CHAPTER 11

Decision Theory

Chapter Outline

Learning Objectives

After completing this chapter, you should be able to:

1. Outline the characteristics of a decision theory approach to decision making.
2. Describe and give examples of decisions under certainty, risk, and complete uncertainty.
3. Construct a payoff table.
4. Make decisions using maximin, maximax, minimax regret, insufficient reason, and expected value criteria.
5. Determine the expected value of perfect information.
6. Use decision trees to lay out decision alternatives and possible consequences of decisions.
7. Determine whether acquiring additional information in a decision problem will be worth the cost.
8. Analyze the sensitivity of alternatives to probability estimates.

DECISION theory represents a generalized approach to decision making, which often serves as the basis for a wide range of managerial decision making. The decision model includes a list of courses of action that are available and the possible consequences of each course of action. An important factor in making a decision is the degree of certainty associated with the consequences. This can range anywhere from complete certainty to complete uncertainty, and it generally affects the way a decision is reached.

The chapter presents two commonly used decision theory approaches, a payoff table and a decision tree. They provide structure for organizing the relevant information in a format conducive to making rational decisions.

The chapter begins with a description of the characteristics of a decision model.

INTRODUCTION

Decision theory problems are characterized by the following:

1. A list of alternatives.
2. A list of possible future states of nature.
3. Payoffs associated with each alternative/state of nature combination.
4. An assessment of the degree of certainty of possible future events.
5. A decision criterion.

Let's examine each of these.

List of Alternatives

The list of alternatives must be a set of mutually exclusive and collectively exhaustive decisions that are available to the decision maker. (Sometimes, but not always, one of these alternatives will be to "do nothing.")

For example, suppose that a real estate developer must decide on a plan for developing a certain piece of property. After careful consideration, the developer has ruled out "do nothing" and is left with the following list of acceptable alternatives:

1. Residential proposal.
2. Commercial proposal #1.
3. Commercial proposal #2.

States of Nature

States of nature refer to a set of possible future conditions, or *events*, beyond the control of the decision maker, that will be the primary determinants of the eventual consequence of the decision. The states of nature, like the list of alternatives, must be mutually exclusive and collectively exhaustive. Suppose, in the case of the real estate developer, the main factor that will influence the profitability of the development is whether or not a shopping center is built, and the size of the shopping center, if one is built. Suppose that the developer views the possibilities as:

1. No shopping center.
2. Medium-size shopping center.
3. Large shopping center.

Payoffs

In order for a decision maker to be able to rationally approach a decision problem, it is necessary to have some idea of the payoffs that would be associated with each decision alternative and the various states of nature. The payoffs might be profits, revenues, costs, or other measure of value. Usually the measures are financial. They may be weekly, monthly or annual amounts, or they might represent *present values*[1] of future cash flows. Usually, payoffs are estimated values. The more accurate these estimates, the more useful they will be for decision making purposes and the more likely it is that the decision maker will choose an appropriate alternative.

The number of payoffs depends on the number of alternative/state of nature combinations. In the case of the real estate developer, there are three alternatives and three states of nature, so there are $3 \times 3 = 9$ possible payoffs that must be determined.

Degree of Certainty

The approach used by a decision maker often depends on the degree of certainty that exists. There can be different degrees of certainty. One extreme is complete certainty and the other is complete uncertainty. The latter exists when the likelihood of the various states of nature are unknown. Between these two extremes is *risk*, a term that implies that probabilities are known for the states of nature.

Knowledge of the likelihood of each of the states of nature can play an important role in selecting a course of action. Thus, if a decision maker feels that a particular state of nature is highly likely, this will mean that the payoffs associated with that state of nature are also highly likely. This enables the decision maker to focus more closely on probable results of a decision. Consequently, probability estimates for the various states of nature can serve an important function *if they can be obtained*. Of course, in some situations,

[1] A *present value* is a lump sum payment that is the current equivalent to one or a set of future cash amounts using an assumed interest rate.

accurate estimates of probabilities may not be available, in which case the decision maker may have to select a course of action without the benefit of probabilities.

Decision Criterion

The process of selecting one alternative from a list of alternatives is governed by a *decision criterion,* which embodies the decision maker's attitudes toward the decision as well as the degree of certainty that surrounds a decision. For instance, some decision makers are more optimistic, whereas others are more pessimistic. Moreover, some want to maximize gains, whereas others are more concerned with protecting against large losses.

One example of a decision criterion is: "Maximize the expected payoff." Another example is: "Choose the alternative that has the best possible payoff." A variety of the most popular decision criteria are presented in the remainder of this chapter.

THE PAYOFF TABLE

A payoff table is a device a decision maker can use to summarize and organize information relevant to a particular decision. It includes a list of the alternatives, the possible future states of nature, and the payoffs associated with each of the alternative/state of nature combinations. If probabilities for the states of nature are available, these can also be listed. The general format of a payoff table is illustrated in Table 11–1.

Table 11–1 **General Format of a Decision Table**

		State of nature		
		s_1	s_2	s_3
	a_1	V_{11}	V_{12}	V_{13}
Alternatives	a_2	V_{21}	V_{22}	V_{23}
	a_3	V_{31}	V_{32}	V_{33}

where

a_i = the ith alternative
s_j = the jth state of nature
V_{ij} = the value or payoff that will be realized if alternative i is chosen and event j occurs

Table 11–2 **Payoff Table for Real Estate Developer**

		No Center	Medium Center	Large Center
	Residential	$4	16	12
Alternative	Commercial #1	5	6	10
	Commercial #2	−1	4	15

A payoff table for the real estate developer's decision is shown in Table 11–2. The three alternatives under consideration are listed down the left side of the table and the three possible states of nature are listed across the top of the table. The payoffs that are associated with each of the alternative/state-of-nature combinations are shown in the body of the table. Suppose that those values represent profits (or losses) in hundred thousand dollar amounts. Hence, if the residential proposal is chosen and no shopping center is built, the developer will realize a profit of $400,000. Similarly, if the second commercial proposal is selected and no center is built, the developer will lose $100,000.

DECISION MAKING UNDER CERTAINTY

The simplest of all circumstances occurs when decision making takes place in an environment of complete certainty. For example, in the case of the real estate problem, an unexpected early announcement concerning the building of the shopping center could reduce the problem to a situation of certainty.

Thus, if there is an announcement that no shopping center will be built, the developer then can focus on the first column of the payoff table (see Table 11–3). Because the Commercial proposal #1 has the highest payoff in that column ($5), it would be selected. Similarly, if the announcement indicated that a medium-size shopping center is planned, only the middle column of the table would be relevant, and the residential alternative would be selected because its estimated payoff of 16 is the highest of the three payoffs for a medium size shopping center; whereas if a large center is planned, the developer could focus on the last column, selecting the Commercial #2 proposal because it has the highest estimated payoff of 15 in that column.

In summary, when a decision is made under conditions of complete certainty, the attention of the decision maker is focused on the column in the payoff table that corresponds to the state of nature that will occur. The decision

Table 11–3 **If It Is Known that No Shopping Center Will Be Built, Only the First Column Payoffs Would Be Relevant**

	No Center	Medium Center	Large Center
Residential	$4	16	12
Commercial #1	5	6	10
Commercial #2	1	4	15

maker then selects the alternative that will yield the best payoff, given that state of nature.

DECISION MAKING UNDER COMPLETE UNCERTAINTY

Under complete uncertainty, the decision maker either is unable to estimate the probabilities for the occurrence of the different states of nature, or else he or she lacks confidence in available estimates of probabilities, and for that reason, probabilities are not included in the analysis. Still another possibility is that the decision is a one-shot case, with an overriding goal that needs to be satisfied (e.g., a firm may be on the verge of bankruptcy and this might be the last chance to turn things around).

Decisions made under these circumstances are at the opposite end of the spectrum from the certainty case just mentioned. We shall consider four approaches to decision making under complete uncertainty. They are:

1. Maximin.
2. Maximax.
3. Minimax regret.
4. Insufficient reason.

Maximin

The *maximin* strategy is a conservative one; it consists of identifying the worst (minimum) payoff for each alternative, and, then, selecting the alternative that has the best (maximum) of the worst payoffs. In effect, the decision maker is setting a floor on the potential payoff; the actual payoff cannot be less than this amount.

For the real estate problem, the maximin solution is to choose the second alternative, Commercial #1, as illustrated in Table 11–4.

Table 11–4 **Maximin Solution for Real Estate Problem**

	State of nature				
	No Center	Medium Center	Large Center	Row Minimum	
Residential	$4	16	12	4	
Commercial #1	5	6	10	5	← Maximum
Commercial #2	−1	4	15	−1	

Many people view the maximin criterion as pessimistic because they believe that the decision maker must assume that the worst will occur. In fact, if the minimum payoffs are all negative, this view is accurate. Others view the maximin strategy in the same light as a decision to buy insurance: protect against the worst possible events, even though you neither expect them nor want them to occur.

Maximax

The *maximax* approach is the opposite of the previous one: The best payoff for each alternative is identified, and the alternative with the maximum of these is the designated decision.

For the real estate problem, the maximax solution is to choose the residential alternative, as shown in Table 11–5.

Table 11–5 **Maximax Solution for Real Estate Problem**

	State of nature				
	No Center	Medium Center	Large Center	Row Maximum	
Residential	$4	16	12	16	← Maximum
Commercial #1	5	6	10	10	
Commercial #2	−1	4	15	15	

Just as the maximin strategy can be viewed as pessimistic, the maximax strategy can be considered optimistic, that is, choosing the alternative that could result in the maximum payoff.

Minimax Regret

Both the maximax and maximin strategies can be criticized because they focus only on a single, extreme payoff and exclude the other payoffs. Thus, the maximax strategy ignores the possibility that an alternative with a slightly smaller payoff might offer a better overall choice. For example, consider this payoff table:

State of nature

	s_1	s_2	s_3
a_1	−5	16	−10
a_2	15	15	15
a_3	15	15	15

The maximax criterion would lead to selecting alternative a_1, even though two out of the three possible states of nature will result in negative payoffs. Moreover, both other alternatives will produce a payoff that is nearly the same as the maximum, regardless of the state of nature.

A similar example could be constructed to demonstrate comparable weakness of the maximin criterion, which is also due to the failure to consider all payoffs.

An approach that does take all payoffs into account is *minimax regret.* In order to use this approach, it is necessary to develop an *opportunity loss* table. The opportunity loss reflects the difference between each payoff and the best possible payoff in a column (i.e., given a state of nature). Hence, opportunity loss amounts are found by identifying the best payoff in a column and, then, subtracting each of the other values in the column from that payoff. For the real estate problem, the conversion of the orginal payoffs into an opportunity loss table is shown in Table 11–6.

Hence, in column 1, the best payoff is 5; therefore, all payoffs are subtracted from 5 to determine the amount of payoff the decision maker would miss by not having chosen the alternative that would have yielded the best payoff *if that state of nature occurs.* Of course, there is no guarantee that it will occur. Similarly, the best payoff in the column 2 is 16, and all payoffs are

Table 11–6 Opportunity Loss Table for Real Estate Problem

Original Payoff Table

	No Center	Medium Center	Large Center
Residential	$4	16	12
Commercial #1	5	6	10
Commercial #2	−1	4	15
Best payoff in column	5	16	15

Opportunity Loss Table

	No Center	Medium Center	Large Center
Residential	5 − 4 =1	16 − 16 =0	15 − 12 =3
Commercial #1	5 − 5 =0	16 − 6 =10	15 − 10 =5
Commercial #2	5 − −1 =6	16 − 4 =12	15 − 15 =0

subtracted from that number to reflect the opportunity losses that would occur if a decision other than "Residential" was selected *and* a medium-size shopping center turned out to be the state of nature that comes to pass. Thus, for column 3, the opportunity costs evolve by subtracting each payoff from 15. Note that for every column, this results in a value of zero in the opportunity loss table in the same position as the best payoff for each column. For example, the best payoff in the last column of the payoff table is 15, and the corresponding position in the last column of the opportunity loss table is 0.

The values in an opportunity loss table can be viewed as potential "regrets"

Table 11–7 **Identifying the Minimax Regret Alternative**

	Opportunity Losses				
	No Center	Medium Center	Large Center	Maximum Loss	
Residential	1	0	3	3	← Minimum
Commercial #1	0	10	5	10	
Commercial #2	6	12	0	12	

that might be suffered as the result of choosing various alternatives. A decision maker could select an alternative in such a way as to minimize the maximum possible regret. This requires identifying the maximum opportunity loss in each row and, then, choosing the alternative that would yield the best (minimum) of those regrets. As illustrated in Table 11–7, for the real estate problem, this leads to selection of the "Residential" alternative.

Although this approach has resulted in the same choice as the maximax strategy, the reasons are completely different; therefore, it is merely coincidence that the two yielded the same result. Under different circumstances, each can lead to selection of a different alternative.

Although this approach makes use of more information than either maximin or maximax, it still ignores some information and, therefore, can lead to a poor decision. Consider, for example, the opportunity loss table illustrated in Table 11–8. Using minimax regret, a decision maker would be indifferent between alternatives a_2 and a_3, although a_1 would be a better choice because for all but one of the states of nature there would be *no* opportunity loss, and in the worst case, would result in an opportunity loss that exceeded the other worst cases by $1.

Principle of Insufficient Reason

The minimax regret criterion weakness is the inability to factor row differences. Hence, sometimes the minimax regret strategy will lead to a poor decision because it ignores certain information.

The *principle of insufficient reason* offers a method that incorporates more of the information. It treats the states of nature as if each were equally likely, and it focuses on the average payoff for each row, selecting the alternative that has the highest row average.

Table 11–8 **Minimax Regret Can Lead to a Poor Decision**

	Opportunity Loss Table					
	s_1	s_2	s_3	s_4	s_5	Worst in Row
a_1	0	0	0	0	24	24
a_2	23	23	23	23	0	23 ← Minimum Regret
a_3	23	23	23	23	0	23 ← Minimum Regret

The payoff table from which the opportunity losses of Table 11–8 were computed is shown in Table 11–9, along with the row averages. Note how a_1 now stands out compared to the others. In fact, we could have obtained a similar result by finding the row averages for the opportunity loss table and, then, choosing the alternative that had the lowest average.

Thus, the row averages for the opportunity losses presented in Table 11–8 are:

Alternative	Row Average	
a_1	4.8	← Minimum
a_2	18.4	
a_3	18.4	

Table 11–9 **The Principle of Insufficient Reason**

	Payoff Table						
	s_1	s_2	s_3	s_4	s_5	Row Average	
a_1	28	28	28	28	4	23.2	← Maximum
a_2	5	5	5	5	28	9.6	
a_3	5	5	5	5	28	9.6	

Note that in both cases, the difference between the average of a_1 and the average of the other two is the same (13.6). Hence, we could obtain the same result from *either* the payoff table *or* the opportunity loss table; they will both always lead to the same decision.

The basis for the criterion of insufficient reason is that under complete uncertainty, the decision maker should not focus on either high or low payoffs, but should treat all payoffs (actually, all states of nature), as if they were *equally likely.* Averaging row payoffs accomplishes this.

DECISION MAKING UNDER RISK

The essential difference between decision making under complete uncertainty and decision making under partial uncertainty is the presence of *probabilities* for the occurrence of the various states of nature under partial uncertainty. The term *risk* is often used in conjunction with partial uncertainty.

The probabilities may be subjective estimates from managers or from experts in a particular field, or they may reflect historical frequencies. If they are reasonably correct, they provide a decision maker with additional information that can dramatically improve the decision-making process.

The sum of the probabilities for all states of nature must be 1.00. Thus, the real estate developer might estimate the probability of no shopping center being built at .2, the probability of a medium-size shopping center at .5, and the probability of a large shopping center at .3. (Note that .2 + .5 + .3 = 1.0.)

Expected Monetary Value

The *expected monetary value* (EMV) approach provides the decision maker with a value which represents an *average* payoff for each alternative. The best alternative is, then, the one that has the highest expected monetary value.

The average or expected payoff of each alternative is a weighted average: the state of nature probabilities are used to weight the respective payoffs. Thus, the expected monetary value is:

$$EMV_i = \sum_{i=1}^{k} P_j V_{ij} \qquad \textbf{(11–1)}$$

where

EMV_i = the expected monetary value for the ith alternative
P_j = the probability of the jth state of nature
V_{ij} = the estimated payoff for alternative i under state of nature j

For example, using the figures in Table 11–10, we can compute the expected payoffs for the real estate developer's alternatives. The expected monetary value of the residential alternative is

$$EMV_R = .2(\$4) + .5(\$16) + .3(\$12) = \$12.40$$

Table 11–10 Real Estate Payoff Table with Probabilities

Probabilities ⟶	.2	.5	.3		
	No Center	Medium Center	Large Center	Expected Payoff	
Residential	$4	16	12	$12.40	← Maximum
Commercial #1	5	6	10	7.00	
Commercial #2	−1	4	15	6.30	

Similarly, the expected monetary values of the other alternatives are:

$$EMV_{C1} = .2(\$5) + .5(\$6) + .3(\$10) = \$7.00$$
$$EMV_{C2} = .2(\$-1) + .5(\$4) + .3(\$15) = \$6.30$$

Because the residential alternative has the largest expected monetary value, it would be selected using this criterion.

Note that it does *not* necessarily follow that the developer will actually realize a payoff equal to the expected monetary value of a chosen alternative. For example, note that the possible payoffs for the residential proposal are 4, 16, and 12, whereas the expected payoff is $12.40, which is not equal to any of the payoffs. Similarly, the expected payoffs for either of the other alternatives do not equal any of the payoffs in those rows. What, then, is the interpretation of the expected payoff? Simply a long-run average amount; the approximate average amount one could reasonably anticipate for a large number of identical situations.

In contrast to the strategies outlined for decision making under complete uncertainty, which are realistically best used for one-time major decisions, the expected value approach is more suited to an ongoing decision strategy. Over the long run, taking probabilities into account will yield the highest payoff, even though in the short run actual payoffs will tend to be higher or lower than the expected amounts. Conversely, over the long run, a strategy that failed to take probabilities into account would tend to yield lower payoffs than one that does take the probabilities into account.

Expected Opportunity Loss

An alternate method for incorporating probabilities into the decision making process is to use expected opportunity loss (EOL). The approach is nearly identical to the EMV approach, except that a table of opportunity losses is used rather than a table of payoffs. Hence, the opportunity losses for each alternative are weighted by the probabilities of their respective states of nature to compute a long-run average opportunity loss, and the alternative with the *smallest* expected loss is selected as the the best choice.

For the real estate problem, the expected opportunity losses can be calculated as follows:

$$EOL_R = .2(1) + .5(0) + .3(3) = 1.1 \leftarrow \text{Minimum}$$
$$EOL_{C1} = .2(0) + .5(10) + .3(5) = 6.5$$
$$EOL_{C2} = .2(6) + .5(12) + .3(0) = 7.2$$

Note that the EOL approach resulted in the same alternative as the EMV approach. This is more than coincidence; the two methods will always result in the same choice because they are equivalent ways of combining the values; maximizing the payoffs is equivalent to minimizing the opportunity losses.

Expected Value of Perfect Information

It can sometimes be useful for a decision maker to determine the potential benefit of knowing for certain which state of nature is going to prevail. For instance, a decision maker might have the option of delaying a decision until it is evident which state of nature is going to materialize. The obvious benefit of waiting would be to move the decision into the realm of certainty, thereby allowing the decision maker to obtain the maximum possible payoff. Such delays typically will involve a cost of some sort (e.g., higher prices, the cost of an option, storage costs). Hence, the question is whether the cost of waiting outweighs the potential benefits that could be realized by waiting. Or, the decision maker might wonder if it would be worth the cost to refine or eliminate the probabilities of the states of nature (e.g., using marketing research or a better forecasting technique). Although such techniques may not completely eliminate uncertainty, the decision maker often can benefit from knowledge of the upper limit of the potential gain that perfect information would permit.

The *expected value of perfect information* (EVPI) is a measure of the difference between the certain payoff that could be realized under a condition of certainty and the expected payoff under a condition involving risk.

Consider the payoff that the real estate developer could expect under certainty. If the developer knew that no center would be built, Commercial #1 proposal would be chosen with a payoff of 5; if the developer knew a medium-size shopping center would be built, the residential alternative would be chosen for a payoff of 16; and if the developer knew that a large center would be built, Commercial #2 proposal would be chosen for a payoff of 15. Hence, if it were possible to remove the uncertainty surrounding the states of nature, the decision maker could capitalize on that knowledge. Obviously, before investing time or money in eliminating the probabilities, it will be impossible for the decision maker to say which state of nature will turn out to be the one that will occur. However, what can be said is that the probability that perfect information will indicate that no center will be built is .2, that the probability that perfect information will indicate a medium center will be built is .5, and the probability of perfect information indicating a large center is .3. Thus, these probabilities, which are the original state of nature probabilities, can be used to weight the payoffs, one of which will occur under certainty. This is called the *expected payoff under certainty* (EPC), and is computed in the following way for the real estate problem:

$$EPC = .2(5) + .5(16) + .3(15) = 13.5$$

The difference between this figure and the expected payoff under risk (i.e., the EMV) is the expected value of perfect information. Thus,

$$EVPI = EPC - EMV \qquad \textbf{(11–2)}$$

For the real estate problem, with $EPC = 13.5$ and $EMV = 12.4$, we find $EVPI = 13.5 - 12.4 = 1.1$.

The EVPI represents an upper bound on the amount of money the real estate developer would be justified in spending to obtain perfect information. Thus, the real estate developer would be justified in spending up to $110,000 to find out for certain which state of nature will prevail. Of course, it is not always possible to completely remove uncertainty. In such cases, the decision maker must weigh the cost to reduce the uncertainty (i.e., obtain better estimates of the probabilities) against the expected benefits that would yield.

Note that the EVPI is exactly equal to the previously computed EOL. In fact, these two quantities will always be equal. The EOL indicates the expected *opportunity* loss due to imperfect information, which is another way of saying the expected *payoff* that could be achieved by having perfect information. Hence, there are two equivalent ways to determine the expected value of perfect information: subtract the EMV from the expected payoff under certainty, or compute the EOL.

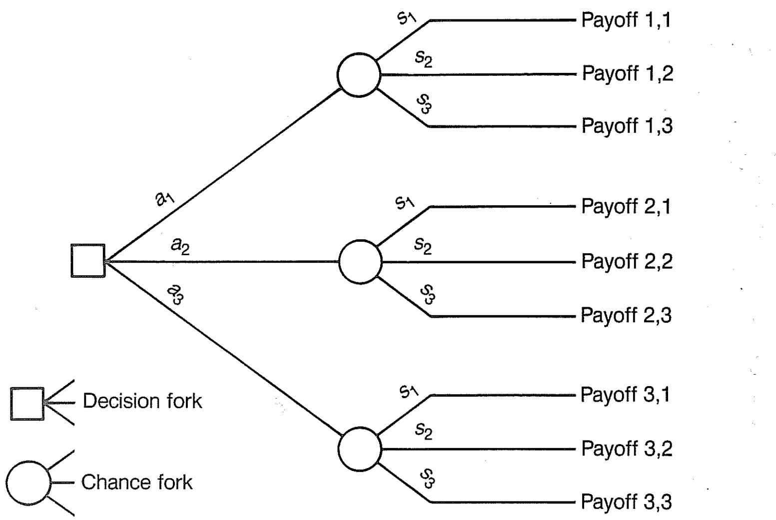
Comment

The expected value approach is particularly useful for decision making when a number of similar decisions must be made; it is a "long-run" approach. For one-shot decisions, especially major ones, other methods (perhaps maximax or maximin) may be preferable. In addition, nonmonetary factors, although not included in a payoff table, may be of considerable importance. Unfortunately, there is no convenient way to include them in an expected value analysis.

DECISION TREES

Decision trees sometimes are used by decision makers to obtain a visual portrayal of decision alternatives and their possible consequences. The term gets its name from the tree-like appearance of the diagram (see Figure 11–1).

Figure 11–1 **Decision Tree Format**



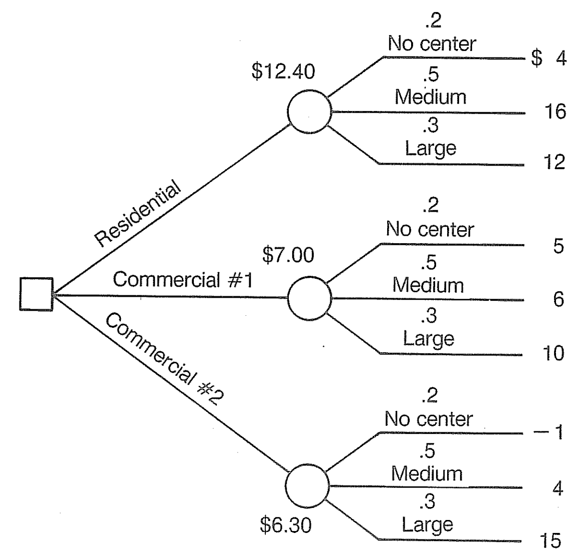
A tree is composed of squares, circles, and lines. The squares indicate decision points while the circles represent chance events. The lines or "branches" that emanate from a square represent alternatives, while the branches which emanate from a circle represent states of nature. The tree is read from right to left.

Decision trees are fairly simple to construct. The decision tree for the real estate developer's problem is shown in Figure 11–2. The dollar amounts along side of each chance node (circle) indicate the expected payoff of the alternative that leads into that particular chance node. The expected payoffs are computed in the same manner as previously described, and, as before, the decision maker will select the alternative with the largest expected payoff if maximizing expected payoff is the decision criterion.

It should be noted that although decision trees represent an alternative approach to payoff tables, they are not commonly used for problems that involve a single decision. Rather, their greatest benefit lies in portraying *sequential* decisions (i.e., a series of chronological decisions). In the case of a single decision, constructing a tree can be cumbersome and time consuming. For example, imagine the decision tree that would be necessary to portray a decision with 7 alternatives and 10 states of nature; there would be 70 payoffs, and, hence, 70 branch-ends on the right side of the tree. Conversely, situations that involve sequential decisions are difficult to represent in payoff tables.

As an example of a sequential decision, suppose that the real estate developer has several options that might be considered after the initial decision. For instance, regardless of which of the three alternatives he chooses, the worst payoff will result if no shopping center is built. Hence, it might be

Figure 11–2 **Decision Tree for Real Estate Developer Problem**



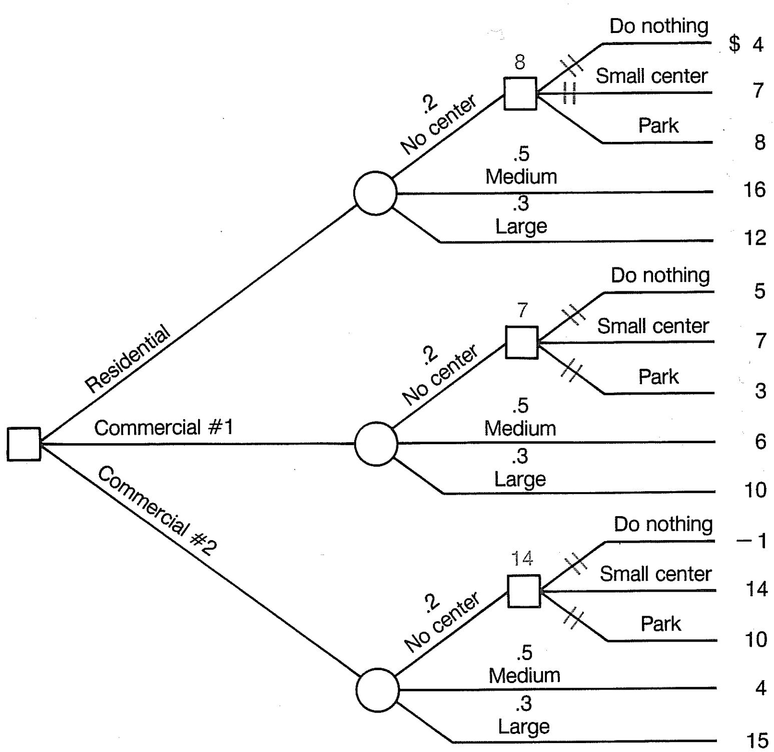
prudent for the developer to plan for that contingency. Thus, the developer might consider certain options. Suppose the developer states that he would consider these additional alternatives in the event that no center is built:

1. Do nothing.
2. Develop a small shopping center.
3. Develop a park.

The tree diagram of Figure 11–2 has been modified to include these additional options, along with their estimated payoffs as supplied by the real estate developer, and it is shown in Figure 11–3. Note that the payoffs for "do nothing" are the same as in the original tree for the event "no center is built."

In order to analyze this modified tree (i.e., to make a choice among the alternatives "Residential," "Commercial #1," and "Commercial #2"), the branches for each possible second decision must be reduced in each instance to a single branch. This is easily accomplished by recognizing that at each of those points, a rational decision maker would simply choose the alternative with the largest payoff. Hence, if "Residential" were chosen initially and no center was built, a park would be selected because it would have the largest payoff. Similarly, if "Commercial #1" was chosen and no center was built, the "small center" option would be chosen because it offers the largest payoff, and if "Commercial #2" were initially chosen and no center was built, the developer would chose the option of building a small center because its

Figure 11–3 **Real Estate Problem with a Second Possible Decision**



payoff is greater than either "do nothing" or "park." Thus, in each case the tree is pruned by cutting the undesirable options and keeping the one best option. This also is illustrated in Figure 11–3. Note that the payoff for the best option, then, becomes the payoff for each "no center" branch. The tree would then be analyzed as previously.

DECISION MAKING WITH ADDITIONAL INFORMATION

Decision makers can sometimes improve decision making by bringing additional information into the process. The additional information can come from a variety of sources. For example, either a market survey might be used to acquire additional information or a forecasting technique might be employed. In certain situations, it may be possible to delay a decision; the passage of time often allows a decision maker to obtain a clearer picture of the future because it shortens the time horizon the decision maker must deal with. Whatever the source of information, the benefit is that *estimates of probabilities* of possible future events tend to become more accurate.

In general, obtaining additional (sample) information includes an associated cost. Consequently, a key question for a decision maker in such circumstances is whether the value of additional information is worth the cost of obtaining that information. The analysis of that type of problem is the subject of this section.

Let's take a look at an example.

An Example

Suppose an advertising manager is trying to decide which of two advertising proposals to use for an upcoming promotion. The manager has developed the following payoff table:

		Market	
		.70 Strong	.30 Weak
Alternative	Print media	40*	20
	Video media	50	10

*($000)

At this point, the manager simply could make a decision using the expected value criterion with the information given. However, suppose that the manager has the option of testing the market, and this testing will provide *additional information* in the form of revised probabilities on whether the market will be strong or weak. If the manager chooses to test the market, it will cost $1,000; the manager, therefore, must decide whether the expected benefit from the test will offset the cost required to conduct the test.

If the manager conducts the test, this will undoubtedly alter the probabilities of a strong and weak market that were originally estimated. In fact, an integral part of the analysis in assessing the value of this sample information involves computing revised probabilities. However, in order to hone in on what we are trying to accomplish, let's suppose that the revised probabilities have been calculated, and consider how the decision maker could use that new information to make a decision.

The market test can show one of two things: a strong market or a weak market. Each result would pertain to the payoff table, but with different probabilities for the states of nature. Suppose these are the two possible results:

If the Market Test Shows a Strong Market

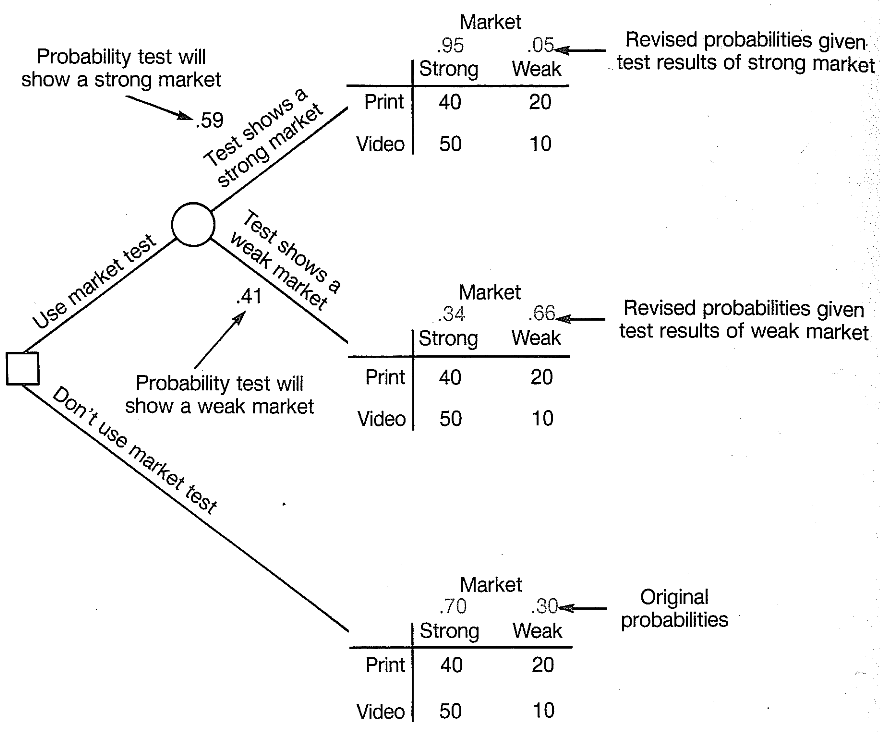
	.95 Strong	.05 Weak
Print	40	20
Video	50	10

If the Market Test Shows a Weak Market

	.34 Strong	.66 Weak
Print	40	20
Video	50	10

Finally, suppose the manager is able to determine that the probability that the market test will show a strong market is .59 and the probability that it will show a weak market is .41.

Figure 11–4 **Conceptual Portrayal of Market Test Example**



The overall problem, given these probabilities, is shown conceptually in the tree diagram of Figure 11–4.

Analysis of the problem will result in determining an expected payoff for the two branches at square node 1. This will enable the manager to select the branch (i.e., alternative) that has the higher expected payoff. Thus, if "use market test" has the higher expected payoff, the manager would select that alternative, assuming the difference between its payoff and the payoff for "don't use market test" is enough to cover the cost ($1,000) of the market test. Of course, if "don't use market test" has the higher expected payoff, the manager would select that alternative because it would not require the cost of the market test.

In order to determine the payoffs for those two branches, it is necessary first to compute the expected monetary value of each of the three payoff tables. These are computed as follows:

	Market .95 Strong	.05 Weak		
Print	40	20	$.95(40) + .05(20) = 39$	
Video	50	10	$.95(50) + .05(10) = 48$	(maximum expected payoff)

	Market .34 Strong	.66 Weak		
Print	40	20	$.34(40) + .66(20) = 26.8$	(maximum expected payoff)
Video	50	10	$.34(50) + .66(10) = 23.6$	

	Market .70 Strong	.30 Weak		
Print	40	20	$.70(40) + .30(20) = 34$	
Video	50	10	$.70(50) + .30(10) = 38$	(maximum expected payoff)

Note that in each instance, we want the alternative (either *print* or *video*) that has the higher expected payoff.

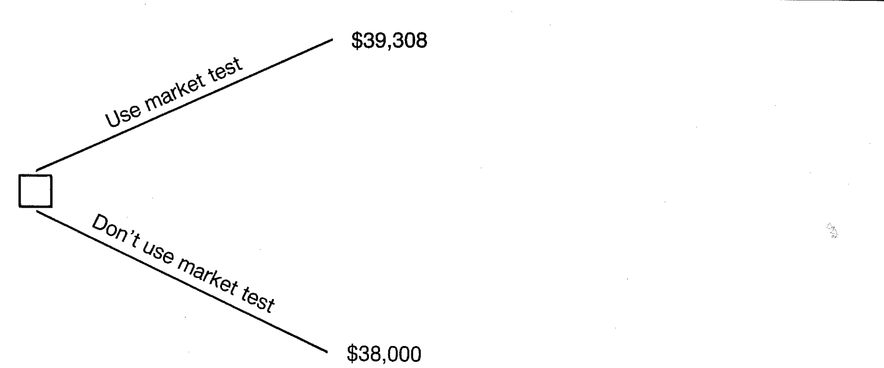
The maximum expected payoff for the original table (i.e., the one with probabilities of .70 and .30) is 38 thousand. This, in effect, is the expected value of the branch "don't use the market test."

To find the expected payoff for the "use market test" branch, we must combine the probability of each possible test result with the expected payoff for that result and, then, sum these. In other words, there is a probability of .59 that the market test will indicate a strong market, in which case the manager will choose the *video* alternative with an expected payoff of 46. Likewise, there is a probability of .41 that the test will show a weak market, and the manager will choose *print* with an expected payoff of 26.8. Hence, the overall or *combined* expected payoff for using the market test is:

$$.59(48) + .41(26.8) = 39.308$$

Thus, our analysis boils down to the results shown in Figure 11–5. Using the market test has an expected value of $39.308 thousand, or $39,308, whereas not using the market test has an expected value of $38 thousand, or $38,000. We can see that using the market test has an expected value

Figure 11–5 **Summary of Analysis of Market Test Example**



that is $308 more than not using the test. Recall, though, that the test will involve an additional cost of $1,000. It would not be prudent to spend $1,000 if the additional expected payoff is only $130. Hence, the manager should not use the market test because to do so would lead to an expected *loss* of $870:

$$\$308 - \$1{,}000 = -\$692$$

The preceding analysis illustrates how a manager can assess the value of additional (sample) information when such information is available. In this instance, we found that the expected gain that would result from using the additional information was outweighed by the cost that would be needed to acquire that additional information.

In sum, we can compute the expected value of sample (additional) information, or EVSI, as:

$$EVSI = \begin{bmatrix}\text{Expected value} \\ \textit{with}\text{ sample} \\ \text{information}\end{bmatrix} - \begin{bmatrix}\text{Expected value} \\ \textit{without}\text{ sample} \\ \text{information}\end{bmatrix} \qquad \textbf{(11–3)}$$

Then, if the *cost* of obtaining the additional information is less than this amount, it would seem reasonable to spend the money to obtain the information. But if the cost equals or exceeds the expected value of the information, it would seem reasonable to *not* spend the additional money needed to obtain the information.

In order to complete our discussion of decision making using additional information, we need to see how the revised probabilities are computed and how the probabilities for the test results are computed. Before doing that, let's take a brief look at a measure that sometimes is used to express the degree of increase in information from a sample (e.g., test results) relative to perfect information.

Efficiency of Sample Information

One way to judge how much information is generated by a sample is to compute the ratio of EVSI to EVPI. This is known as the *efficiency of sample information.* Thus:

$$\text{Efficiency of sample information} = \frac{EVSI}{EVPI} \qquad \textbf{(11–4)}$$

For the preceding example, the probabilities *without* additional information were .70 and .30, and the payoff table was:

	Market .70 Strong	.30 Weak
Print	40	20
Video	50	10

The expected monetary value was 38 (i.e., $38,000). The expected profit under certainty (EPC) is:

$$.70(50) + .30(20) = 41, \text{ or } \$41{,}000$$

(To compute EPC, multiply the best payoff in each column by the column probability and sum the products.)

EVPI is the difference between EPC and EMV. Thus:

$$EVPI = \$41{,}000 - \$38{,}000 = \$3{,}000$$

In the preceding example, it was determined that the EVSI = $308. Hence, the efficiency of the sample information is:

$$\frac{\$308}{\$3{,}000} = .1027$$

This number is interpreted as follows. The number can range from 0 to 1.00. The closer the number is to 1.00, the closer the sample information is to being perfect; the closer the number is to 0, the less the amount of information there is in the sample. Thus, a value such as .1027 is fairly low, meaning that relative to perfect information, the information that could be gained from the market test is small.

Computing the Probabilities

Two sets of probabilities were used in the analysis of sample information: the probabilities of the test results (.59 and .41) and the revised probabilities for the states of nature (i.e., strong and weak markets) given the test results (i.e., .95, .05 and .34, .66). We now turn our attention to the calculation of those values.

A basic piece of information that is necessary to this procedure is the reliability of the source of sample information (in this case, the market test). In assessing this reliability, the manager might make use of historical data on test results versus actual results, expert opinion, or his or her personal judgment of the probabilities. Let's suppose that in this case the manager was able to obtain the reliability information from past records. The reliability information pertains to every possible combination of test result and actual result. The reliability figures for the preceding example are shown in Table 11–11.

Table 11–11 **Reliability of Market Test**

Results of Market Test	Actual State of Nature: *Strong Market*	*Weak Market*
Shows strong market	.80	.10
Shows weak market	.20	.90

The figures indicate that in past cases when the market actually was strong, the market test correctly indicated this information 80 percent of the time, and incorrectly indicated a weak market 20 percent of the time. Moreover, when a weak market existed, the market test incorrecly indicated a strong market 10 percent of the time, while it correctly indicated a weak market 90 percent of the time. (Note that the probabilities in each *column* add to 1.00.) These probabilities are known as *conditional* probabilities because they express the reliability of the sampling device (e.g., market test) *given* the condition of actual market type.

In order to calculate the desired probabilities, we must combine these conditional probabilities with the original *(prior)* probabilities (.70 and .30) that were associated with the original payoff table. We must do this for each of the possible test results.

For a "strong market" test result, the calculations are shown in Table 11–12.

The first column of the table lists the two possible actual market conditions: strong and weak. The next column shows the probability of a market test that will show a strong market, given each possible actual market condition. The prior probabilities are the initial estimates of each type of market condition. Multiplying the prior probabilities by the conditional probabilities yields the *joint* probability of each market condition. The sum of these (e.g., .59) is the probability that a test result will show a strong market. (Note that this is one of the two types of probabilities we set out to compute.) The last column of the table illustrates the computation of the revised probabilities, given a market test that shows a strong market. The computation involves obtaining the ratio of the joint probability of each market condition to the total joint probability (in this case, .59). The resulting values of .95 and .05 are the ones shown in Figure 11–4 (top). (Note that these are two of the revised probabilities we set out to compute.)

Probabilities for a market test that shows a weak market are computed in a similar way. These are illustrated in Table 11–13. As in the preceding table, the sum of the joint probabilities indicates the probability of this test result (weak market), and the ratios in the last column are the revised probabilities, given this test result.

It should be noted that in both tables the computations shown in the last column involve the use of Bayes' Theorem.

Table 11–12 **Probability Calculations Given the Market Test Indicates a Strong Market**

Actual Market	Conditional Probabilities		Prior Probabilities		Joint Probabilities	Revised Probabilities
Strong	.80	×	.70	=	.56	.56/.59 = .95
Weak	.10	×	.30	=	.03	.03/.59 = .05
					.59	

Table 11–13 **Probability Calculations Given the Market Test Indicates a Weak Market**

Actual Market	Conditional Probabilities		Prior Probabilities		Joint Probabilities	Revised Probabilities
Strong	.20	×	.70	=	.14	.14/.41 = .34
Weak	.90	×	.30	=	.27	.27/.41 = .66
					.41	

SENSITIVITY ANALYSIS

Analyzing decisions under risk requires working with estimated values: Both the payoffs and the probabilities for the states of nature are typically estimated values. Inaccuracies in these estimates can have an impact on the choice of an alternative, and ultimately, on the outcome of a decision. Given such possibilities, it is easy to see that a decision maker could benefit from an analysis of the *sensitivity* of a decision to possible errors in estimation. If it turns out that a certain decision will be deemed optimal over a wide range of values, the decision maker can proceed with relative confidence. Conversely, if analysis indicates a low tolerance for errors in estimation, additional efforts to pin down values may be needed.

In this section, sensitivity to *probability* estimates is examined. Sensitivity to payoff estimates is not covered; that topic is beyond the scope of this text.

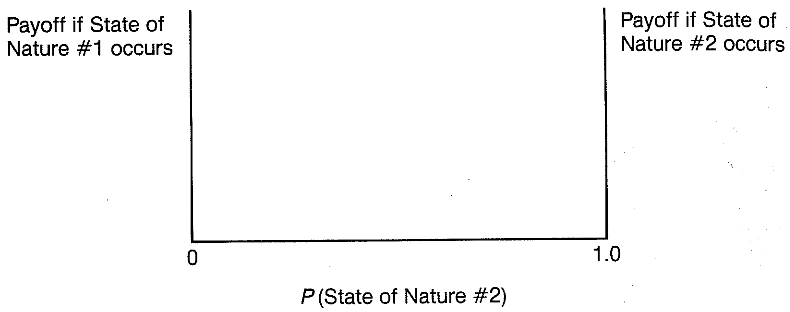
Probability estimates are particularly interesting because it is not unusual to find instances in which managers are reluctant to attempt to pinpoint probabilities. This may stem from a desire to avoid having to justify those estimates, or it may be that certain managers are uncomfortable with making such estimates. The approach described here enables decision makers to identify a *range* of probability over which a particular alternative would be optimal. In other words, the manager or decision maker is presented with ranges of probabilities for various alternatives, and he or she need only decide if a probability is within a range, rather than decide on a specific value for the probability of a state of nature.

Let's consider an example that has two states of nature. Because only two states of nature can occur, this permits us to use *graphical analysis*. Suppose a decision maker has prepared this profit payoff table:

		State of nature #1	State of nature #2
Alternative	*a*	3	9
	b	12	1
	c	9	6

The analysis is designed to provide ranges for the probability of State of nature #2, merely because it is convenient to do so. Nonetheless, these ranges

Figure 11–6 **Format of Graph for Sensitivity Analysis**



can easily be converted into ranges for State of nature #1, as you will see. We will use a graph that has two vertical axes and one horizontal axis, as shown in Figure 11–6. The left vertical axis pertains to payoffs if State of nature #1 occurs, whereas the right vertical axis pertains to payoffs if State of nature #2 occurs. The horizontal axis represents the probability of State of nature #2, P(#2). Each alternative can be represented on the graph by plotting its payoff for State of nature #1 on the left side and its payoff for State of nature #2 on the right side and, then, connecting those two points with a straight line. This is illustrated for Alternative *a* in Figure 11–7. The line represents the expected value of Alternative *a* for the entire range of *P*(#2). Thus, for any value of *P*(#2), the expected value of Alternative *a* can be found by running a vertical line from the value of *P*(#2) on the horizontal axis up to the point where it intersects the line. By running a horizontal line to either axis from that intersection, the expected value for that probability can be determined. An example is illustrated in Figure 11–8.

Figure 11–7 **The Expected Value Line for Alternative *a***

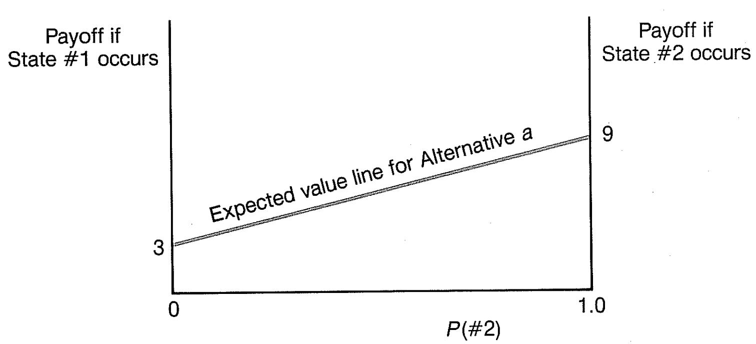
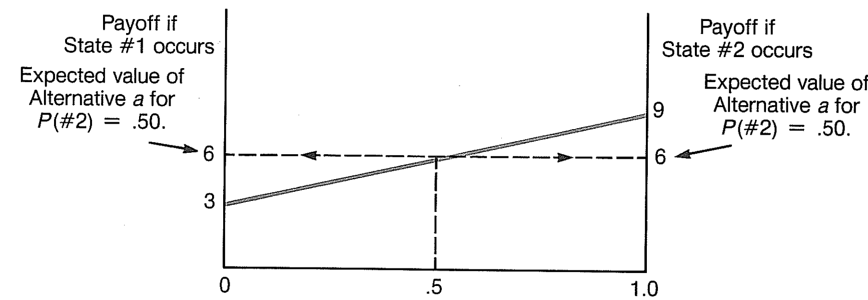


Figure 11–8 **Example of Finding the Expected Value for Alternative *a* when *P*(#2) Is .50**

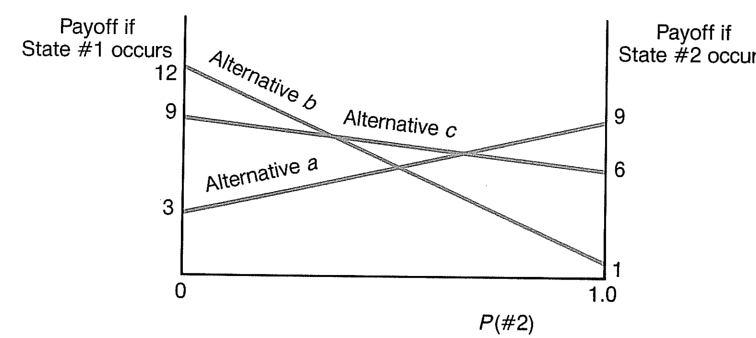


Of course, different values of *P*(#2) would produce different expected values. In general, you should be able to see from the graph that the nearer *P*(#2) is to 0, the closer the expected value of Alternative *a* will be to the payoff for State of nature #1, whereas the nearer *P*(#2) is to 1.0, the closer the expected value will be to the payoff for State of nature #2.

Our analysis of sensitivity requires that all the alternatives be plotted on the same graph. Adding the other two alternatives produces the graph shown if Figure 11–9. You will recall that plotting the line for an alternative involves connecting its payoff for #1 (left axis) and its payoff for #2 (right axis).

Because higher expected profits are more desirable than lower expected profits, the highest line for any given value of *P*(#2) represents the optimal alternative for that probability. Thus, referring to Figure 11–9, for low values of *P*(#2), Alternative *b* would give higher expected profits than either Alternative *a* or *c*. However, for values of *P*(#2) close to 1.0, Alternative *a* would have higher expected profits than either *b* or *c*, whereas for values of *P*(#2) somewhere in the middle, Alternative *c* would yield the highest expected

Figure 11–9 **All Three Alternatives Are Plotted on a Single Graph**



profits. What we want to determine is the *range* of $P(\#2)$ for which each alternative is the best.

We can see in Figure 11–10 that Alternative *b* is best up to the point (probability) where lines *b* and *c* intersect because the *b* line is highest from $P(\#2) = 0$ up to that probability. Then, line *c* is highest from that point until it intersects with line *a*; after that, line *a* is highest all the way to $P(\#2) = 1.0$. Hence, the values of $P(\#2)$ at these intersections are the key values in our analysis because they represent the end points of the ranges. These concepts are illustrated in Figure 11–10.

In order to be able to determine the $P(\#2)$ values at the line intersections, it is necessary to first develop equations of the lines in terms of $P(\#2)$. This

$$EV = \text{Payoff } \#1 + (\text{Payoff } \#2 - \text{Payoff } \#1)P \qquad \textbf{(11–5)}$$

where

EV = expected value of alternative
$P = P(\#2)$

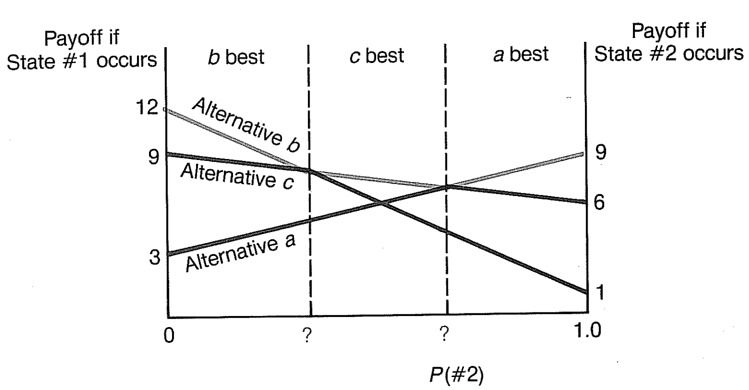
Thus, for Alternative *a*, the equation is:

$$EV_a = 3 + (9 - 3)P, \text{ which is } EV_a = 3 + 6P$$

Similarly, for *b* and *c* we have:

$$EV_b = 12 + (1 - 12)P, \text{ which is } EV_b = 12 - 11P$$
$$EV_c = 9 + (6 - 9)P, \text{ which is } EV_c = 9 - 3P$$

Figure 11–10 **The Line with the Highest Expected Profit Is Optimal for a Given Value of $P(\#2)$**



Now, to find the values of *P* at the intersections, we can set two equations equal to each other and solve for *P*. Thus, for the intersection of lines *b* and *c*, we have:

$$12 - 11P = 9 - 3P$$

Solving for *P* yields:

$$8P = 3, \text{ so } P = 3/8, \text{ or } .375$$

For the intersection of lines *a* and *c*, we set $EV_a = EV_c$:

$$3 + 6P = 9 - 3P$$

Solving for *P*, we find:

$$9P = 6, \text{ so } P = 6/9 \text{ or } .67$$

Thus, lines *b* and *c* intersect at $P(\#2) = .375$. So, Alternative *b* is best over the range of $P(\#2)$ from 0 to less than .375 (note that for $P(\#2) = .375$, *b* and *c* are equivalent). Similarly, Alternative *c* is best from $P(\#2) > .375$ to $P(\#2) < .67$, and from there up to $P(\#2) = 1.0$, Alternative *a* is best.

In sum, the range of $P(\#2)$ over which each alternative is best is:

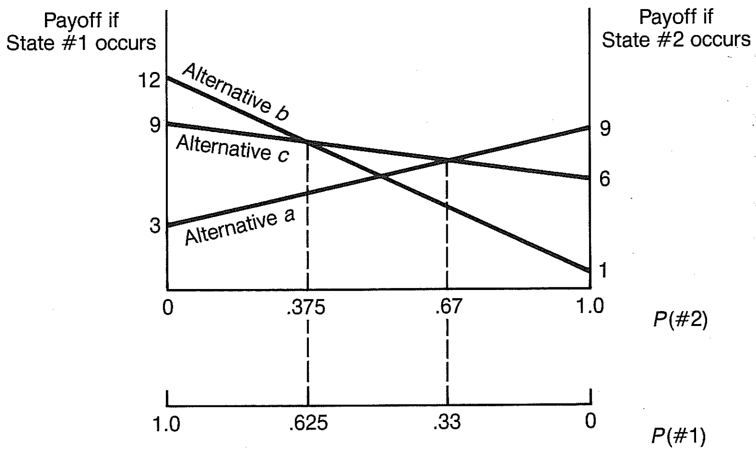
For Alternative *a*: $.67 < P(\#2) \leq 1.0$
For Alternative *b*: $0 \leq P(\#2) < .375$
For Alternative *c*: $.375 < P(\#2) < .67$

These ranges give the decision maker important insight on probability estimates. For example, a decision maker may be reluctant to specify an exact probability for State of nature #2. However, with this information, the decision maker merely has to identify the most appropriate *range* for $P(\#2)$. Thus, if the decision maker believes that $P(\#2)$ is somewhere in the range of, say .80 to .90, according to the preceding calculations, Alternative *a* would be best. Or, if the decision maker believes that $P(\#2)$ lies close to .50, then Alternative *c* would be best.

A similar analysis can be performed if the payoffs are costs or other values that are to be minimized rather than maximized. In such cases, the *lowest* line for a given value of $P(\#2)$ would be most desirable. An example of this is illustrated in the Solved Problems section at the end of this chapter.

One final comment regarding the use of $P(\#2)$. It was mentioned previously that $P(\#2)$ is used for convenience. It happens that the equations of the lines are a bit easier to develop using $P(\#2)$ rather than $P(\#1)$. However, should a problem refer to $P(\#1)$ ranges rather than $P(\#2)$, you can proceed by finding the ranges in terms of $P(\#2)$ and, then, converting these into $P(\#1)$ ranges as the final step. This merely involves recognizing that $P(\#1)$ and $P(\#2)$ are complements. For example, if $P(\#2) = 0$, then $P(\#1) = 1.0$; if $P(\#2) = .40$, then $P(\#1) = .60$; and so on. Hence, if Alternative *a* is optimal for the range $0 = P(\#2) < .40$, then in terms of $P(\#1)$, Alternative *a* is optimal for the range $.60 < P(\#1) = 1.00$. Figure 11–11 further illustrates this concept using the previous example.

Figure 11–11 **Converting $P(\#2)$ Ranges into $P(\#1)$ Ranges**



UTILITY

Throughout this chapter decision criteria have been illustrated that use monetary value as the basis of choosing among alternatives. Although monetary value is a common basis for decision making, it is not the only basis, even for business decisions. In certain instances, decision makers use *multiple criteria,* one of which is the potential *satisfaction* or *dissatisfaction* associated with possible payoffs.

For example, a great many people participate in state lotteries. However, from a strict standpoint, lotteries have a *negative* expected value; the *expected* return is less than the cost of the lottery. If it were not, the states would lose money by running lotteries. Why do people play lotteries, then? The answer is that they are hoping to win a large amount of money, and they are willing to sacrifice a relatively small amount of money to have that chance. In other words, even though their chances of winning are close to zero, they have a greater *utility* for the potential winnings, despite a negative expected value, than for the amount of money they have to give up (pay) to participate in the lottery. Similar arguments can be made for other forms of wagering. People who behave in this fashion whether for purposes of wagering or in other forms of decision making, are sometimes referred to as *risk takers.*

Just the opposite happens when a person buys insurance, giving up a fixed dollar amount to insure against an event (e.g., a fire) that has very little chance of occurring. Even so, if a fire or other insured event did occur, the consequences would be so catastrophic that an individual would not want to be exposed to that degree of risk. Thus, even though buying insurance carries a negative monetary value, most individuals recognize the merit of doing so. We refer to such individuals as *risk averters.* Of course, some individuals exhibit both forms of behavior in their decision making; they are risk takers for certain kinds of decisions but risk averters for others. A lottery player who owns a life insurance policy would be an example of this.

Thus, ***utility*** is a measure of the potential satisfaction derived from money. Although utility can be an important factor in certain kinds of decision making, assessing and using utility values can be rather complex. Not only does utility vary within an individual for different types of situations, but it also seems to vary among individuals for the same situations. That is, different people might choose different alternatives in a given instance because of utility considerations.

An expanded discussion of the topic of utility is beyond the scope of this text. Interested readers might want to consult some of the references listed for this chapter.

SUMMARY

Decision theory is a general approach to decision making. It is very useful for a decision maker who must choose from a list of alternatives, knowing that one of a number of possible future states of nature will occur and that this will have an impact on the payoff realized by a particular alternative.

Decision models can be categorized according to the degree of uncertainty that exists relative to the occurrence of the states of nature. This can range from complete knowledge about which state will occur to partial knowledge (probabilities) to no knowledge (no probabilities, or complete uncertainty). When complete uncertainty exists, the approach a decision maker takes in choosing among alternatives depends on how optimistic or pessimistic he or she is, and it also depends on other circumstances related to the eventual outcome or payoff. Under complete certainty, decisions are relatively straightforward. Under partial uncertainty, expected values often are used to evaluate alternatives. An extension of the use of expected values enables decision makers to assess the value of improved or perfect information about which state of nature will occur.

Problems that involve a single decision are usually best handled through payoff tables, whereas problems that involve a sequence, or possible sequence, of decisions, are usually best handled using tree diagrams.

Sometimes, decision makers can improve the decision process by taking into account additional (sample) information, which enables them to modify state of nature probabilities. Because there is almost always an additional cost associated with obtaining that sample information, the decision maker must decide whether the expected value of that information is worth the cost necessary to obtain it.

Sensitivity analysis can sometimes be useful to decision makers, particularly for situations in which they find it difficult to accurately assess the probabilities of the various states of nature. Sensitivity analysis can help by providing ranges of probabilities for which a given alternative would be chosen, using expected monetary value as the criterion. Hence, the problem of specifying probabilities is reduced to deciding whether a probability merely falls within a range of values.

Although expected monetary value is a widely used approach to decision making, certain individuals and certain situations may require consideration of utilities, which reflect how decision makers view the satisfaction associated with different monetary payoffs.

Glossary

decision criterion A standard or rule for choosing among alternatives (e.g., choose the alternative with the highest expected profit).

decision tree A schematic representation of a decision problem that involves the use of branches and nodes.

expected monetary value (EMV) For an alternative, the sum of the products of each possible payoff and the probability of that payoff.

expected opportunity loss (EOL) For an alternative, the sum of the products of each possible regret and the probability of that regret.

expected payoff under certainty (EPC) For a set of alternatives, the sum of products of the best payoff for each state of nature and that state's probability.

expected regret (*See* expected opportunity loss.)

expected value of perfect information (EVPI) The maximum additional benefit attainable if a problem involving risk could be reduced to a problem in which it was certain which state of nature would occur. Equal to the minimum expected regret. Also equal to EPC minus best EMV.

expected value of sample information The expected benefit of acquiring sample information. Equal to the difference between the best EMV without information and the best EMV with information.

maximax A decision criterion that specifies choosing the alternative with the best overall payoff.

maximin A decision criterion that specifies choosing the alternative with the best of the worst payoffs for all alternatives.

minimax regret A decision criterion that specifies choosing the alternative that has the lowest regret (opportunity loss).

opportunity loss For an alternative given a state of nature, the difference between that alternative's payoff and the best possible payoff for that state of nature.

payoff table A table that shows the payoff for each alternative for each state of nature.

principle of insufficient reason A decision criterion that seeks the alternative with the best average payoff, assuming all states of nature are equally likely to occur.

regret (*See* opportunity loss.)

risk A decision problem in which the states of nature have probabilities associated with their occurrence.

state of nature Possible future events.

uncertainty Refers to a decision problem in which probabilities of occurrence for the various states of nature are unknown.

utility Of a payoff, a measure of the personal satisfaction associated with a payoff.

SOLVED PROBLEMS

1. Given this *profit* payoff table:

		State of nature #1	#2	#3
Alternative	*a*	12	18	15
	b	17	10	14
	c	22	16	10
	d	14	14	14

Determine which alternative would be chosen using each of these decision criteria:

a. Maximax.

b. Maximin.

c. Minimax regret.

d. Principle of insufficient reason.

Solution

a. The maximax approach seeks the alternative that has the best overall payoff. Because these are profits, the best payoff would be the largest value, which is the payoff 22. Thus, in order to have a chance at that payoff, the decision maker should choose Alternative *c*.

b. The maximin approach is to choose the alternative that will provide the best of the worst possible payoffs. To find this, first identify the worst profit possible for each alternative:

Alternative	Worst Payoff
a	12
b	10
c	10
d	14 (best)