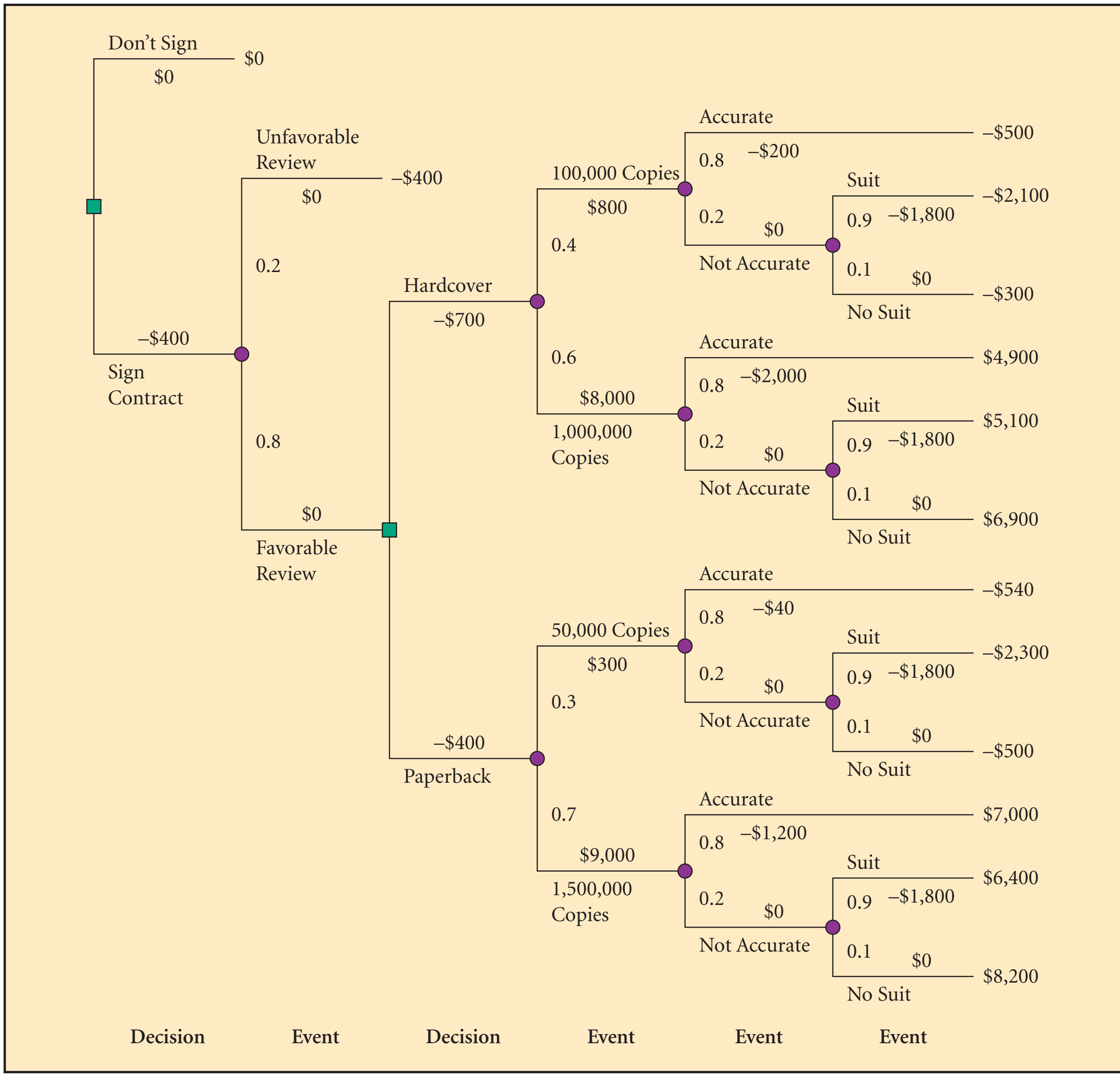


but in this text we will limit our definition of cash flows to dollars.) The cash flows are displayed on the tree branches indicating the time at which they will occur. Unlike probabilities, which are assigned only to events, cash flows can occur for both decisions and events. For Harris Publishing Company, the first cash flow will occur when the author signs the contract. This will be an expense of $400,000. Figure 19.8 shows this as −$400 (amounts are in thousands) directly above the *Sign Contract* branch. The *Don't Sign Contract* branch has a cash flow of $0, indicating that if this decision is made, there will be no change in the company's asset position.

The editorial review is done by salaried staff members. Thus, we can treat this cost as part of administrative overhead and not assign any cash flows to the review branches in Figure 19.8. When the decision to publish hardcover or paperback books is made, a fixed expense occurs. The expense is $700,000 for hardcover and $400,000 for paperback. These cash flows are displayed in Figure 19.8.

FIGURE 19.8

Harris Publishing Co.—Assigning Cash Flows ($ × 1,000)



Next, we assign the cash flows associated with the demand levels for hardcover and paperback. For example, if the hardcover decision is selected and demand is 100,000 copies, the following cash flow will occur:

Revenue 100,000 at $24.00 each	=	$2,400,000
Expenses 100,000 at $16.00 each	=	−1,600,000
Net cash flow	=	$ 800,000

This $800,000 cash flow is shown in Figure 19.8. You may be wondering what happened to the author's royalties. These are to be paid only when the book's accuracy has been verified. For purposes of this decision, this is the same as paying the author when the books are sold and having him return the money if the book proves to be inaccurate.

If the hardcover book sells 1,000,000 copies, the cash flow will be

Revenue 1,000,000 at $24.00 each	=	$24,000,000
Expenses 1,000,000 at $16.00 each	=	−16,000,000
Net cash flow	=	$ 8,000,000

Likewise, if the paperback option is selected, the cash flow associated with 50,000 copies will be

Revenue 50,000 at $8.00 each	=	$400,000
Expenses 50,000 at $2.00 each	=	−100,000
Net cash flow	=	$300,000

The total cash flow for 1,500,00 copies will be

Revenue 1,500,000 at $8.00 each	=	$12,000,000
Expenses 1,500,000 at $2.00 each	=	−3,000,000
Net cash flow	=	$ 9,000,000

These cash flows are shown in Figure 19.8.

Now, if the book turns out to be accurate, the publisher must pay the author royalties based on the number of books sold. For a hardcover book, the royalty rate is $2.00 per copy; for a paperback, it is $0.80 per copy. For example, if the paperback sells 1.5 million copies, the author must be paid $1,200,000. The royalty costs are shown under the branches labeled *Accurate* in Figure 19.8. If the book proves to be inaccurate, the author gets no royalties; so $0 cash flow is shown on the *Not Accurate* branch.

Finally, if the book is not accurate, the publisher might be sued for libel. In that case, the company's lawyer has told Harris that the government official who was libeled will be paid $1,800,000 to settle (Figure 19.8). The editor agrees this amount is more than adequate to stop the suit. Because there are no other cash flows to be considered in this decision, the last step is to accumulate the cash flows from left to right and put the net cash flow for each branch to the right of the each branch in Figure 19.8. These are called the end values.

Step 4 **Folding Back the Tree**

Figure 19.9 shows the completed decision tree for Harris Publishing Company. (We have removed the intermediate values from the branches and have expressed the end values in thousands to make the numbers easier to work with.) This sets the stage for the process *of folding back the decision tree*, a process employed whenever the decision criterion being used is the expected-value criterion. Recall that Harris Publishing plans to select the alternative with the highest expected payoff.

Remember that the decision tree is a diagram of the sequence of decisions and events. To fold back the decision tree, we begin with the end values at the right of the tree and work our way back to the initial decision at the far left. To do this, we must determine the expected value of each decision branch. (Please refer to Figure 19.10 as we discuss the fold-back steps.)

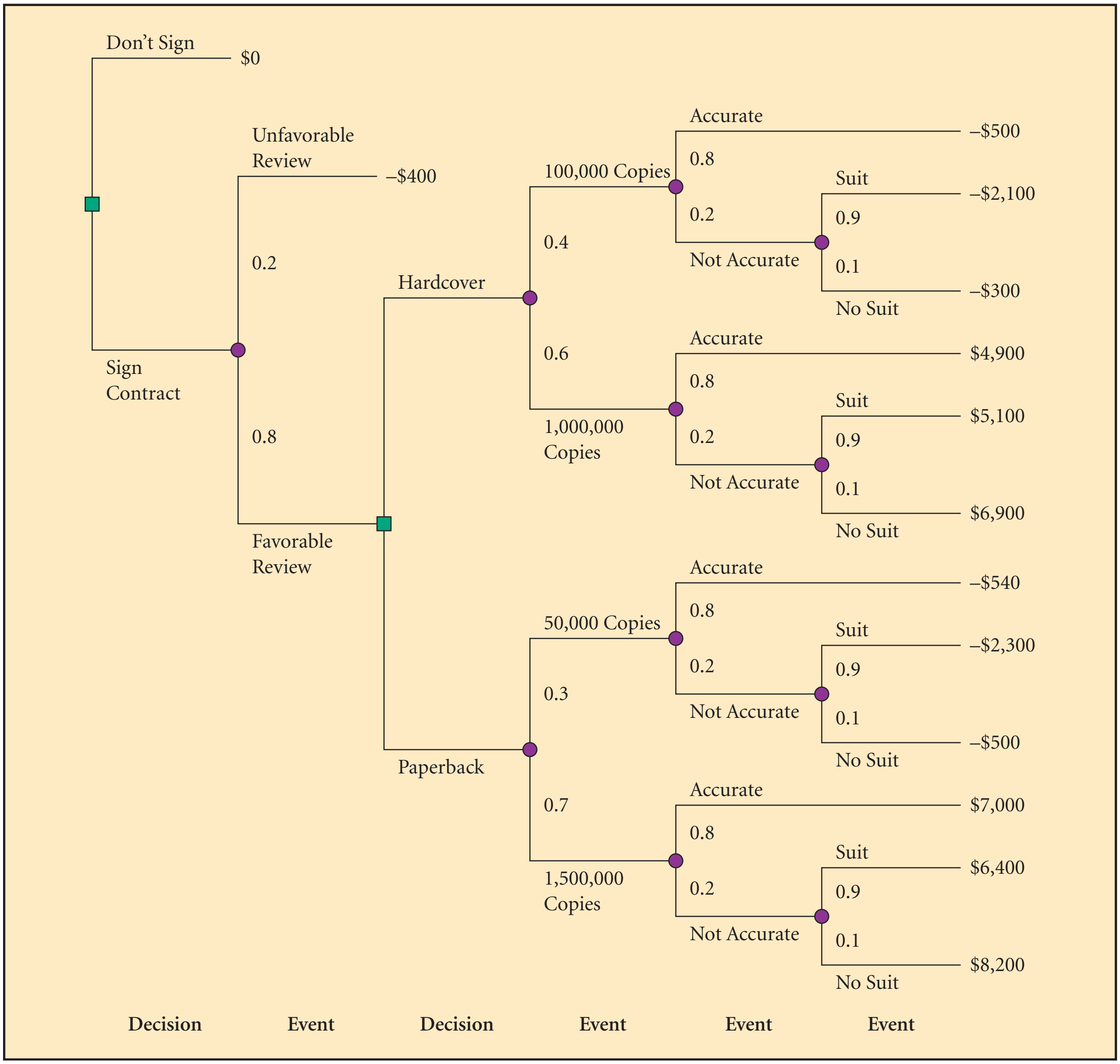
Because the Don't *Sign Contract* branch has no following uncertain events, the end value of $0 is the expected value of that decision alternative. This expected value is displayed in a box near the decision fork.

The process of finding the expected value for the *Sign Contract* branch requires a little more effort. To begin, we go to each event branch at which *Suit* and *No Suit* are the possible outcomes. We compute the expected values of these events by multiplying the end value times the probability of each outcome. For instance, for the event branch emanating from the Hardcover, 100,000 *Copies, Not Accurate* branch, the expected value is

$$EV = -\$2,100(0.90) + -\$300(0.10) = -\$1,920$$

FIGURE 19.9

Harris Publishing Co.—Final Decision Tree



This expected value is displayed inside the oval between the two event branches. We use the same procedure to find expected values for all *Suit/No Suit* event branches, as shown in Figure 19.10. (*Note:* All dollar amounts are in thousands.)

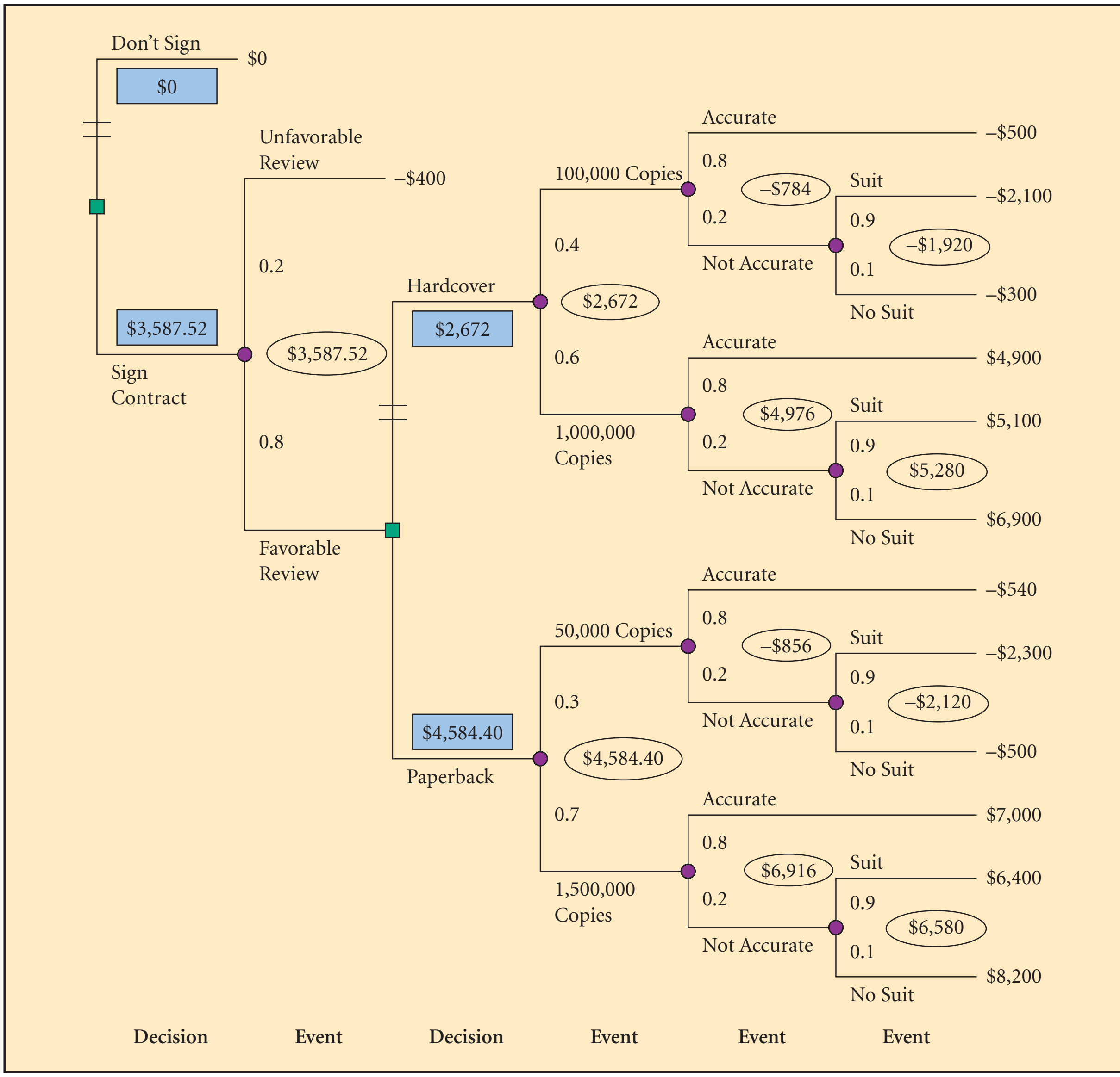
Next, we determine the expected value of the event *Accurate/Not Accurate* in each instance in the tree where the event appears. To illustrate, we will use the event emanating from the *Hardcover, 100,000 Copies* branch. The expected value is

$$EV = -\$500(0.80) + -\$1{,}920(0.20) = -\$784$$

This value is shown in the oval between the two event branches. Note that in computing the expected value, we used −$1,920, the expected value of the

FIGURE 19.10

Harris Publishing Co.—Folding Back the Decision Tree



Suit/No Suit event. This value was multiplied by the 0.20 probability that the content of the manuscript will not be accurate. The 0.80 chance that the manuscript will be accurate is multiplied by −$500, because that is the expected value of the *Accurate* branch.

The expected value of the *Accurate/Not Accurate* event emanating from the *Hardcover, 1,000,000 Copies* branch is

$$EV = \$4{,}900(0.80) + \$5{,}280(0.20) = \$4{,}976$$

This value is also shown in Figure 19.10, in the oval between the two outcome branches. The same methodology is used in the lower portion of the tree. This process of moving from right to left is what we mean by "folding back the tree."

We continue by determining the expected values of the demand events. For instance, the expected value for the demand event emanating from the *Hardcover* branch is

$$EV = -\$784(0.40) + \$4{,}976(0.60) = \$2{,}672$$

This value is also the expected value of the *Hardcover* decision branch. This means that the expected value of the hardcover alternative is \$2,672 (actually \$2,672,000).

The expected value for the demand event emanating from the *Paperback* decision branch is

$$EV = -\$856(0.30) + \$6,916(0.70) = \$4,584.40$$

This value is the expected value of the *Paperback* decision alternative. Because \$4,584.40 > \$2,672, the best decision is to select the paperback option if the editor reaches that decision point. She would expect a net payoff of \$4,584.40 (actually \$4,584,400) from the paperback decision. Note that the hardcover decision branch is blocked, indicating that it is not the best decision.

The final step in the fold-back process is to determine the expected value of the review event. We again multiply the appropriate cash flows by their probabilities.

$$EV = -\$400(0.20) + \$4,584.40(0.80) = \$3,587.52$$

Thus, as shown in Figure 19.10, the expected value is \$3,587.52, which is the expected value of the *Sign Contract* branch. This means that if the company signs the publishing contract, its expected payoff is \$3,587.52 (actually \$3,587,520). Because this value exceeds the \$0 expected payoff for the *Don't Sign Contract* branch, the best decision is to sign the contract. If the editorial review is favorable, then publish in paperback. (Notice that the *Don't Sign* branch is blocked, indicating that this alternative won't be selected.)

This example demonstrates the use of a decision tree to help in making a decision under uncertainty. The decision tree provides a framework for analyzing alternatives and dealing with uncertainties. The decision reached is the best decision given the expected-value criterion. However, as we indicated earlier, the best decision does not always lead to the best outcome. For instance, if the contract is signed and the book is published in paperback, demand may be only 50,000 copies and, worse yet, the contents might not be accurate. If this chain of events occurs, a lawsuit will be filed. Harris Publishing would lose \$2,300,000 on the deal. Remember, a "bad outcome" can occur from this one-time decision. But then again, an extremely good outcome could occur if the demand for the book is 1.5 million copies, the book proves inaccurate (no royalties are paid), and no suit is filed. The payoff under this scenario is \$8,200,000. The expected-value criterion takes into consideration all the possible payoffs and the probabilities of those payoffs occurring.

SUMMARY Decision-Tree Analysis

To solve a decision-tree problem, the following steps are used:

1. Grow the decision tree. Arrange the decisions and events in the order in which they will occur. This is often difficult with complex decision problems, but unless the decision tree accurately represents the situation, the decision made may not be the best decision.
2. Assign the probabilities. Make the necessary probability assessments and show them on the event branches. These probabilities can be determined using classical assessment, relative frequency of occurrence, or subjective techniques. (Remember that probabilities are associated with the uncertain events and not with the decision alternatives.)
3. Assign cash flows by showing costs and payoffs on the branches where they occur. Accumulate these cash flows and determine the end value for each branch of the decision tree.
4. Fold back the decision tree. At each decision fork, select the decision that maximizes expected payoff or minimizes expected cost.

This example illustrates an important virtue of decision-tree analysis. That is, the tree allows future decisions that have an influence on the current decision to be systematically considered. Chronologically, the decision about whether to publish in hardcover or paperback comes after the initial decision of whether to sign a contract. However, the decision of whether to sign is made only after the expected profits associated with publishing in hardcover and paperback are determined. In this case, the editor decided to publish in paperback because her analysis indicated the contract should be signed. The ability to use projected future events to help make a current decision is a natural part of the fold-back process.

Sensitivity Analysis In a decision problem such as the one facing Harris Publishing Company, uncertainty in the events is measured by the probabilities assessed for each event outcome. The expected-value criterion utilizes these probability assessments. But a question that arises when decision analysis is applied is how *sensitive* is the decision to the probabilities being assessed. For instance, the company might want to know how much the probability of a favorable review would have to change to make not signing the contract the best decision.

To answer this question, refer to Figure 19.10. Instead of using 0.80 for the probability of a favorable review, let the probability be p. Then the probability of an unfavorable review is $1 - p$. We next solve for p such that the expected value of the *Sign Contract* alternative (now \$3,587.52) is the same as the expected value of the *Don't Sign Contract* alternative, which in this case is \$0.

$$
\begin{aligned}
0 &= 4{,}584.40p + -400(1 - p) \\
0 &= 4{,}584.40p - 400 + 400p \\
400 &= 4{,}984.40p \\
400/4{,}984.40 &= p \\
0.08025 &= p
\end{aligned}
$$

Thus, the probability of a favorable report would have to decrease from 0.80 to less than 0.1 in order for the best decision to be not to sign the contract. This means the decision is quite insensitive to the probability assessed for a favorable editorial review, and there is probably no need to investigate this assessment any further.

Another question might be: How sensitive is the decision to publish the softcover book to the probability assessment associated with the number of hardcover books that might be sold? That is, how much higher than 0.60 would the probability of selling 1 million copies have to be before the best decision would be to go with the hardcover books? The approach to answering this question is essentially the same as before. We let $p =$ the probability of selling 1 million copies and $1 - p$ be the probability of selling 100,000 copies. We then solve for p such that the expected payoff for hardcover is equal to that for paperback: \$4,584.40 (see Figure 19.10). We solve for p as follows:

$$
\begin{aligned}
4{,}584.40 &= 4{,}976p + -784(1 - p) \\
4{,}584.40 &= 4{,}976p - 784 + 784p \\
5{,}368.40 &= 5{,}760p \\
5{,}368.40/5{,}760 &= p \\
0.9320 &= p
\end{aligned}
$$

The probability of selling 1 million books would have to be higher than 0.9320 for the best decision to be to publish a hardcover book. When this is compared with the current assessment of 0.60, we see the decision is not very sensitive to this probability assessment. Depending on how much information and thought went into the original probability assessment, there does not appear to be a need to allocate substantial resources to study the hardcover-demand issue further.

Sensitivity analysis can also investigate how much a cash-flow value would have to change before the decision would change. The method for determining the sensitivity of a cash-flow item is the same as for a probability. Let the cash-flow value in question equal x, and then solve for x such that the decision branches have the same expected payoff. When sensitivity analysis indicates that the resulting decision is sensitive to a probability or cash-flow value, you will want to spend extra time studying this factor before arriving at the final decision.

19-3: Exercises

Business Applications

19-24. Tom and Joe operate a rock quarry that provides local stone for landscaping. They currently have an offer for $50,000 to sell the quarry. They are hesitant to sell because they believe there will be an increase in demand in the next 2 years that would improve their financial situation. If they decide to keep the quarry, the current buyer would be willing to pay $30,000 in 2 years, regardless of the situation. Tom and Joe think there is a 60% chance of an increase, at which point they would operate at a profit of $75,000 or sell the quarry to a new buyer for $60,000. If demand does not increase, they would operate at a profit of only $10,000. Use a decision tree to determine what they should do.

19-25. Vegetable Farms is a small, family-operated ranch that sells produce to local markets. The owners are currently trying to decide whether they should expand their operation next year. Because this is a fairly new business, the owners have assessed the following demand levels and probabilities: high (probability 0.50), medium (0.30), or low (0.20). The payoffs they expect for each demand/acreage scenario are listed. Use a decision tree to help decide whether to expand the farm.

	DEMAND		
ACREAGE	High	Medium	Low
Expanded	$100,000	$40,000	−$40,000
Same size	50,000	40,000	30,000

19-26. Aquatech currently holds the lease to a site with good potential for geothermal development to generate electricity. Aquatech is now looking at three options for the site: (1) sell the rights to the property for $1.5 million; (2) extend the lease for 25 years at a cost of $0.5 million, with the possibility of selling later; or (3) extend the lease and drill exploratory wells at a total cost of $2 million.

If the company decides to extend the lease in order to drill, future revenue from the site would be determined by the temperature of the water. The following chart lists the probabilities associated with the three states of nature possible, along with the projected drill revenues:

Water Temperature	Probability	Drill Revenue (in Millions)
High	0.4	$5
Medium	0.4	3
Low	0.2	1

If the company extends the lease in order to sell the property later without drilling, the sale price will be determined by the demand for electricity. The following chart lists the probabilities associated with the three levels of demand and the projected sale prices:

Demand	Probability	Sale Price (in Millions)
High	0.3	$2.5
Medium	0.6	2.0
Low	0.1	1.5

Use a decision tree to diagram Aquatech's possible solutions and determine which option management should choose.

19-27. Paradise Springs is in the position of having to decide what size cross-country ski resort to build. The majority owners are adamant that a resort be built and that future plans for the resort should be determined by revenues generated during the first 2 years of the project.

The developer has the option of building a small complex now and later expanding, if demand warrants, to a large complex or build a large complex now. The expansion project would increase the size of a small complex to that of a large complex and could be completed in the off-season to allow the resort to function as a large resort the second season. The costs of construction are as follows:

Size	Cost (in Millions)
Small	$2.0
Expansion (2nd year)	1.5
Large	3.0

The developer believes that demand for the resort will be either high or low and thinks there will be a 50–50 chance the resort will be popular in its first season. If demand is high the first year, she feels there is a 60% chance the resort will be popular its second season. If demand is low, she would not want to expand. She feels if demand is low the first year, there is a 70% chance it will remain low for the second season. The expected annual revenues for the resort are as follows:

Expected Annual Revenues (in Millions)		
Size	**High**	**Low**
Small	\$2	\$1
Large	3	2

Revenue figures do not include the costs of construction. Use a decision tree to determine which size the resort should develop.

Summary and Conclusions

Making decisions under uncertainty is a regular part of business. Although decision makers usually cannot eliminate uncertainty, they can use the tools of decision analysis to help deal with it.

In this chapter, we explained the steps for constructing a payoff table and an opportunity-loss table. We also introduced nonprobabilistic decision criteria, such as maximin, maximax, and minimax regret. More importantly, we discussed the expected-value criterion, which utilizes probabilities assigned to uncertain outcomes. We demonstrated how to determine the cost of uncertainty and how to determine an upper limit on the value of new information using either a payoff or an opportunity-cost approach.

One of the most important decision analysis tools is the decision tree, which provides a chronological ordering of the decisions and events involved in making a decision. In this chapter, we illustrated how to use a decision tree in making a decision under uncertainty. In addition, we showed how decision-tree analysis, through the fold-back process, takes into account future decisions that affect the current decision.

Equations

Expected Value

$$E(x) = \sum_{i=1}^{k} x_i P(x_i) \quad \textbf{(19.1)}$$

$$\sum_{i=1}^{k} P(x_i) = 1 \quad \textbf{(19.2)}$$

$$0 \le P(x_i) \le 1 \quad \textbf{(19.3)}$$

Key Terms

Certainty 892
Decision tree 905
Expected-value criterion 897
Maximax criterion 896
Maximin criterion 896
Minimax regret criterion 896
Opportunity loss 896
Payoff 895
States of nature 895
Uncertainty 893

Chapter Exercises

Business Applications

Exercises 19-28 through 19-31 refer to the following situation.

Hatchman Electronics makes specialized fuel-injection units for automobile engines. The company is currently completing its 5-year strategic plan. A major component of this plan involves analyzing the following situation.

Hatchman currently makes an injection unit that it sells to automobile manufacturers for \$200. The operating profit (revenue – direct manufacturing costs) for this unit is \$90. The company estimates that the probability is 80% that demand for this product will continue, at the same price, for the next 5 years. But if a competitor introduces a better unit, the selling price will be dropped to \$140 to a cash-flow item is the same as for a probability. Let the cash-flow value in question equal *x*, and then solve for *x* such that the decision branches have the same expected payoff. When sensitivity analysis indicates that the resulting decision is sensitive to a probability or cash-flow value, you will want to spend extra time studying this factor before arriving at the final decision.

19-3: Exercises

Business Applications

19-24. Tom and Joe operate a rock quarry that provides local stone for landscaping. They currently have an offer for $50,000 to sell the quarry. They are hesitant to sell because they believe there will be an increase in demand in the next 2 years that would improve their financial situation. If they decide to keep the quarry, the current buyer would be willing to pay $30,000 in 2 years, regardless of the situation. Tom and Joe think there is a 60% chance of an increase, at which point they would operate at a profit of $75,000 or sell the quarry to a new buyer for $60,000. If demand does not increase, they would operate at a profit of only $10,000. Use a decision tree to determine what they should do.

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	DEMAND		
ACREAGE	**High**	**Medium**	**Low**
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19-26. Aquatech currently holds the lease to a site with good potential for geothermal development to generate electricity. Aquatech is now looking at three options for the site: (1) sell the rights to the property for $1.5 million; (2) extend the lease for 25 years at a cost of $0.5 million, with the possibility of selling later; or (3) extend the lease and drill exploratory wells at a total cost of $2 million.

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Size	Cost (in Millions)
Small	$2.0
Expansion (2nd year)	1.5
Large	3.0

Develop the payoff table that reflects these states of nature.

19-39. Given the payoff table developed in Exercise 19-38, what decision should the company's managers make if they wish to maximize the expected payoff?

19-40. The manager of the Pink Flounder restaurant must decide how many orders of its special butter-broiled catfish to make for Thursday's lunch special. The orders must be made in advance, because the restaurant guarantees lunchtime service in less than 15 minutes and the catfish special takes 45 minutes to prepare. Each order costs $3.50 to prepare and is sold for $7.00. Any leftover orders can be used in the restaurant's fish gumbo, for a savings of $1.50. People who order catfish after it has run out are given a free catfish dinner on their next visit. Sales records from past Thursdays indicate that demand should have the following probability distribution:

Demand Level	Probability
3	0.10
4	0.30
5	0.25
6	0.20
7	0.10
8	0.05
9 or more	0.00
	1.00

Develop a payoff table for the Pink Flounder's decision problem.

19-41. Referring to Exercise 19-40, how many orders of catfish should be prepared on Thursday?

19-42. In Exercises 19-40 and 19-41, you used the expected-value criterion to determine the optimal number of catfish orders to prepare. Convert the table you used in making your decision to an opportunity-loss table. Make the appropriate decision using the opportunity-loss table. What is the EVPI? What is the expected cost of uncertainty?

19-43. In Exercises 19-32 to 19-35, you constructed a payoff table and used expected values to determine the appropriate number of condominiums for Far Horizons to build in Maine. Convert this table to an opportunity-loss table. Using expected opportunity loss as the decision criterion, determine how many units should be built. In this case, what is the EVPI? Suppose for $10,000 someone offered to sell the company perfect information about demand. Would the information be worth that price? Explain.

19-44. East Coast Imports is considering two alternative advertising and marketing plans for a new line of consumer products it buys from a manufacturer in Singapore. The first plan involves contracting with a television shopping channel and is projected to have a monthly cost of $200,000. East Coast's marketing director has analyzed this alternative and, after a joint meeting with the shopping channel's manager, believes that the following probability distribution for additional profit generated is accurate:

Increased Revenue	Probability	Increased Revenue	Probability
$120,000	0.10	260,000	0.20
150,000	0.10	290,000	0.10
200,000	0.20	320,000	0.10
230,000	0.20		1.00

The second marketing alternative—to rely on advertising in airline magazines and newspaper inserts—is projected to have a monthly cost of $120,000. However, the marketing director thinks that this approach would not be as effective for generating added monthly revenue as the shopping channel approach. This is reflected in the following probability distribution:

Increased Revenue	Probability
$70,000	0.10
90,000	0.10
110,000	0.25
140,000	0.25
170,000	0.20
200,000	0.10
	1.00

Because of the fear of "overkill," the company has decided not to try both approaches simultaneously. However, the managers did agree that if the print-advertising approach is chosen and results in $90,000 or less in added revenues, they can switch to the shopping channel for an additional cost of $20,000. They assume that the probabilities would not be affected, but all profit projections will be reduced by this cost.

a. Set up the appropriate decision tree for this problem.
b. Using the criterion of maximizing the expected increase in net revenues, what marketing strategy should be chosen?

Exercises 19-45 through 19-47 refer to the following situation.

The Grimm Group presents in-house training seminars to organizations throughout the United

States. The company currently presents seminars on three topics: quality control, material management, and just-in-time (JIT) manufacturing. The quality control seminar costs each participant $500, and the Grimm Group's gross margin (revenue – direct expenses) is 40% of this amount. The material-management seminar costs $450 for each attendee and also has a 40% gross margin; the JIT seminar costs $600 and has a 35% gross margin. After 5 years of expansion, attendance at the seminars has declined more than 10% in the past year. The revenues from the three operations last year were quality control, $1,200,000; material management, $900,000; and JIT, $1,400,000.

At the yearly forecasting meeting, Graciela Grimm, the company's founder, projects that if no changes are made in marketing philosophy, revenues will be stagnant this year. She is, however, considering two options that should increase demand for the three seminars. The first option is to incorporate a computer simulation game as part of each seminar. Projections indicate that adding this type of game will increase the demand for the quality control seminar by 10% and the demand for the other two seminars by 15% each. Adding a game will increase the cost associated with each seminar participant by $50; but because the market is very competitive, the company will have to hold the line on the price change. The second option is to offer 3-day training seminars on the same topics but at 60% of the price of the 5-day seminars. Unfortunately, the cost of presenting the 3-day seminars will be reduced by only 20% from the cost of the original seminars. The president estimates the demand for the shorter seminars this year will generate revenues equal to 50% of the revenues realized from each 5-day seminar in the past year. Also, adding the shorter seminars will reduce the projected demand for the original seminars to 75% of last year's level.

19-45. Develop a decision tree describing the Grimm Group's decision situation.

19-46. Assuming President Grimm is risk-neutral for this decision, what alternative would you recommend?

19-47. An initial market survey of the acceptance of simulation games indicates they are so popular that there is a 70% chance the Grimm Group will be able to raise the price of the seminars by enough to maintain its previous margins without affecting the demand. Incorporate this new information into your previous problem analysis.

Exercises 19-48 through 19-51 refer to the Major League Corporation, which makes sports-related items at a plant in South Carolina. Before the baseball season, the company was approached by representatives from the Sports Connection, a company that supplies baseball items to be sold at major league parks and at sports souvenir stores. The Sports Connection has offered to contract to buy 300,000 baseball hats for $3.00 each. The company's production capacity is 500,000 hats. The problem facing Major League is whether to accept this offer or to attempt to independently sell all its baseball hats. If the demand for hats is high, the company will be able to sell hats for much more than $3.00 each, but if demand is low, the hats will have to be sold for much less than $3.00.

At least two uncertainties exist that will affect the demand for hats. First, if the league races are tight, the demand will be high; clear leaders early in the season will lead to low demand. Second, if the players strike this year, demand will be reduced. Using available information on injury levels and team-strength analysis, Major League's executives estimate a 60% probability that the league races will be tight. In addition, the executives estimate the probability of a strike this year to be 30%. Assuming the two events, tight races and a player strike, are independent, the following table shows the possible selling prices for the company's hats and the associated probabilities:

	League Race	
Player Strike	**Tight**	**Not Tight**
No	$5.00	$2.50
	$p = 0.42$	$p = 0.28$
Yes	$4.00	$2.00
	$p = 0.18$	$p = 0.12$

19-48. Assuming Major League will sell its entire output, should it accept the Sports Connection's offer if it wishes to maximize its expected revenue?

19-49. Suppose Major League's executives believe the company will be able to negotiate the following deal with the Sports Connection: The contract price for hats will be reduced to $2.70 per hat; Major League will commit to delivering 150,000 hats at this price, with the option of supplying the remaining 150,000 hats at $2.70 each after it determines whether the players will strike. This decision must be made before the status of the league races is known.

This proposal, if made, will require the services of legal counsel, with a fee estimated to be $25,000. Determine the decision tree describing this situation.

19-50. Should Major League make the proposal? Base your recommendation on expected values.

19-51. Assume you are the purchasing manager for the Sports Connection. If you receive the proposed offer, would you recommend that it be accepted if your only other alternative is to buy 300,000 baseball hats on the open market? Assume that you have assessed the same probabilities as Major League regarding league races and player strikes. Base your conclusions on expected costs.

19-52. New Age Marketing is considering two alternative advertising plans for a client. The first plan uses radio and television commercials that will cost \$100,000. The account executive estimates a 40% chance that the client's revenues will increase by \$80,000, a 25% chance that revenues will increase by \$110,000, and a 35% chance that revenues will increase by \$120,000 as a result of this advertising approach.

The second plan is to use newspaper and magazine advertisements, at a cost of \$20,000. However, print media are thought to be less effective than radio and television. The account executive estimates the chances are 20% that this plan will increase revenues by \$14,000, 50% that revenues will increase by \$30,000, and 30% that revenues will increase by \$40,000.

If the newspaper and magazine option is chosen, New Age can later take the radio and TV option, but expected revenue will decline by \$10,000 from what it would have been had that been the first choice. The account executive has indicated that it would not be feasible to try the newspaper and magazine approach after first choosing radio and TV.

Use a decision-tree approach to determine what decision(s) the New Age agency should make.

19-53. The Gregston Corporation has purchased a petroleum lease tract in the Pacific Ocean that may contain extensive oil deposits. Drilling a dry hole would be very expensive, so Gregston's managers are considering conducting a test to determine whether the geologic structure is favorable for the presence of oil. Unfortunately, the test is not perfect. Suppose Gregston's managers have determined the correct structure will be found 70% of the time when the reading is positive. Recent industry evidence with the test has shown a correct structure will be found 40% of the time when the reading is negative. Further, records show that when this test was conducted in this region in the past, 40% of the time the reading was positive. However, records also show that oil is struck for only 10% of all holes drilled worldwide.

The test will cost the company \$400,000 to perform, and the cost of drilling the hole is \$2 million. If Gregston does drill and hit oil, there are three possible outcomes:

Oil Outcome	Revenue	Probability
Small find	\$ 2 million	0.40
Medium find	\$ 5 million	0.40
Large find	\$10 million	0.20

Considering this information, what decision should Gregston make? Base your decision on expected profits.

19-54. In Exercise 19-53, Gregston's managers did not take into account the fact that they had already paid \$500,000 for the drilling lease. What, if any, effect does this new information have on the decision facing the company? Discuss.

19-55. Referring to Exercise 19-54, how sensitive is the decision to the probability assessment that the tester will give a positive reading in this region of the ocean? That is, how much would this probability have to change in order to change the decision that Gregston will make?

CASE 19.1

Rockstone International

Rockstone International is one of the world's largest diamond brokers. The firm purchases rough stones and has them cut and polished for sale in the United States and Europe. The diamond business has been very profitable, and from all indications it will continue to be so. However, R. B. Randall, president and chief executive officer for Rockstone, has stressed the need for effective management decisions throughout the organization if the firm is to remain profitable and competitive.

Normally, R. B. does not involve herself in personnel decisions, but today's situation is not typical. Beth Harkness, Rockstone's personnel manager, is considering whether to hire Hans Marquis, a world-famous diamond cutter, to replace Omar Barboa, who broke both his hands in a freak skateboard accident almost a month ago. If he is hired, Hans Marquis will be paid on a commission basis at the rate of \$5,000 for each stone he cuts successfully. (Because of his professional pride, Hans will accept no fee if he is unsuccessful in cutting a stone.)

In the past, the decision of whether to hire Hans would have been simple. If he was available, he would be hired. However, 6 months ago, the Liechtenstein Corporation introduced the world's first diamond-cutting machine. This machine, which can be leased for $1,000,000 per year, is guaranteed to cut stones successfully 90% of the time.

Although Hans Marquis has an excellent reputation, Rockstone International cannot be sure about his success rate because of the extreme secrecy among people in the diamond business. Hans claims that his success rate is 95%, but he has been known to exaggerate. Rockstone executives have made the following assessments, based on all the information they could obtain:

Actual Success Rate	Probability
0.97	0.10
0.95	0.40
0.90	0.30
0.85	0.10
0.80	0.10
	1.00

Rockstone purchases gemstones at a cost of $15,000 each. A successful cut yields four diamonds that can be sold at an average price of $35,000 each. Harry Winkler, sales and purchasing manager, reports that his projections for the next year indicate a need for 100 stones to be cut.

R. B. Randall knows there must be a way to decide whether to hire Hans Marquis or lease the new cutting machine.

CASE 19.2

Hadden Materials and Supplies, Inc.

Mark Hadden and his son, Greg, began Hadden Materials and Supplies, Inc., in the mid-1980s. Both Mark and Greg had had successful careers with major U.S. corporations, but after several years of talking about it they came to the conclusion that they wanted to work together in their own business. They also decided that they wanted to be in manufacturing, where they could take advantage of their previous experience and business contacts.

From the beginning, Mark has run the production shop and Greg has concentrated on sales. About 2 years ago, they got a contract to make an electronic component for natural gas heaters. At first they made this part exclusively for one company, but about 6 months ago they started making the same component for other heater manufacturers. The component is produced in large volume and sells for $30. The variable production cost per unit is $13, making this a very profitable product for the company.

However, until recently there was no way to determine whether a component would work properly until it had actually been installed in the heater unit. Whenever the heater manufacturer found a defect, Hadden Materials and Supplies would refund the full $30 plus pay a penalty of $10. Although the company has made major improvements in its quality control program, this particular component is very difficult to build and to have work properly. As a result, the defect rate has been approximately 25%.

A week ago, the company was approached by a representative of Tech-Notics, Inc., who said her company had a device for testing components such as the one Hadden makes for gas heaters. By using this tester, Hadden could determine before shipping whether the component would work. This was one sales call that really got Mark and Greg's attention, and the sales representative agreed to bring a unit by for a trial the next morning. Greg called their largest customer and made arrangements to "test the tester" at the customer's plant the next afternoon.

Over the next 2 days, Mark, Greg, and the Tech-Notics sales representative tested 400 components. Of these, 320 tested positive, indicating that they would turn out to be good, however, of the 320 that tested positive, 72 ended up actually being defective. In addition, of the components that got a negative reading, 8 were found to be good: Although the testing device was not perfect, the Haddens were still encouraged.

The sales representative explained that her company preferred to lease the testers, with a financial arrangement that called for the lessor to pay $3 per test. (The tester had an automatic counter.) If the unit were sold outright, it would cost $6 million. Mark and Greg realized that there was no way that they could afford to purchase the unit, so that option was immediately eliminated. However, they were interested in the lease plan and told the sales representative they would call her soon with their decision.

As Mark and Greg conferred over lunch, they estimated the heater component would remain in production for about 2 more years. During that time, they could expect orders for about 100,000 units. They also agreed that if they leased the tester, they would use it to test every component that they built. As Greg said, "Why should we lease it if we don't use it!" They also concluded that if an item tested negative, it would be scrapped and not shipped.

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