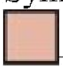
What makes the difference between a good decision and a bad decision? A "good" decision—one that uses analytic decision making—is based on logic and considers all available data and possible alternatives. It also follows these six steps:

- **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.

Throughout this book, we have introduced a broad range of mathematical models and tools that help operations managers make better decisions. Effective operations depend on careful decision making. Fortunately, there are a whole variety of analytic tools to help make these decisions. This module introduces two of them—decision tables and decision trees. They are used in a wide number of OM situations, ranging from new-product analysis (Chapter 5), to capacity planning (Supplement 7), to location planning (Chapter 8), to supply-chain disaster planning (Supplement 11), to scheduling (Chapter 15), and to maintenance planning (Chapter 17).

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.

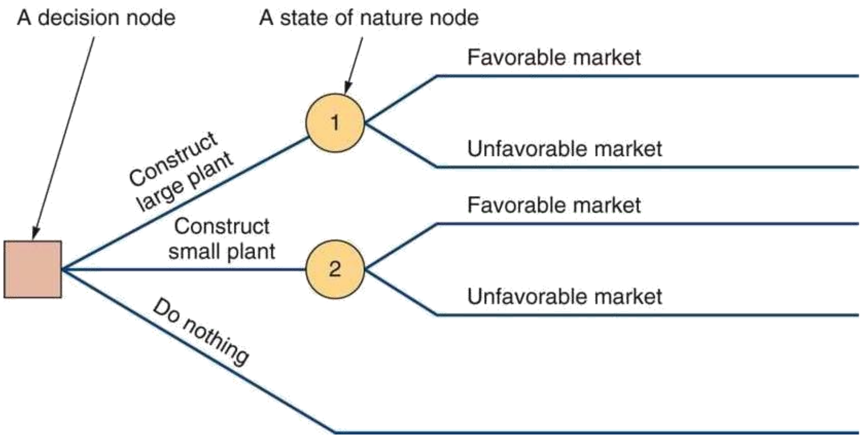
INSIGHT We never want to overlook the option of "doing nothing," as that is usually a possible decision.

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.14a, A.15a, A.17a, A.18

LO1 *Create* a simple decision tree

Figure A.1 Getz Products' Decision Tree



Decision Tables

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**.

Decision table

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

Example A2 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.

LO2 *Build* a decision table

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

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.

STUDENT TIP

Decision tables force logic into decision making.

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

LO3 *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.

Maximax

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

- **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.

Maximin

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

- **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.

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.

SOLUTIONTable 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 ← Maximax	–180,000	$10,000
Construct small plant	$100,000	–$ 20,000	$100,000	–$20,000	$40,000 ← Equally likely
Do nothing	$ 0	$ 0	$ 0	$ 0 ← Maximin	$ 0

- **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

Decision Making Under Risk

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.*

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

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

Example A4 illustrates how to compute the maximum EMV.

LO4 *Calculate* an expected monetary value (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

[1] To review these other statistical terms, refer to Tutorial 1, "Statistical Review for Managers," at www.pearsonhighered.com/heizer or www.myomlab.com.

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.14a, b, A.16a, A.22

EXCEL OM Data File **ModAExA4.xls** can be found at www.pearsonhighered.com/heizer.

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)

LO5 *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)**.

EVPI = Expected value with perfect information − Maximum EMV

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 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.

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:

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

$$= \$120{,}000 - \$52{,}000 = \$68{,}000$$

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.

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.14, A.16

STUDENT TIP

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

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.

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.

Decision tree

A graphical means of analyzing decision alternatives and states 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.