Decision-Making Tools

MODULE A

MODULE OUTLINE

Alaska Airlines

Alaska Airlines

LEARNING OBJECTIVES

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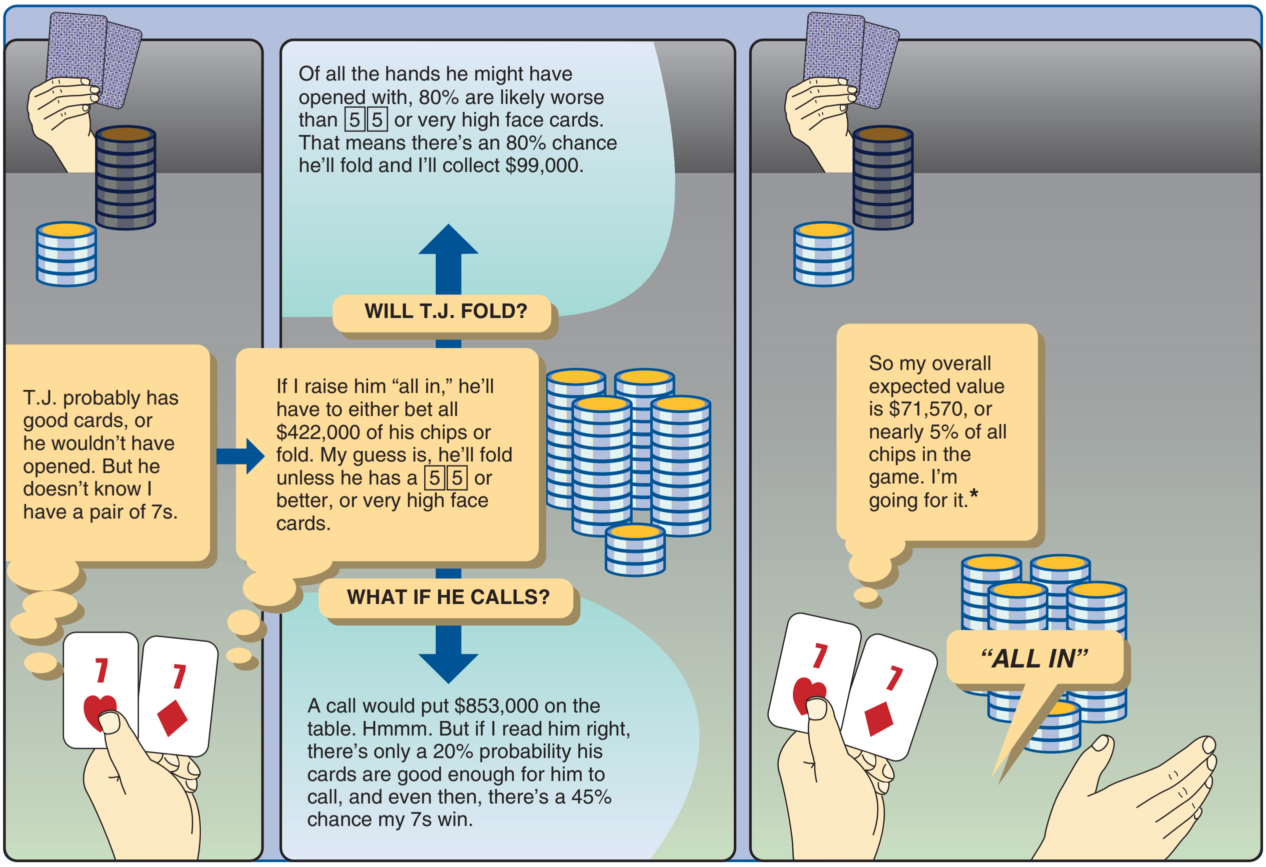
WOULD *YOU* GO ALL IN?

At the Legends of Poker tournament in Los Angeles, veteran T.J. Cloutier opens with a $60,000 bet. (Antes and required bets of $39,000 are already on the table.) Former Go2net CTO Paul Phillips ponders going "all in"—betting virtually all his chips. Using decision theory, here's how he decided.



Source: Based on *Business 2.0* (November 2003): 128–134.

*To see the details of Phillips's decision, see Example A8.

The Decision Process in Operations

Operations managers are not gamblers. But they are decision makers. To achieve the goals of their organizations, managers must understand how decisions are made and know which decision-making tools to use. To a great extent, the success or failure of both people and companies depends on the quality of their decisions. Overcoming uncertainty is a manager's challenge.

What makes the difference between a good decision and a bad decision? A "good" decision—one that uses analytic decision making—is based on logic and considers all available data and possible alternatives. It also follows these six steps:

1. Clearly define the problem and the factors that influence it.
2. Develop specific and measurable objectives.
3. Develop a model—that is, a relationship between objectives and variables (which are measurable quantities).
4. Evaluate each alternative solution based on its merits and drawbacks.
5. Select the best alternative.
6. Implement and evaluate the decision and then set a timetable for completion.

So analytic decision making requires models, objectives, and quantifiable variables, often in the form of probabilities and payoffs. Such information is not always easy to obtain or derive from existing data. This challenge exists because of either a lack of data or an overabundance of data. However, because data are now easily generated and stored in digital form, we tend to have the latter—massive volumes of data. Data are collected automatically from production processes, as well as from websites, credit cards, point-of-sale records, and social media. Although this mass of data is a potential source of information, it requires sophistication in how it is stored, processed, and analyzed. **Big data** is the term used to describe this huge amount of data, which often cannot be efficiently processed by traditional data techniques.

Big data
The huge amount of economic, production, and consumer data now being collected in digital form.

Throughout this text, we have introduced a broad range of mathematical models and tools that help operations managers make better decisions. Because good decisions require data that can be analyzed and turned into information, decision makers appreciate the potential of big data. This module provides an introduction to the challenges facing managers by introducing two of the tools of decision making—decision tables and decision trees. These two tools are used in numerous OM situations, ranging from new-product analysis, to capacity planning, to location planning, to supply-chain disaster planning, to scheduling, and to maintenance planning.

Fundamentals of Decision Making

Regardless of the complexity of a decision or the sophistication of the technique used to analyze it, all decision makers are faced with alternatives and "states of nature." The following notation will be used in this module:

1. Terms:
   a. *Alternative*—A course of action or strategy that may be chosen by a decision maker (e.g., not carrying an umbrella tomorrow).
   b. *State of nature*—An occurrence or a situation over which the decision maker has little or no control (e.g., tomorrow's weather).
2. Symbols used in a decision tree:
   a. □—Decision node from which one of several alternatives may be selected.
   b. ○—A state-of-nature node out of which one state of nature will occur.

To present a manager's decision alternatives, we can develop *decision trees* using the above symbols. When constructing a decision tree, we must be sure that all alternatives and states of nature are in their correct and logical places and that we include *all* possible alternatives and states of nature.

Example A1

A SIMPLE DECISION TREE

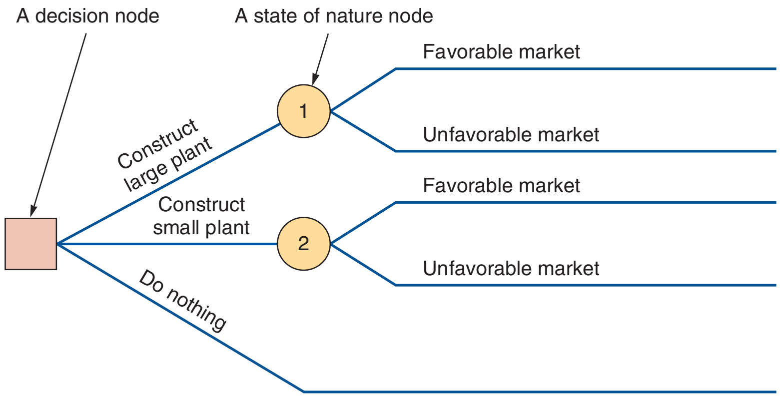
Getz Products Company is investigating the possibility of producing and marketing backyard storage sheds. Undertaking this project would require the construction of either a large or a small manufacturing plant. The market for the product produced—storage sheds—could be either favorable or unfavorable. Getz, of course, has the option of not developing the new product line at all.

APPROACH ▶ Getz decides to build a decision tree.

SOLUTION ▶ Figure A.1 illustrates Getz's decision tree.

Figure **A.1**

Getz Products' Decision Tree



LO A.1 *Create* a simple decision tree

INSIGHT ▶ We never want to overlook the option of "doing nothing," as that is usually a possible decision.

LEARNING EXERCISE ▶ Getz now considers constructing a medium-sized plant as a fourth option. Redraw the tree in Figure A.1 to accommodate this. [Answer: Your tree will have a new node and branches between "Construct large plant" and "Construct small plant."]

RELATED PROBLEMS ▶ A.2e, A.8b, A.22–A.25

Decision Tables

Decision table
A tabular means of analyzing decision alternatives and states of nature.

We may also develop a decision or payoff table to help Getz Products define its alternatives. For any alternative and a particular state of nature, there is a *consequence* or *outcome*, which is usually expressed as a monetary value. This is called a *conditional value*. Note that all of the alternatives in Example A2 are listed down the left side of the table, that states of nature (outcomes) are listed across the top, and that conditional values (payoffs) are in the body of the **decision table**.

Example A2

A DECISION TABLE

LO A.2 *Build* a decision table

Getz Products now wishes to organize the following information into a table. With a favorable market, a large facility will give Getz Products a net profit of $200,000. If the market is unfavorable, a $180,000 net loss will occur. A small plant will result in a net profit of $100,000 in a favorable market, but a net loss of $20,000 will be encountered if the market is unfavorable.

APPROACH ▶ These numbers become conditional values in the decision table. We list alternatives in the left column and states of nature across the top of the table.

SOLUTION ▶ The completed table is shown in Table A.1.

TABLE A.1 Decision Table with Conditional Values for Getz Products

	STATES OF NATURE	
ALTERNATIVES	FAVORABLE MARKET	UNFAVORABLE MARKET
Construct large plant	$200,000	−$180,000
Construct small plant	$100,000	−$ 20,000
Do nothing	$ 0	$ 0

STUDENT TIP Decision tables force logic into decision making.

INSIGHT ▶ The toughest part of decision tables is obtaining the data to analyze.

LEARNING EXERCISE ▶ In Examples A3 and A4, we see how to use decision tables to make decisions.

Types of Decision-Making Environments

The types of decisions people make depend on how much knowledge or information they have about the situation. There are three decision-making environments:

- Decision making under uncertainty
- Decision making under risk
- Decision making under certainty

LO A.3 *Explain* when to use each of the three types of decision-making environments

Decision Making Under Uncertainty

When there is complete *uncertainty* as to which state of nature in a decision environment may occur (i.e., when we cannot even assess probabilities for each possible outcome), we rely on three decision methods:

1. **Maximax**: This method finds an alternative that *max*imizes the *max*imum outcome for every alternative. First, we find the maximum outcome within every alternative, and then we pick the alternative with the maximum number. Because this decision criterion locates the alternative with the *highest* possible *gain*, it has been called an "optimistic" decision criterion.
2. **Maximin**: This method finds the alternative that *max*imizes the *min*imum outcome for every alternative. First, we find the minimum outcome within every alternative, and then we pick the alternative with the maximum number. Because this decision criterion locates the alternative that has the *least* possible *loss*, it has been called a "pessimistic" decision criterion.
3. **Equally likely**: This method finds the alternative with the highest average outcome. First, we calculate the average outcome for every alternative, which is the sum of all outcomes divided by the number of outcomes. We then pick the alternative with the maximum number. The equally likely approach assumes that each state of nature is equally likely to occur.

Maximax
A criterion that finds an alternative that maximizes the maximum outcome.

Maximin
A criterion that finds an alternative that maximizes the minimum outcome.

Equally likely
A criterion that assigns equal probability to each state of nature.

Example A3

A DECISION TABLE ANALYSIS UNDER UNCERTAINTY

Getz Products Company would like to apply each of these three approaches now.

APPROACH ▶ Given Getz's decision table from Example A2, he determines the maximax, maximin, and equally likely decision criteria.

SOLUTION ▶ Table A.2 provides the solution.

TABLE A.2 Decision Table for Decision Making Under Uncertainty

	STATES OF NATURE				
ALTERNATIVES	FAVORABLE MARKET	UNFAVORABLE MARKET	MAXIMUM IN ROW	MINIMUM IN ROW	ROW AVERAGE
Construct large plant	$200,000	–$180,000	$200,000 ◀	–180,000	$10,000
Construct small plant	$100,000	–$ 20,000	$100,000	–$20,000	$40,000 ◀
Do nothing	$ 0	$ 0	$ 0	$ 0 ◀	$ 0
			Maximax	Maximin	Equally likely

1. The maximax choice is to construct a large plant. This is the *max*imum of the *max*imum number within each row, or alternative.

2. The maximin choice is to do nothing. This is the *max*imum of the *min*imum number within each row, or alternative.
3. The equally likely choice is to construct a small plant. This is the maximum of the average outcome of each alternative. This approach assumes that all outcomes for any alternative are *equally likely*.

INSIGHT ▶ There are optimistic decision makers ("maximax") and pessimistic ones ("maximin"). Maximax and maximin present best case–worst case planning scenarios.

LEARNING EXERCISE ▶ Getz reestimates the outcome for constructing a large plant when the market is favorable and raises it to $250,000. What numbers change in Table A.2? Do the decisions change? [Answer: The maximax is now $250,000, and the row average is $35,000 for large plant. No decision changes.]

RELATED PROBLEMS ▶ A.1, A.2b–d, A.4, A.6 (A.15 is available in MyOMLab)

Decision Making Under Risk

Expected monetary value (EMV)
The expected payout or value of a variable that has different possible states of nature, each with an associated probability.

Decision making under risk, a more common occurrence, relies on probabilities. Several possible states of nature may occur, each with an assumed probability. The states of nature must be mutually exclusive and collectively exhaustive and their probabilities must sum to 1.[1] Given a decision table with conditional values and probability assessments for all states of nature, we can determine the **expected monetary value (EMV)** for each alternative. This figure represents the expected value or *mean* return for each alternative *if we could repeat this decision (or similar types of decisions) a large number of times.*

The EMV for an alternative is the sum of all possible payoffs from the alternative, each weighted by the probability of that payoff occurring:

LO A.4 *Calculate* an expected monetary value (EMV)

$$\begin{aligned}\text{EMV (Alternative } i) = \; & (\text{Payoff of 1st state of nature}) \\ & \times (\text{Probability of 1st state of nature}) \\ & + (\text{Payoff of 2nd state of nature}) \\ & \times (\text{Probability of 2nd state of nature}) \\ & + \ldots + (\text{Payoff of last state of nature}) \\ & \times (\text{Probability of last state of nature})\end{aligned}$$

Example A4 illustrates how to compute the maximum EMV.

Example A4

EXPECTED MONETARY VALUE

Getz would like to find the EMV for each alternative.

APPROACH ▶ Getz Products' operations manager believes that the probability of a favorable market is 0.6, and that of an unfavorable market is 0.4. He can now determine the EMV for each alternative (see Table A.3).

SOLUTION ▶

1. EMV (A_1) = (0.6) ($200,000) + (0.4) (–$180,000) = $48,000
2. EMV (A_2) = (0.6) ($100,000) + (0.4) (–$20,000) = $52,000
3. EMV (A_3) = (0.6) ($0) + (0.4) ($0) = $0

TABLE A.3 Decision Table for Getz Products

	STATES OF NATURE	
ALTERNATIVES	FAVORABLE MARKET	UNFAVORABLE MARKET
Construct large plant (A_1)	$200,000	–$180,000
Construct small plant (A_2)	$100,000	–$ 20,000
Do nothing (A_3)	$ 0	$ 0
Probabilities	0.6	0.4

INSIGHT ▶ The maximum EMV is seen in alternative A_2. Thus, according to the EMV decision criterion, Getz would build the small facility.

LEARNING EXERCISE ▶ What happens to the three EMVs if Getz increases the conditional value on the "large plant/favorable market" result to $250,000? [Answer: EMV ($A_1$) = $78,000. A_1 is now the preferable decision.]

RELATED PROBLEMS ▶ A.2e, A.3a, A.5a, A.7a, A.8, A.9a, A.10, A.11, A.12, A.13a, A.14, A.22b,c (A.16, A.17, A.18, A.19, A.20 are available in MyOMLab)

EXCEL OM Data File **ModAExA4.xls** can be found in MyOMLab.

Decision Making Under Certainty

Now suppose that the Getz operations manager has been approached by a marketing research firm that proposes to help him make the decision about whether to build the plant to produce storage sheds. The marketing researchers claim that their technical analysis will tell Getz with certainty whether the market is favorable for the proposed product. In other words, it will change Getz's environment from one of decision making *under risk* to one of decision making *under certainty*. This information could prevent Getz from making a very expensive mistake. The marketing research firm would charge Getz $65,000 for the information. What would you recommend? Should the operations manager hire the firm to make the study? Even if the information from the study is perfectly accurate, is it worth $65,000? What might it be worth? Although some of these questions are difficult to answer, determining the value of such *perfect information* can be very useful. It places an upper bound on what you would be willing to spend on information, such as that being sold by a marketing consultant. This is the concept of the expected value of perfect information (EVPI), which we now introduce.

Expected Value of Perfect Information (EVPI)

LO A.5 *Compute* the expected value of perfect information (EVPI)

If a manager were able to determine which state of nature would occur, then he or she would know which decision to make. Once a manager knows which decision to make, the payoff increases because the payoff is now a certainty, not a probability. Because the payoff will increase with knowledge of which state of nature will occur, this knowledge has value. Therefore, we now look at how to determine the value of this information. We call this difference between the payoff under perfect information and the payoff under risk the **expected value of perfect information (EVPI)**.

Expected value of perfect information (EVPI)
The difference between the payoff under perfect information and the payoff under risk.

$$\text{EVPI} = \text{Expected value with perfect information} - \text{Maximum EMV}$$

Expected value *with* perfect information (EVwPI)
The expected (average) return if perfect information is available.

To find the EVPI, we must first compute the **expected value *with* perfect information (EVwPI)**, which is the expected (average) return if we have perfect information before a decision has to be made.

To calculate this value, we choose the best alternative for each state of nature and multiply its payoff times the probability of occurrence of that state of nature:

Expected value *with*
perfect information (EVwPI) = (Best outcome or consequence for 1st state of nature)
× (Probability of 1st state of nature)
+ (Best outcome for 2nd state of nature)
× (Probability of 2nd state of nature)
+ . . . + (Best outcome for last state of nature)
× (Probability of last state of nature)

In Example A5 we use the data and decision table from Example A4 to examine the expected value of perfect information.

Example A5

EXPECTED VALUE OF PERFECT INFORMATION

The Getz operations manager would like to calculate the maximum that he would pay for information—that is, the expected value of perfect information, or EVPI.

APPROACH ▶ Referring to Table A.3 in Example 4, he follows a two-stage process. First, the expected value *with* perfect information (EVwPI) is computed. Then, using this information, the EVPI is calculated.

SOLUTION ▶

1. The best outcome for the state of nature "favorable market" is "build a large facility" with a payoff of \$200,000. The best outcome for the state of nature "unfavorable market" is "do nothing" with a payoff of \$0. Expected value *with* perfect information = (\$200,000)(0.6) + (\$0)(0.4) = \$120,000. Thus, if we had perfect information, we would expect (on the average) \$120,000 if the decision could be repeated many times.
2. The maximum EMV is \$52,000 for A_2, which is the expected outcome without perfect information. Thus:

$$\begin{aligned} \text{EVPI} &= \text{EVwPI} - \text{Maximum EMV} \\ &= \$120{,}000 - \$52{,}000 = \$68{,}000 \end{aligned}$$

INSIGHT ▶ The *most* Getz should be willing to pay for perfect information is \$68,000. This conclusion, of course, is again based on the assumption that the probability of the first state of nature is 0.6 and the second is 0.4.

STUDENT TIP EVPI places an upper limit on what you should pay for information.

LEARNING EXERCISE ▶ How does the EVPI change if the "large plant/favorable market" conditional value is \$250,000? [Answer: EVPI = \$72,000.]

RELATED PROBLEMS ▶ A.3b, A.5b, A.7, A.9, A.13, A.22c

Decision Trees

STUDENT TIP Decision trees can become complex, so we illustrate two of them in this section.

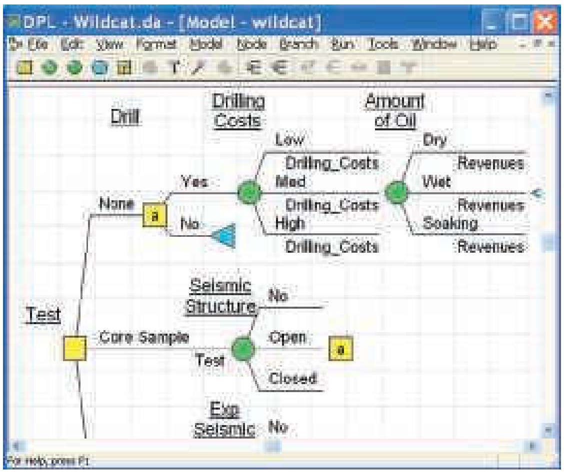
Decisions that lend themselves to display in a decision table also lend themselves to display in a decision tree. We will therefore analyze some decisions using decision trees. Although the use of a decision table is convenient in problems having one set of decisions and one set of states of nature, many problems include *sequential* decisions and states of nature.

Decision tree A graphical means of analyzing decision alternatives and states of nature.

When there are two or more sequential decisions, and later decisions are based on the outcome of prior ones, the decision tree approach becomes appropriate. A **decision tree** is a graphic display of the decision process that indicates decision alternatives, states of nature and their respective probabilities, and payoffs for each combination of decision alternative and state of nature.

Expected monetary value (EMV) is the most commonly used criterion for decision tree analysis. One of the first steps in such analysis is to graph the decision tree and to specify the monetary consequences of all outcomes for a particular problem.

Stockbyte/Getty Images



Screenshot from DPL Software. Reprinted with permission.

When Tomco Oil had to decide which of its new Kentucky lease areas to drill for oil, it turned to decision tree analysis. The 74 different factors, including geological, engineering, economic, and political factors, became much clearer. Decision tree software such as DPL (shown here), Tree Plan, and Supertree allow decision problems to be analyzed with less effort and greater depth than ever before.

Analyzing problems with *decision trees* involves five steps:

1. Define the problem.
2. Structure or draw the decision tree.
3. Assign probabilities to the states of nature.
4. Estimate payoffs for each possible combination of decision alternatives and states of nature.
5. Solve the problem by computing the expected monetary values (EMV) for each state-of-nature node. This is done by working *backward*—that is, by starting at the right of the tree and working back to decision nodes on the left.

Example A6

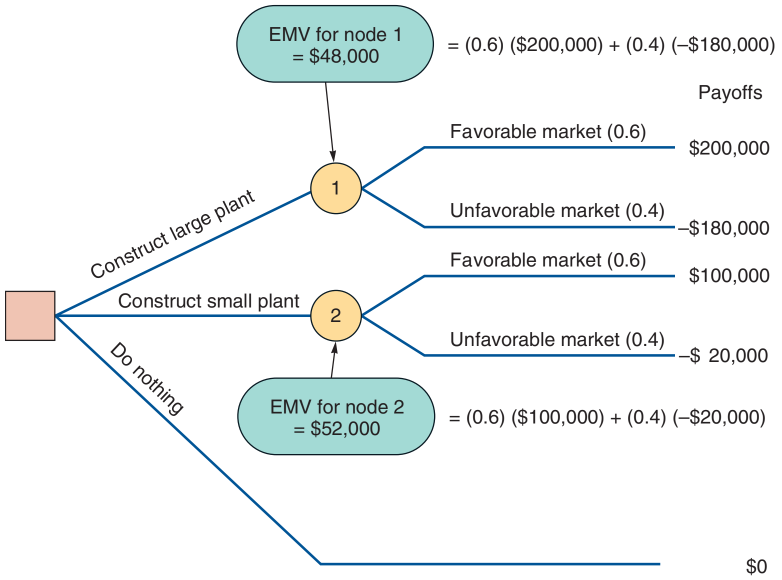
SOLVING A TREE FOR EMV

Getz wants to develop a completed and solved decision tree.

APPROACH ▶ The payoffs are placed at the right-hand side of each of the tree's branches (see Figure A.2). The probabilities (first used by Getz in Example A4) are placed in parentheses next to each

Figure **A.2**

Completed and Solved Decision Tree for Getz Products



LO A.6 *Evaluate* the nodes in a decision tree

state of nature. The expected monetary values for each state-of-nature node are then calculated and placed by their respective nodes. The EMV of the first node is $48,000. This represents the branch from the decision node to "construct a large plant." The EMV for node 2, to "construct a small plant," is $52,000. The option of "doing nothing" has, of course, a payoff of $0.

SOLUTION ▶ The branch leaving the decision node leading to the state-of-nature node with the highest EMV will be chosen. In Getz's case, a small plant should be built.

INSIGHT ▶ This graphical approach is an excellent way for managers to understand all the options in making a major decision. Visual models are often preferred over tables.

LEARNING EXERCISE ▶ Correct Figure A.2 to reflect a $250,000 payoff for "construct large plant/favorable market." [Answer: Change one payoff and recompute the EMV for node 1.]

RELATED PROBLEMS ▶ A.2e, A.8b, A.22a,b, A.24, A.25

EXCEL OM Data File **ModAExA6.xls** can be found in MyOMLab.

A More Complex Decision Tree

When a *sequence* of decisions must be made, decision trees are much more powerful tools than are decision tables. Let's say that Getz Products has two decisions to make, with the second decision dependent on the outcome of the first. Before deciding about building a new plant, Getz has the option of conducting its own marketing research survey, at a cost of $10,000. The information from this survey could help it decide whether to build a large plant, to build a small plant, or not to build at all. Getz recognizes that although such a survey will not provide it with *perfect* information, it may be extremely helpful.

Getz's new decision tree is represented in Figure A.3 of Example A7. Take a careful look at this more complex tree. Note that *all possible outcomes and alternatives* are included in their logical sequence. This procedure is one of the strengths of using decision trees. The manager is forced to examine all possible outcomes, including unfavorable ones. He or she is also forced to make decisions in a logical, sequential manner.

Example A7

A DECISION TREE WITH SEQUENTIAL DECISIONS

Getz Products wishes to develop the new tree for this sequential decision.

APPROACH ▶ Examining the tree in Figure A.3, we see that Getz's first decision point is whether to conduct the $10,000 market survey. If it chooses not to do the study (the lower part of the tree), it can either build a large plant, a small plant, or no plant. This is Getz's second decision point. If the decision is to build, the market will be either favorable (0.6 probability) or unfavorable (0.4 probability). The payoffs for each of the possible consequences are listed along the right-hand side. As a matter of fact, this lower portion of Getz's tree is *identical* to the simpler decision tree shown in Figure A.2.

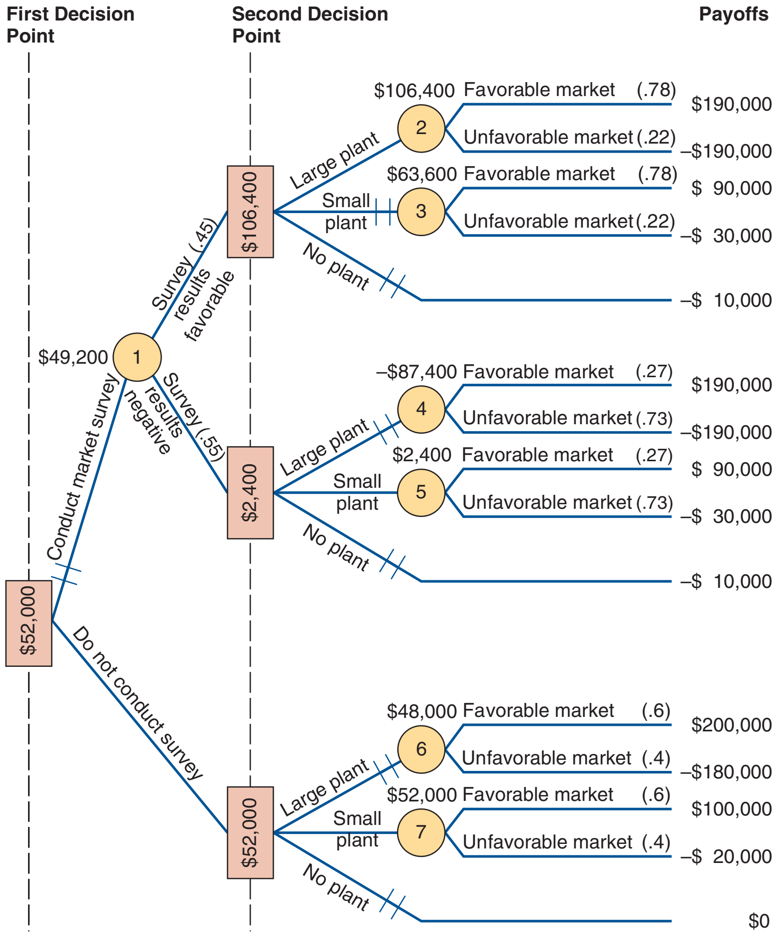
SOLUTION ▶ The upper part of Figure A.3 reflects the decision to conduct the market survey. State-of-nature node number 1 has 2 branches coming out of it. Let us say there is a 45% chance that the survey results will indicate a favorable market for the storage sheds. We also note that the probability is 0.55 that the survey results will be negative.

The rest of the probabilities shown in parentheses in Figure A.3 are all *conditional* probabilities. For example, 0.78 is the probability of a favorable market for the sheds given a favorable result from the market survey. Of course, you would expect to find a high probability of a favorable market given that the research indicated that the market was good. Don't forget, though: There is a chance that Getz's $10,000 market survey did not result in perfect or even reliable information. Any market research study is subject to error. In this case, there remains a 22% chance that the market for sheds will be unfavorable given positive survey results.

Likewise, we note that there is a 27% chance that the market for sheds will be favorable given negative survey results. The probability is much higher, 0.73, that the market will actually be unfavorable given a negative survey.

Figure A.3

Getz Products Decision Tree with Probabilities and EMVs Shown



STUDENT TIP

The short parallel lines mean "prune" that branch, as it is less favorable than another available option and may be dropped.

LO A.7 *Create a decision tree with sequential decisions*

Finally, when we look to the payoff column in Figure A.3, we see that $10,000—the cost of the marketing study—has been subtracted from each of the top 10 tree branches. Thus, a large plant constructed in a favorable market would normally net a $200,000 profit. Yet because the market study was conducted, this figure is reduced by $10,000. In the unfavorable case, the loss of $180,000 would increase to $190,000. Similarly, conducting the survey and building *no plant* now results in a –$10,000 payoff.

With all probabilities and payoffs specified, we can start calculating the expected monetary value of each branch. We begin at the end or right-hand side of the decision tree and work back toward the origin. When we finish, the best decision will be known.

1. Given favorable survey results:

$$\text{EMV (node 2)} = (.78)(\$190{,}000) + (.22)(-\$190{,}000) = \$106{,}400$$
$$\text{EMV (node 3)} = (.78)(\$90{,}000) + (.22)(-\$30{,}000) = \$63{,}600$$

   The EMV of no plant in this case is −$10,000. Thus, if the survey results are favorable, a large plant should be built.

2. Given negative survey results:

$$\text{EMV (node 4)} = (.27)(\$190{,}000) + (.73)(-\$190{,}000) = -\$87{,}400$$
$$\text{EMV (node 5)} = (.27)(\$90{,}000) + (.73)(-\$30{,}000) = \$2{,}400$$

   The EMV of no plant is again −$10,000 for this branch. Thus, given a negative survey result, Getz should build a small plant with an expected value of $2,400.

3. Continuing on the upper part of the tree and moving backward, we compute the expected value of conducting the market survey:

$$\text{EMV (node 1)} = (.45)(\$106{,}400) + (.55)(\$2{,}400) = \$49{,}200$$

4. If the market survey is *not* conducted:

$$\text{EMV (node 6)} = (.6)(\$200{,}000) + (.4)(-\$180{,}000) = \$48{,}000$$
$$\text{EMV (node 7)} = (.6)(\$100{,}000) + (.4)(-\$20{,}000) = \$52{,}000$$

The EMV of no plant is \$0. Thus, building a small plant is the best choice, given the marketing research is not performed.

5. Because the expected monetary value of not conducting the survey is \$52,000—vs. an EMV of \$49,200 for conducting the study—the best choice is to *not seek marketing information*. Getz should build the small plant.

INSIGHT ▶ You can reduce complexity in a large decision tree by viewing and solving a number of smaller trees—start at the end branches of a large one. Take one decision at a time.

LEARNING EXERCISE ▶ Getz estimates that if he conducts a market survey, there is really only a 35% chance the results will indicate a favorable market for the sheds. How does the tree change? [Answer: The EMV of conducting the survey = \$38,800, so Getz should still not do it.]

RELATED PROBLEMS ▶ A.21, A.25–A.29 (A.31, A.32 are available in MyOMLab)

The Poker Decision Process

We opened Module A with ex-dot-commer Paul Phillips's decision to go "all in" at the Legends of Poker tournament in Los Angeles. Example A8 shows how he computed the expected value. Problem A.30 gives you a chance to create a decision tree for this process.

Example A8

PHILLIPS'S POKER DECISION

As on the first page in this module, Paul Phillips is deciding whether to bet all his chips against poker star T.J. Cloutier. Phillips holds a pair of 7s. Phillips reasons that T.J. will fold (with 80% probability) if he does not have a pair of 5s or better, or very high cards like a jack, queen, king, or ace. But he also figures that a call would put \$853,000 into the pot and surmises that even then, there is 45% chance his pair of 7s will win.

APPROACH ▶ Phillips does an expected monetary analysis.

SOLUTION ▶ If T.J. folds,

$$\begin{aligned}\text{EMV} &= (.80)\underbrace{(\$99{,}000)}_{\text{The amount of money already in the pot}} \\ &= \$79{,}200\end{aligned}$$

If T.J. calls,

$$\begin{aligned}\text{EMV} &= \underbrace{.20}_{\text{the chance T.J. will call}}\,[(.45)(\$853{,}000) - \text{Phillips's bet of } \$422{,}000] \\ &= .20\,[\$383{,}850 - \$422{,}000] \\ &= .20\,[-\$38{,}150] = -\$7{,}630\end{aligned}$$

Overall EMV = \$79,200 − \$7,630 = \$71,570

INSIGHT ▶ The overall EMV of \$71,570 indicates that if this decision were to be made many times, the average payoff would be large. So Phillips decides to bet almost all of his chips. As it turns out, T.J. was holding a pair of jacks. Even though Phillips's decision in this instance did not work out, his analysis and procedure was the correct one.

LEARNING EXERCISE ▶ What would happen if the amount of money already in the pot were only \$39,000? [Answer: The overall EMV = \$23,570.]

RELATED PROBLEM ▶ A.30

Summary

This module examines two of the most widely used decision techniques—decision tables and decision trees. These techniques are especially useful for making decisions under risk. Many decisions in research and development, plant and equipment, and even new buildings and structures can be analyzed with these decision models. Problems in inventory control, aggregate planning, maintenance, scheduling, and production control also lend themselves to decision table and decision tree applications.

Key Terms

Big data (p. 679)
Decision table (p. 680)
Maximax (p. 681)
Maximin (p. 681)
Equally likely (p. 681)
Expected monetary value (EMV) (p. 682)
Expected value of perfect information (EVPI) (p. 683)
Expected value *with* perfect information (EVwPI) (p. 683)
Decision tree (p. 684)

Discussion Questions

1. Identify the six steps in the decision process.
2. Give an example of a good decision you made that resulted in a bad outcome. Also give an example of a bad decision you made that had a good outcome. Why was each decision good or bad?
3. What is the *equally likely* decision model?
4. Discuss the differences between decision making under certainty, under risk, and under uncertainty.
5. What is a decision tree?
6. Explain how decision trees might be used in several of the 10 OM decisions.
7. What is the expected value of perfect information (EVPI)?
8. What is the expected value *with* perfect information (EVwPI)?
9. Identify the five steps in analyzing a problem using a decision tree.
10. Why are the maximax and maximin strategies considered to be optimistic and pessimistic, respectively?
11. The expected value criterion is considered to be the rational criterion on which to base a decision. Is this true? Is it rational to consider risk?
12. When are decision trees most useful?

Using Software for Decision Models

Analyzing decision tables is straightforward with Excel, Excel OM, and POM for Windows. When decision trees are involved, Excel OM or commercial packages such as DPL, Tree Plan, and Supertree provide flexibility, power, and ease. POM for Windows will also analyze trees but does not have graphic capabilities.

CREATING AN EXCEL SPREADSHEET TO EVALUATE A DECISION TABLE

In Program A.1, we illustrate how you can build your own Excel spreadsheet to analyze decision making under uncertainty and under risk. The data from Getz Products in Examples A3 and A4 are used. Maximax, maximin, equally likely, and EMV are computed, along with EVPI.

USING EXCEL OM

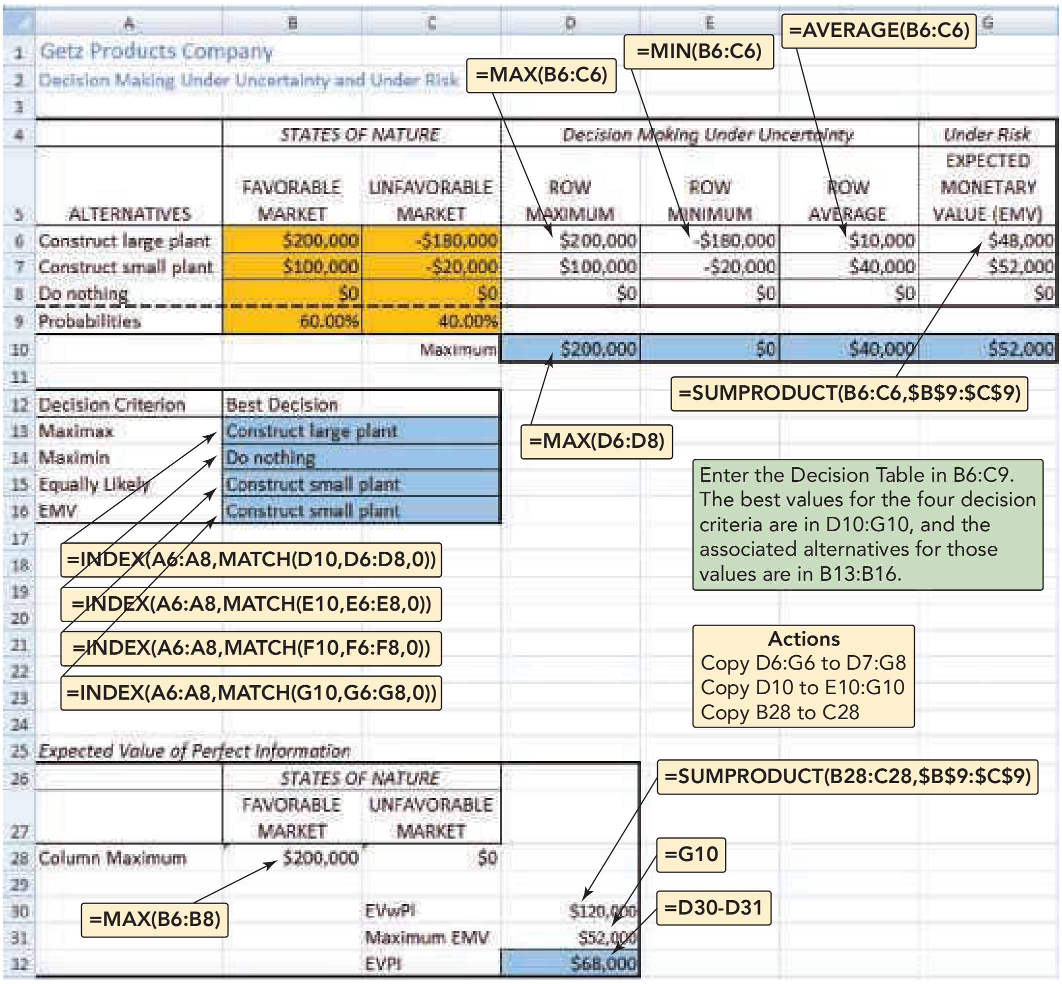
Excel OM allows decision makers to evaluate decisions quickly and to perform sensitivity analysis on the results. Program A.2 uses Excel OM to create the decision tree for Getz Products shown earlier in Example A6. The tool to create the tree is seen in the window on the right.

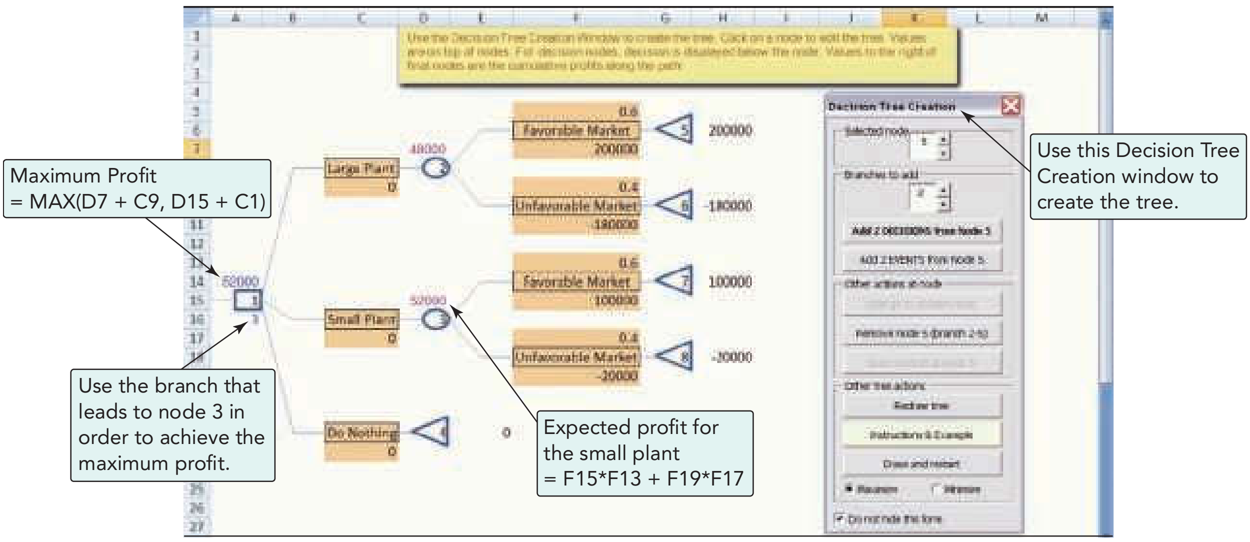
USING POM FOR WINDOWS

POM for Windows can be used to calculate all of the information described in the decision tables and decision trees in this module. For details on how to use this software, please refer to Appendix IV.

Program **A.1**

An Excel Spreadsheet for Analyzing Data in Examples A3 and A4 for Getz Products





Program **A.2**

Getz Products' Decision Tree Using Excel OM

Solved Problems

Virtual Office Hours help is available in MyOMLab.

SOLVED PROBLEM A.1

Stella Yan Hua is considering the possibility of opening a small dress shop on Fairbanks Avenue, a few blocks from the university. She has located a good mall that attracts students. Her options are to open a small shop, a medium-sized shop, or no shop at all. The market for a dress shop can be good, average, or bad. The probabilities for these three possibilities are .2 for a good market, .5 for an average market, and .3 for a bad market. The net profit or loss for the medium-sized or small shops for the various market conditions are given in the adjacent table. Building no shop at all yields no loss and no gain. What do you recommend?

	STATES OF NATURE		
ALTERNATIVES	GOOD MARKET ($)	AVERAGE MARKET ($)	BAD MARKET ($)
Small shop	75,000	25,000	–40,000
Medium-sized shop	100,000	35,000	–60,000
No shop	0	0	0
Probabilities	.20	.50	.30

SOLUTION

The problem can be solved by computing the expected monetary value (EMV) for each alternative:

$$\text{EMV (Small shop)} = (.2)(\$75{,}000) + (.5)(\$25{,}000) + (.3)(-\$40{,}000) = \$15{,}500$$
$$\text{EMV (Medium-sized shop)} = (.2)(\$100{,}000) + (.5)(\$35{,}000) + (.3)(-\$60{,}000) = \$19{,}500$$
$$\text{EMV (No shop)} = (.2)(\$0) + (.5)(\$0) + (.3)(\$0) = \$0$$

As you can see, the best decision is to build the medium-sized shop. The EMV for this alternative is $19,500.

SOLVED PROBLEM A.2

T.S. Amer's Ski Shop in Nevada has a 100-day season. T.S. has established the probability of various store traffic, based on historical records of skiing conditions, as indicated in the table to the right. T.S. has four merchandising plans, each focusing on a popular name brand. Each plan yields a daily net profit as noted in the table. He also has a meteorologist friend who, for a small fee, will accurately tell tomorrow's weather so T.S. can implement one of his four merchandising plans.

a) What is the expected monetary value (EMV) under risk?
b) What is the expected value *with* perfect information (EVwPI)?
c) What is the expected value of perfect information (EVPI)?

	TRAFFIC IN STORE BECAUSE OF SKI CONDITIONS (STATES OF NATURE)			
DECISION ALTERNATIVES (MERCHANDISING PLAN FOCUSING ON:)	1	2	3	4
Patagonia	$40	92	20	48
North Face	50	84	10	52
Cloud Veil	35	80	40	64
Columbia	45	72	10	60
Probabilities	.20	.25	.30	.25

SOLUTION

a) The highest expected monetary value under risk is:

$$\text{EMV (Patagonia)} = .20(40) + .25(92) + .30(20) + .25(48) = \$49$$
$$\text{EMV (North Face)} = .20(50) + .25(84) + .30(10) + .25(52) = \$47$$
$$\text{EMV (Cloud Veil)} = .20(35) + .25(80) + .30(40) + .25(64) = \$55$$
$$\text{EMV (Columbia)} = .20(45) + .25(72) + .30(10) + .25(60) = \$45$$

So the maximum EMV = $55

b) The expected value *with* perfect information is:

$$\begin{aligned}\text{EVwPI} &= .20(50) + .25(92) + .30(40) + .25(64)\\ &= 10 + 23 + 12 + 16 = \$61\end{aligned}$$

c) The expected value of perfect information is:

$$\text{EVPI} = \text{EVwPI} - \text{Maximum EMV} = 61 - 55 = \$6$$

SOLVED PROBLEM A.3

Daily demand for cases of Tidy Bowl cleaner at Ravinder Nath's Supermarket has always been 5, 6, or 7 cases. Develop a decision tree that illustrates her decision alternatives as to whether to stock 5, 6, or 7 cases.

SOLUTION

The decision tree is shown in Figure A.4.

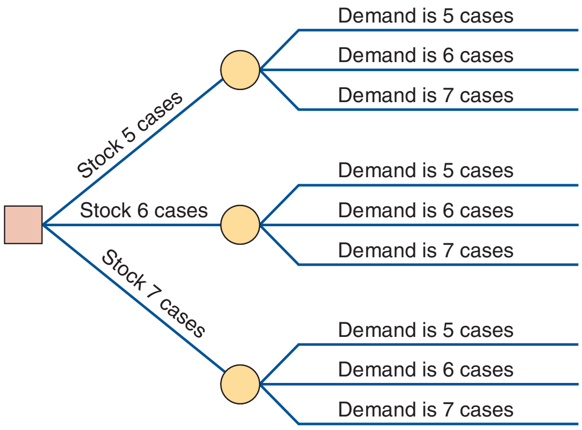


Figure A.4

Demand at Ravinder Nath's Supermarket

Problems

Note: Px means the problem may be solved with POM for Windows and/or Excel OM.

Problems A.1–A.20 relate to Types of Decision-Making Environments

• **A.1** Given the following conditional value table, determine the appropriate decision under uncertainty using:
a) Maximax
b) Maximin
c) Equally likely Px

	STATES OF NATURE		
ALTERNATIVES	VERY FAVORABLE MARKET	AVERAGE MARKET	UNFAVORABLE MARKET
Build new plant	$350,000	$240,000	–$300,000
Subcontract	$180,000	$ 90,000	–$ 20,000
Overtime	$110,000	$ 60,000	–$ 10,000
Do nothing	$ 0	$ 0	$ 0

••• **A.2** Even though independent gasoline stations have been having a difficult time, Ian Langella has been thinking about starting his own independent gasoline station. Ian's problem is to decide how large his station should be. The annual returns will depend on both the size of his station and a number of marketing factors related to the oil industry and demand for gasoline. After a careful analysis, Ian developed the following table:

SIZE OF FIRST STATION	GOOD MARKET ($)	FAIR MARKET ($)	POOR MARKET ($)
Small	50,000	20,000	–10,000
Medium	80,000	30,000	–20,000
Large	100,000	30,000	–40,000
Very large	300,000	25,000	–160,000

For example, if Ian constructs a small station and the market is good, he will realize a profit of $50,000.
a) Develop a decision table for this decision, like the one illustrated in Table A.2 earlier.
b) What is the maximax decision?
c) What is the maximin decision?
d) What is the equally likely decision?
e) Develop a decision tree. Assume each outcome is equally likely, then find the highest EMV. Px

• **A.3** Andrew Thomas, a sandwich vendor at Hard Rock Cafe's annual Rockfest, created a table of conditional values for the various alternatives (stocking decision) and states of nature (size of crowd):

	STATES OF NATURE (DEMAND)		
ALTERNATIVES	BIG	AVERAGE	SMALL
Large stock	$22,000	$12,000	–$2,000
Average stock	$14,000	$10,000	$6,000
Small stock	$ 9,000	$ 8,000	$4,000

The probabilities associated with the states of nature are 0.3 for a big demand, 0.5 for an average demand, and 0.2 for a small demand.
a) Determine the alternative that provides Andrew the greatest expected monetary value (EMV).
b) Compute the expected value of perfect information (EVPI).

•• **A.4** Jeffrey Helm owns a health and fitness center called Bulk-Up in Harrisburg. He is considering adding more floor space to meet increasing demand. He will either add no floor space (N), a moderate area of floor space (M), a large area of floor space (L), or an area of floor space that doubles the size of the facility (D). Demand will either stay fixed, increase slightly, or increase greatly. The following are the changes in Bulk-Up's annual profits under each combination of expansion level and demand change level:

	EXPANSION LEVEL			
DEMAND CHANGE	N	M	L	D
Fixed	$ 0	–$4,000	–$10,000	–$50,000
Slight increase	$2,000	$8,000	$ 6,000	$ 4,000
Major increase	$3,000	$9,000	$20,000	$40,000

Jeffrey is risk averse and wishes to use the maximin criterion.

a) What are his decision alternatives and what are the states of nature?

b) What should he do?

• **A.5** Howard Weiss, Inc., is considering building a sensitive new radiation scanning device. His managers believe that there is a probability of 0.4 that the ATR Co. will come out with a competitive product. If Weiss adds an assembly line for the product and ATR Co. does not follow with a competitive product, Weiss's expected profit is $40,000; if Weiss adds an assembly line and ATR follows suit, Weiss still expects $10,000 profit. If Weiss adds a new plant addition and ATR does not produce a competitive product, Weiss expects a profit of $600,000; if ATR does compete for this market, Weiss expects a loss of $100,000.

a) Determine the EMV of each decision.

b) Compute the expected value of perfect information.

• • • **A.6** Jerry Bildery's factory is considering three approaches for meeting an expected increase in demand. These three approaches are increasing capacity, using overtime, and buying more equipment. Demand will increase either slightly (S), moderately (M), or greatly (G). The profits for each approach under each possible scenario are as follows:

	DEMAND SCENARIO		
APPROACH	**S**	**M**	**G**
Increasing capacity	$700,000	$700,000	$ 700,000
Using overtime	$500,000	$600,000	$1,000,000
Buying equipment	$600,000	$800,000	$ 800,000

Since the goal is to maximize, and Jerry is risk-neutral, he decides to use the *equally likely* decision criterion to make the decision as to which approach to use. According to this criterion, which approach should be used?

• **A.7** The following payoff table provides profits based on various possible decision alternatives and various levels of demand at Robert Klassan's print shop:

	DEMAND	
	LOW	**HIGH**
Alternative 1	$10,000	$30,000
Alternative 2	$ 5,000	$40,000
Alternative 3	–$ 2,000	$50,000

The probability of low demand is 0.4, whereas the probability of high demand is 0.6.

a) What is the highest possible expected monetary value?

b) What is the expected value *with* perfect information (EVwPI)?

c) Calculate the expected value of perfect information for this situation.

• **A.8** Leah Johnson, director of Urgent Care of Brookline, wants to increase capacity to provide low-cost flu shots but must decide whether to do so by hiring another full-time nurse or by using part-time nurses. The table below shows the expected *costs* of the two options for three possible demand levels:

	STATES OF NATURE		
ALTERNATIVES	**LOW DEMAND**	**MEDIUM DEMAND**	**HIGH DEMAND**
Hire full-time	$300	$500	$ 700
Hire part-time	$ 0	$350	$1,000
Probabilities	.2	.5	.3

a) Using expected value, what should Ms. Johnson do?

b) Draw an appropriate decision tree showing payoffs and probabilities.

• • **A.9** Zhu Manufacturing is considering the introduction of a family of new products. Long-term demand for the product group is somewhat predictable, so the manufacturer must be concerned with the risk of choosing a process that is inappropriate. Faye Zhu is VP of operations. She can choose among batch manufacturing or custom manufacturing, or she can invest in group technology. Faye won't be able to forecast demand accurately until after she makes the process choice. Demand will be classified into four compartments: poor, fair, good, and excellent. The table below indicates the payoffs (profits) associated with each process/demand combination, as well as the probabilities of each long-term demand level:

	POOR	**FAIR**	**GOOD**	**EXCELLENT**
Probability	.1	.4	.3	.2
Batch	–$ 200,000	$1,000,000	$1,200,000	$1,300,000
Custom	$ 100,000	$ 300,000	$ 700,000	$ 800,000
Group technology	–$1,000,000	–$ 500,000	$ 500,000	$2,000,000

a) Based on expected value, what choice offers the greatest gain?

b) What would Faye Zhu be willing to pay for a forecast that would accurately determine the level of demand in the future?

• • **A.10** Consider the following decision table, which Joe Blackburn has developed for Vanderbilt Enterprises:

	STATES OF NATURE		
DECISION ALTERNATIVES	**LOW**	**MEDIUM**	**HIGH**
A	$40	$100	$60
B	$85	$ 60	$70
C	$60	$ 70	$70
D	$65	$ 75	$70
E	$70	$ 65	$80
Probability	.40	.20	.40

Which decision alternative maximizes the expected value of the payoff?

• • **A.11** The University of Miami bookstore stocks textbooks in preparation for sales each semester. It normally relies on departmental forecasts and preregistration records to determine how many copies of a text are needed. Preregistration shows 90 operations management students enrolled, but bookstore manager Vaidy Jayaraman has second thoughts, based on his intuition and some historical evidence. Vaidy believes that the distribution of sales may range from 70 to 90 units, according to the following probability model:

Demand	70	75	80	85	90
Probability	.15	.30	.30	.20	.05

This textbook costs the bookstore $82 and sells for $112. Any unsold copies can be returned to the publisher, less a restocking fee and shipping, for a net refund of $36.

a) Construct the table of conditional profits.

b) How many copies should the bookstore stock to achieve highest expected value?

•• **A.12** Palmer Jam Company is a small manufacturer of several different jam products. One product is an organic jam that has no preservatives, sold to retail outlets. Susan Palmer must decide how many cases of jam to manufacture each month. The probability that demand will be 6 cases is .1, for 7 cases it is .3, for 8 cases it is .5, and for 9 cases it is .1. The cost of every case is $45, and the price Susan gets for each case is $95. Unfortunately, any cases not sold by the end of the month are of no value as a result of spoilage. How many cases should Susan manufacture each month? PX

•• **A.13** Deborah Hollwager, a concessionaire for the Amway Center in Orlando, has developed a table of conditional values for the various alternatives (stocking decisions) and states of nature (size of crowd):

	STATES OF NATURE (SIZE OF CROWD)		
ALTERNATIVES	**LARGE**	**AVERAGE**	**SMALL**
Large inventory	$20,000	$10,000	–$2,000
Average inventory	$15,000	$12,000	$6,000
Small inventory	$ 9,000	$ 6,000	$5,000

If the probabilities associated with the states of nature are 0.3 for a large crowd, 0.5 for an average crowd, and 0.2 for a small crowd, determine:

a) The alternative that provides the greatest expected monetary value (EMV).
b) The expected value of perfect information (EVPI). PX

•••• **A.14** The city of Belgrade, Serbia, is contemplating building a second airport to relieve congestion at the main airport and is considering two potential sites, X and Y. Hard Rock Hotels would like to purchase land to build a hotel at the new airport. The value of land has been rising in anticipation and is expected to skyrocket once the city decides between sites X and Y. Consequently, Hard Rock would like to purchase land now. Hard Rock will sell the land if the city chooses not to locate the airport nearby. Hard Rock has four choices: (1) buy land at X, (2) buy land at Y, (3) buy land at both X and Y, or (4) do nothing. Hard Rock has collected the following data (which are in millions of euros):

	SITE X	**SITE Y**
Current purchase price	27	15
Profits if airport and hotel built at this site*	45	30
Sale price if airport not built at this site	9	6

*The second row of the table represents net operating profits from the hotel, not including the upfront cost of land.

Hard Rock determines there is a 45% chance the airport will be built at X (hence, a 55% chance it will be built at Y).

a) Set up the decision table.
b) What should Hard Rock decide to do to maximize total net profit? PX

Additional problems **A.15–A.20** *are available in* MyOMLab.

Problems A.21–A.32 relate to Decision Trees

••• **A.21** Ronald Lau, chief engineer at South Dakota Electronics, has to decide whether to build a new state-of-the-art processing facility. If the new facility works, the company could realize a profit of $200,000. If it fails, South Dakota Electronics could lose $180,000. At this time, Lau estimates a 60% chance that the new process will fail.

The other option is to build a pilot plant and then decide whether to build a complete facility. The pilot plant would cost $10,000 to build. Lau estimates a 50–50 chance that the pilot plant will work. If the pilot plant works, there is a 90% probability that the complete plant, if it is built, will also work. If the pilot plant does not work, there is only a 20% chance that the complete project (if it is constructed) will work. Lau faces a dilemma. Should he build the plant? Should he build the pilot project and then make a decision? Help Lau by analyzing this problem. PX

•• **A.22** Dwayne Whitten, president of Whitten Industries, is considering whether to build a manufacturing plant in north Texas. His decision is summarized in the following table:

ALTERNATIVES	FAVORABLE MARKET	UNFAVORABLE MARKET
Build large plant	$400,000	–$300,000
Build small plant	$ 80,000	–$ 10,000
Don't build	$ 0	$ 0
Market probabilities	0.4	0.6

a) Construct a decision tree.
b) Determine the best strategy using expected monetary value (EMV).
c) What is the expected value of perfect information (EVPI)? PX

•• **A.23** Deborah Kellogg buys Breathalyzer test sets for the Winter Park Police Department. The quality of the test sets from her two suppliers is indicated in the following table:

PERCENT DEFECTIVE	PROBABILITY FOR WINTER PARK TECHNOLOGY	PROBABILITY FOR DAYTON ENTERPRISES
1	.70	.30
3	.20	.30
5	.10	.40

For example, the probability of getting a batch of tests that are 1% defective from Winter Park Technology is .70. Because Kellogg orders 10,000 tests per order, this would mean that there is a .70 probability of getting 100 defective tests out of the 10,000 tests if Winter Park Technology is used to fill the order. A defective Breathalyzer test set can be repaired for $0.50. Although the quality of the test sets of the second supplier, Dayton Enterprises, is lower, it will sell an order of 10,000 test sets for $37 less than Winter Park.


Jabiru/Shutterstock

a) Develop a decision tree.
b) Which supplier should Kellogg use? PX

• **A.24** Joseph Biggs owns his own ice cream truck and lives 30 miles from a Florida beach resort. The sale of his products is highly dependent on his location and on the weather. At the resort, his profit will be \$120 per day in fair weather, \$10 per day in bad weather. At home, his profit will be \$70 in fair weather and \$55 in bad weather. Assume that on any particular day, the weather service suggests a 40% chance of foul weather.

a) Construct Joseph's decision tree.
b) What decision is recommended by the expected value criterion? PX

•• **A.25** Jonatan Jelen is considering opening a bicycle shop in New York City. Jonatan enjoys biking, but this is to be a business endeavor from which he expects to make a living. He can open a small shop, a large shop, or no shop at all. Because there will be a 5-year lease on the building that Jonatan is thinking about using, he wants to make sure he makes the correct decision. Jonatan is also thinking about hiring his old marketing professor to conduct a marketing research study to see if there is a market for his services. The results of such a study could be either favorable or unfavorable. Develop a decision tree for Jonatan. PX

•• **A.26** F. J. Brewerton Retailers, Inc., must decide whether to build a small or a large facility at a new location in Omaha. Demand at the location will either be low or high, with probabilities 0.4 and 0.6, respectively. If Brewerton builds a small facility and demand proves to be high, he then has the option of expanding the facility. If a small facility is built and demand proves to be high, and then the retailer expands the facility, the payoff is \$270,000. If a small facility is built and demand proves to be high, but Brewerton then decides not to expand the facility, the payoff is \$223,000.

If a small facility is built and demand proves to be low, then there is no option to expand and the payoff is \$200,000. If a large facility is built and demand proves to be low, Brewerton then has the option of stimulating demand through local advertising. If he does not exercise this option, then the payoff is \$40,000. If he does exercise the advertising option, then the response to advertising will either be modest or sizable, with probabilities of 0.3 and 0.7, respectively. If the response is modest, the payoff is \$20,000. If it is sizable, the payoff is \$220,000. Finally, if a large facility is built and demand proves to be high, then no advertising is needed and the payoff is \$800,000.

a) What should Brewerton do to maximize his expected payoff?
b) What is the value of this expected payoff?

••• **A.27** Philip Musa can build either a large electronics section or a small one in his Birmingham drugstore. He can also gather additional information or simply do nothing. If he gathers additional information, the results could suggest either a favorable or an unfavorable market, but it would cost him \$3,000 to gather the information. Musa believes that there is a 50–50 chance that the information will be favorable. If the market is favorable, Musa will earn \$15,000 with a large section or \$5,000 with a small one. With an unfavorable electronics market, however, Musa could lose \$20,000 with a large section or \$10,000 with a small section. Without gathering additional information, Musa estimates that the probability of a favorable market is .7. A favorable report from the study would increase the probability of a favorable market to .9. Furthermore, an unfavorable report from the additional information would decrease the probability of a favorable market to .4. Of course, Musa could ignore these numbers and do nothing. What is your advice to Musa?

•••• **A.28** Jeff Kaufmann's machine shop sells a variety of machines for job shops. A customer wants to purchase a model XPO2 drilling machine from Jeff's store. The model XPO2 sells for \$180,000, but Jeff is out of XPO2s. The customer says he will wait for Jeff to get a model XPO2 in stock. Jeff knows that there is a wholesale market for XPO2s from which he can purchase an XPO2. Jeff can buy an XPO2 today for \$150,000, or he can wait a day and buy an XPO2 (if one is available) tomorrow for \$125,000. If at least one XPO2 is still available tomorrow, Jeff can wait until the day after tomorrow and buy an XPO2 (if one is still available) for \$110,000.

There is a 0.40 probability that there will be no model XPO2s available tomorrow. If there are model XPO2s available tomorrow, there is a 0.70 probability that by the day after tomorrow, there will be no model XPO2s available in the wholesale market. Three days from now, it is certain that no model XPO2s will be available on the wholesale market. What is the maximum expected profit that Jeff can achieve? What should Jeff do?

•••• **A.29** Louisiana is busy designing new lottery scratch-off games. In the latest game, Bayou Boondoggle, the player is instructed to scratch off one spot: A, B, or C. A can reveal "Loser," "Win \$1," or "Win \$50." B can reveal "Loser" or "Take a Second Chance." C can reveal "Loser" or "Win \$500." On the second chance, the player is instructed to scratch off D or E. D can reveal "Loser" or "Win \$1." E can reveal "Loser" or "Win \$10." The probabilities at A are .9, .09, and .01. The probabilities at B are .8 and .2. The probabilities at C are .999 and .001. The probabilities at D are .5 and .5. Finally, the probabilities at E are .95 and .05. Draw the decision tree that represents this scenario. Use proper symbols and label all branches clearly. Calculate the expected value of this game.

•••• **A.30** On the opening page of Module A and in Example A8, we follow the poker decision made by Paul Phillips against veteran T.J. Cloutier. Create a decision tree that corresponds with the decision made by Phillips. PX

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Additional problems **A.31–A.32** *are available in* MyOMLab.

CASE STUDY

Warehouse Tenting at the Port of Miami

The Collector's Choice Inc. (CCI), a luxury car import company, has an old warehouse at the Port of Miami, Florida, where it temporarily stores expensive sports cars and automotive parts that arrive from Europe. This summer, CCI has noticed that the termite infestation in the warehouse has escalated to a point where tenting cannot be postponed anymore. (Tenting is the process of wrapping a building inside a huge tent that is subsequently filled with a poisonous gas capable of killing most forms of life inside, including insects, plants, pets, and human beings.) CCI's pest control company's contract specifies a to-do list of pre-tenting tasks, which include:

- Turning off all air-conditioning units and opening all windows of the warehouse
- Turning off all internal and external lights, including those operating on a timer
- Pruning all outdoor vegetation at least 18″ away from the warehouse
- Soaking the soil around the warehouse on the first day of tenting

Halima Ahkdar/Shutterstock

The requirement of opening all windows is particularly worrisome to CCI because it means turning off the alarm system, leaving the warehouse vulnerable to burglary for 48 hours—the required amount of time for the poisonous gas to do its job. Therefore, Alex Ferrari, the warehouse manager, is thinking about hiring a security company to monitor the facility during that period. CCI's property insurance deductible is $25,000, and Alex is assuming that if thieves are willing to enter a building full of poisonous gas to steal something, they would certainly take more than $25,000 worth of parts—or even an entire car!

After making a few phone calls, Alex gets in touch with ProGuard, a trustworthy local security company that charges $150 per hour to have a security guard stationed outside their warehouse. The city of Miami police records indicate that about 30% of businesses that left their facilities unattended during tenting reported stolen property in the past 3 years. Although Alex thinks ProGuard's prices are reasonable, and having a guard outside the warehouse would certainly help, he is still not sure whether it is worth spending the extra money. After all, ProGuard's contract does not guarantee the protection it provides is infallible. In fact, an analysis of the company's records indicates that 3% of their clients were burglarized over the past 3 years. (Despite this figure, ProGuard is still the best security company in the area.)

Discussion Questions

1. Create a decision tree analysis to help decide whether Alex Ferrari should hire ProGuard's services.
2. Come up with a simple rule of thumb that can be applied to decisions of this nature, given any deductible amount d, extra surveillance cost c, and burglary probabilities p_1 (without surveillance) and p_2 (with surveillance).
3. Does your decision based on the tree guarantee success? Why or why not?

Source: Professor Tallys Yunes, University of Miami. Reprinted with permission.

- **Additional Case Studies:** Visit MyOMLab for these additional free case studies:
  Arctic, Inc.: A refrigeration company has several major options with regard to capacity and expansion.
  Ski Right Corp.: Which of four manufacturers should be selected to manufacture ski helmets?
  Tom Tucker's Liver Transplant: An executive must decide whether or not to opt for a dangerous surgery.

Endnote

1. To review these other statistical terms, refer to Tutorial 1, "Statistical Review for Managers," in MyOMLab.

Module A *Rapid* Review

Main Heading | **Review Material** | **MyOMLab**

THE DECISION PROCESS IN OPERATIONS
(pp. 678–679)

To achieve the goals of their organizations, managers must understand how decisions are made and know which decision-making tools to use. Overcoming uncertainty is a manager's mission.

Decision tables and decision trees are used in a wide number of OM situations.

- **Big data**—The huge amount of economic, production, and consumer data now being collected in digital form.

Concept Questions: 1.1–1.4

FUNDAMENTALS OF DECISION MAKING
(pp. 679–680)

Alternative—A course of action or strategy that may be chosen by a decision maker.

State of nature—An occurrence or a situation over which a decision maker has little or no control.

Symbols used in a decision tree:

1. □—A decision node from which one of several alternatives may be selected.

2. ○—A state-of-nature node out of which one state of nature will occur.

When constructing a decision tree, we must be sure that all alternatives and states of nature are in their correct and logical places and that we include *all* possible alternatives and states of nature, usually including the "do nothing" option.

Concept Questions: 2.1–2.4

DECISION TABLES
(p. 680)

- **Decision table**—A tabular means of analyzing decision alternatives and states of nature.

A decision table is sometimes called a payoff table. For any alternative and a particular state of nature, there is a *consequence*, or an *outcome*, which is usually expressed as a monetary value; this is called the *conditional value*.

Concept Questions: 3.1–3.4

TYPES OF DECISION-MAKING ENVIRONMENTS
(pp. 681–684)

There are three decision-making environments: (1) decision making under uncertainty, (2) decision making under risk, and (3) decision making under certainty.

When there is complete *uncertainty* about which state of nature in a decision environment may occur (i.e., when we cannot even assess probabilities for each possible outcome), we rely on three decision methods: (1) maximax, (2) maximin, and (3) equally likely.

- **Maximax**—A criterion that finds an alternative that maximizes the maximum outcome.
- **Maximin**—A criterion that finds an alternative that maximizes the minimum outcome.
- **Equally likely**—A criterion that assigns equal probability to each state of nature.

Maximax is also called an "optimistic" decision criterion, while maximin is also called a "pessimistic" decision criterion. Maximax and maximin present best case/worst case planning scenarios.

Decision making under risk relies on probabilities. The states of nature must be mutually exclusive and collectively exhaustive, and their probabilities must sum to 1.

- **Expected monetary value (EMV)**—The expected payout or value of a variable that has different possible states of nature, each with an associated probability.

The EMV represents the expected value or *mean* return for each alternative *if we could repeat this decision (or similar types of decisions) a large number of times.*

The EMV for an alternative is the sum of all possible payoffs from the alternative, each weighted by the probability of that payoff occurring:

$$\begin{aligned}\text{EMV (Alternative } i) = {} & (\text{Payoff of 1st state of nature}) \\ & \times (\text{Probability of 1st of state of nature}) \\ & + (\text{Payoff of 2nd state of nature}) \times (\text{Probability of 2nd state of nature}) \\ & + \ldots + (\text{Payoff of last state of nature}) \times (\text{Probability of last state of nature})\end{aligned}$$

- **Expected value of perfect information (EVPI)**—The difference between the payoff under perfect information and the payoff under risk.
- **Expected value *with* perfect information (EVwPI)**—The expected (average) return if perfect information is available.

EVPI represents an upper bound on what you would be willing to spend on state-of-nature information:

$$\text{EVPI} = \text{EVwPI} - \text{Maximum EMV}$$

$$\begin{aligned}\text{EVwPI} = {} & (\text{Best outcome for 1st state of nature}) \times (\text{Probability of 1st state of nature}) \\ & + (\text{Best outcome for 2nd state of nature}) \times (\text{Probability of 2nd state of nature}) \\ & + \ldots + (\text{Best outcome for last state of nature}) \times (\text{Probability of last state of nature})\end{aligned}$$

Concept Questions: 4.1–4.4

Problems: A.1–A.20

Virtual Office Hours for Solved Problems: A.1, A.2

Module A *Rapid Review* *continued*

Main Heading | **Review Material** | MyOMLab

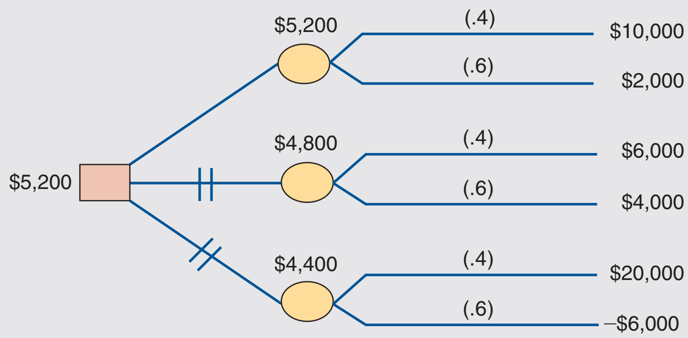
DECISION TREES
(pp. 684–688)

When there are two or more sequential decisions, and later decisions are based on the outcome of prior ones, the decision tree (as opposed to decision table) approach becomes appropriate.

- **Decision tree**—A graphical means of analyzing decision alternatives and states of nature.

Analyzing problems with *decision trees* involves five steps:

1. Define the problem.
2. Structure or draw the decision tree.
3. Assign probabilities to the states of nature.
4. Estimate payoffs for each possible combination of decision alternatives and states of nature.
5. Solve the problem by computing the expected monetary values (EMV) for each state-of-nature node. This is done by working *backward*—that is, by starting at the right of the tree and working back to decision nodes on the left:



Decision trees force managers to examine all possible outcomes, including unfavorable ones. A manager is also forced to make decisions in a logical, sequential manner. Short parallel lines on a decision tree mean "prune" that branch, as it is less favorable than another available option and may be dropped.

Concept Questions: 5.1–5.4

Problems: A.21–A.32

Virtual Office Hours for Solved Problem: A.3

Self Test

- **Before taking the self-test,** refer to the learning objectives listed at the beginning of the module and the key terms listed at the end of the module.

LO A.1 On a decision tree, at each state-of-nature node:
a) the alternative with the greatest EMV is selected.
b) an EMV is calculated.
c) all probabilities are added together.
d) the branch with the highest probability is selected.

LO A.2 In decision table terminology, a course of action or a strategy that may be chosen by a decision maker is called a(n):
a) payoff.
b) alternative.
c) state of nature.
d) all of the above.

LO A.3 If probabilities are available to the decision maker, then the decision-making environment is called:
a) certainty. **b)** uncertainty.
c) risk. **d)** none of the above.

LO A.4 What is the EMV for Alternative 1 in the following decision table?

	STATE OF NATURE	
Alternative	***S1***	***S2***
A1	$15,000	$20,000
A2	$10,000	$30,000
Probability	0.30	0.70

a) $15,000 **b)** $17,000
c) $17,500 **d)** $18,500
e) $20,000

LO A.5 The most that a person should pay for perfect information is:
a) the EVPI.
b) the maximum EMV minus the minimum EMV.
c) the minimum EMV.
d) the maximum EMV.

LO A.6 On a decision tree, once the tree has been drawn and the payoffs and probabilities have been placed on the tree, the analysis (computing EMVs and selecting the best alternative):
a) is done by working backward (starting on the right and moving to the left).
b) is done by working forward (starting on the left and moving to the right).
c) is done by starting at the top of the tree and moving down.
d) is done by starting at the bottom of the tree and moving up.

LO A.7 A decision tree is preferable to a decision table when:
a) a number of sequential decisions are to be made.
b) probabilities are available.
c) the maximax criterion is used.
d) the objective is to maximize regret.

Answers: LO A.1. b; LO A.2. b; LO A.3. c; LO A.4. d; LO A.5. a; LO A.6. a; LO A.7. a.