CHAPTER 4

Making Choices

In this chapter, we learn how to use the details in a structured problem to find the preferred alternative. "Using the details" typically means analyzing: performing calculations, creating graphs, and examining the results to gain insight into the decision.

We begin by studying the analysis of decision models that involve only one objective or attribute. Although most of our examples use money as the attribute, it could be anything that can be measured as discussed in Chapter 3. After discussing the calculation of expected values and the use of risk profiles for single attribute decisions, we turn to decisions with multiple attributes and present some simple analytical approaches. The chapter concludes with a discussion of software for doing decision-analysis calculations on personal computers.

Our main example for this chapter is from the famous Texaco-Pennzoil court case.

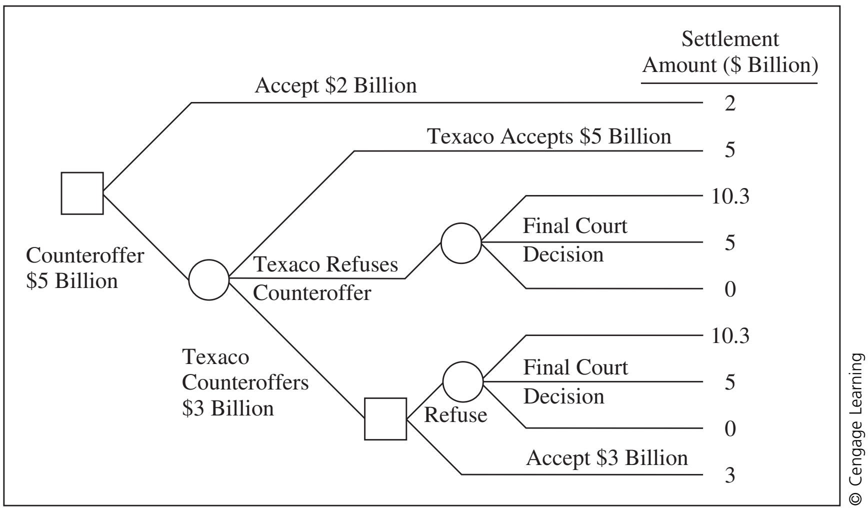
Texaco versus Pennzoil

In early 1984, Pennzoil and Getty Oil agreed to the terms of a merger. But before any formal documents could be signed, Texaco offered Getty a substantially better price, and Gordon Getty, who controlled most of the Getty stock, reneged on the Pennzoil deal and sold to Texaco. Naturally, Pennzoil felt as if it had been dealt with unfairly and immediately filed a lawsuit against Texaco alleging that Texaco had interfered illegally in the Pennzoil-Getty negotiations. Pennzoil won the case; in late 1985, it was awarded $11.1 billion, the largest judgment ever in the United States at that time. A Texas appeals court reduced the judgment by $2 billion, but interest and penalties drove the total back up to $10.3 billion. James Kinnear, Texaco's chief executive officer, had said that Texaco would file for bankruptcy if Pennzoil obtained court permission to secure the judgment by filing liens against Texaco's assets. Furthermore, Kinnear had promised to fight the case all the way to the U.S. Supreme Court if necessary, arguing in part that Pennzoil had not followed Security and Exchange Commission regulations in its negotiations with Getty. In April 1987, just before Pennzoil began to file the liens, Texaco offered to pay Pennzoil $2 billion to settle the entire case. Hugh Liedtke, chairman of Pennzoil, indicated that his advisors were telling him that a settlement between $3 and $5 billion would be fair.

What do you think Liedtke (pronounced "lid-key") should do? Should he accept the offer of $2 billion, or should he refuse and make a firm counteroffer? If he refuses the sure $2 billion, he faces a risky situation. Texaco might agree to pay $5 billion, a reasonable amount in Liedtke's mind. If he counteroffered $5 billion as a settlement amount, perhaps Texaco would counter with $3 billion or simply pursue further appeals. Figure 4.1 is a decision tree that shows a simplified version of Liedtke's problem.

The decision tree in Figure 4.1 is simplified in a number of ways. First, we assume that Liedtke has only one fundamental objective: maximizing the amount of the settlement. No other objectives need be considered. Also, Liedtke has a more varied set of decision alternatives than those shown. He could counteroffer a variety of possible values in the initial decision, and in the second decision, he could counteroffer some amount between $3 and $5 billion. Likewise, Texaco's counteroffer, if it makes one, need not be exactly $3 billion. The outcome of the final court decision could be anything between zero and the current judgment of $10.3 billion. Finally, we have not included in our model of the decision anything regarding Texaco's option of filing for bankruptcy.

FIGURE **4.1** Hugh Liedtke's decision in the Texaco-Pennzoil affair.



Why all of the simplifications? A straightforward answer (which just happens to have some validity) is that for our purposes in this chapter we need a relatively simple decision tree to work with. But this is just a pedagogical reason. If we were to try to analyze Liedtke's problem in all of its glory, how much detail should be included? As you now realize, all of the relevant information should be included, and the model should be constructed in a way that makes it easy to analyze. Does our representation accomplish this? Let us consider the following points.

1. *Liedtke's objective.* Certainly maximizing the amount of the settlement is a valid objective. The question is whether other objectives, such as minimizing attorney fees or improving Pennzoil's public image, might also be important. Although Liedtke may have other objectives, the fact that the settlement can range all the way from zero to $10.3 billion suggests that this objective will swamp any other concerns.
2. *Liedtke's initial counteroffer.* The counteroffer of $5 billion could be replaced by an offer for another amount, and then the decision tree reanalyzed. Different amounts may change the chance of Texaco accepting the counteroffer. At any rate, other possible counteroffers are easily dealt with.
3. *Liedtke's second counteroffer.* Other possible offers could be built into the tree, leading to a Texaco decision to accept, reject, or counter. The reason for leaving these out reflects an impression from the media accounts (especially *Fortune,* May 11, 1987, pp. 50–58) that Kinnear and Liedtke were extremely tough negotiators and that further negotiations were highly unlikely.
4. *Texaco's counteroffer.* The $3 billion counteroffer could be replaced by a fan representing a range of possible counteroffers. It would be necessary to find a "break-even" point, above which Liedtke would accept the offer and below which he would refuse. Another approach would be to replace the $3 billion value with other values, recomputing the tree each time. Thus, we have a variety of ways to deal with this issue.
5. *The final court decision.* We could include more branches, representing additional possible outcomes, or we could replace the three branches with a fan representing a range of possible outcomes. For a first-cut approximation, the possible outcomes we have chosen do a reasonably good job of capturing the uncertainty inherent in the court outcome.
6. *Texaco's bankruptcy option.* A detail left out of the case is that Texaco's net worth is much more than the $10.3 billion judgment. Thus, even if Texaco does file for bankruptcy, Pennzoil probably would still be able to collect. In reality, negotiations can continue even if Texaco has filed for bankruptcy; the purpose of filing is to protect the company from creditors seizing assets while the company proposes a financial reorganization plan. In fact, this is exactly what Texaco needs to do in order to figure out a way to deal with Pennzoil's claims.

In terms of Liedtke's options, however, whether Texaco files for bankruptcy appears to have no impact.

The purpose of this digression has been to explore the extent to which our structure for Liedtke's problem is requisite in the sense of Chapter 1. The points above suggest that the main issues in the problem have been represented in the problem. While it may be necessary to rework the analysis with slightly different numbers or structure later, the structure in Figure 4.1 should be adequate for a first analysis. The objective is to develop a representation of the problem that captures the essential features of the problem so that the ensuing analysis will provide the decision maker with insight and understanding.

One small detail remains before we can solve the decision tree. We need to specify the chances or probabilities associated with Texaco's possible reactions to the $5 billion counteroffer, and we also need to assess the chances of the various court awards. The probabilities that we assign to the outcome branches in the tree should reflect Liedtke's beliefs about the uncertain events that he faces. As a matter of fact, one of the strengths of decision analysis is the ability to model or represent the knowledge and beliefs of the decision maker, in this case Hugh Liedtke. Instead of using preset probability values (such as equal probability values for all outcomes), we customize the probabilities to match Liedtke's beliefs. For this reason, any numbers that we include to represent these beliefs should be based on what Liedtke has to say about the matter or on information from individuals whose judgments in this matter he would trust. For our purposes, imagine overhearing a conversation between Liedtke and his advisors. Here are some of the issues they might raise:

- Given the tough negotiating stance of the two executives, it could be an even chance (50%) that Texaco will refuse to negotiate further. If Texaco does not refuse, then what? What are the chances that Texaco would accept a $5 billion counteroffer? How likely is this outcome compared to the $3 billion counteroffer from Texaco? Liedtke and his advisors might figure that a counteroffer of $3 billion from Texaco is about twice as likely as Texaco accepting the $5 billion. Thus, because there is already a 50% chance of refusal, there must be a 33% chance of a Texaco counteroffer and a 17% chance of Texaco accepting $5 billion.
- What are the probabilities associated with the final court decision? In the *Fortune* article cited previously, Liedtke is said to admit that Texaco could win its case, leaving Pennzoil with nothing but lawyer bills. Thus, there is a significant possibility that the outcome would be zero. Given the strength of Pennzoil's case so far, there is also a good chance that the court will uphold the judgment as it stands. Finally, the possibility exists that the judgment could be reduced somewhat (to $5 billion in our model). Let us assume that Liedtke and his advisors agree that there is a 20% chance that the court will award the entire $10.3 billion and a

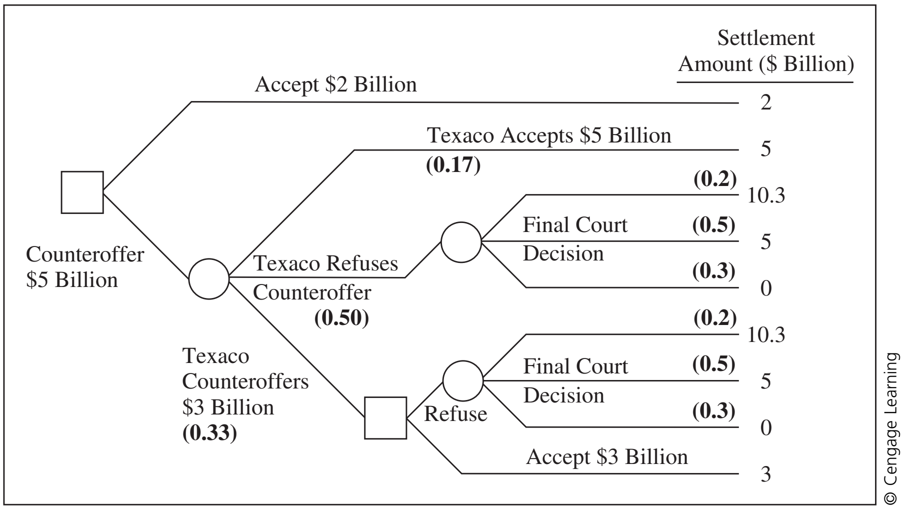


FIGURE **4.2** Hugh Liedtke's decision tree with chances (probabilities) included.

slightly larger, or 30%, chance that the award will be zero. Thus, there must be a 50% chance of an award of $5 billion.

Figure 4.2 shows the decision tree with these chances included. The chances have been phrased in terms of probabilities rather than percentages.

DECISION TREES AND EXPECTED MONETARY VALUE

One way to choose among risky alternatives is to pick the one with the highest *expected value* (EV). When the decision's consequences involve only monetary gains or losses, we call the expected value the *expected monetary value* (EMV), sometimes called the mean. Finding EMVs when using decision trees is called "folding back the tree" for reasons that will become obvious. (The procedure is called "rolling back" in some texts.) We start at the endpoints of the branches on the far-right side and move to the left, (1) calculating expected values (to be defined in a moment) when we encounter a chance node, or (2) choosing the branch with the highest value or expected value[1] when we encounter a decision node. These instructions sound rather cryptic. It is much easier to understand the procedure through a few examples. We will start with a simple example, the double risk dilemma shown in Figure 4.3.

Recall that a double-risk dilemma is a matter of choosing between two risky alternatives. The situation is one in which you choose between Ticket A and Ticket B, each of which allows you participate in a game of chance.

[1] Usually our objective is to maximize EV or EMV, but there are times when we wish to minimize EV, such as minimizing costs. In such cases, we choose the branch with the smallest expected value.

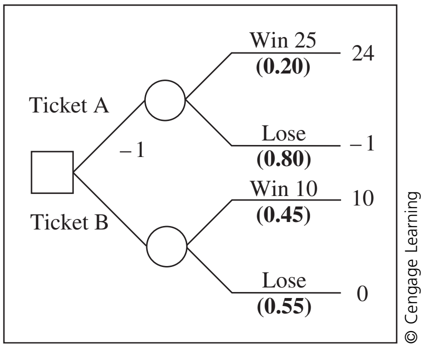


FIGURE **4.3** A double-risk dilemma.

With Ticket A, there is a 20% chance of winning \$25 and an 80% chance of winning \$0; with Ticket B, there is a 45% chance of winning \$10 and a 55% chance of winning \$0. Ticket B is free for the asking, but Ticket A costs \$1. You must choose one or the other, either A for \$1 or B for free. Ticket A has the higher payoff, but is it worth the \$1?

Figure 4.3 displays your decision situation. In particular, notice that the dollar consequences at the ends of the branches are the net values as discussed in Chapter 3. Thus, if you chose Ticket A and win, you will have gained a net amount of \$24, having paid one dollar for the ticket.

To solve or fold back the decision tree, begin by calculating the expected value of Ticket B, that is, playing for \$10. The expected value of Ticket B is simply the weighted average of the possible outcomes of the lottery, the weights being the chances with which the outcomes occur. The calculation is:

$$\begin{aligned}\text{EMV(Ticket B)} &= 0.45 \times \$10 + 0.55 \times \$0 \\ &= \$4.50\end{aligned}$$

This formula states that 45% of the time, Ticket B pays \$10, and 55% of the time, it pays zero dollars. Thus, the EMV tells us that playing this lottery many times would yield an average of \$4.50 per game.

Next, we compare the EMV of Ticket B to the EMV of Ticket A. Calculating EMV for Ticket A gives us the following:

$$\begin{aligned}\text{EMV(Ticket A)} &= 0.20 \times \$24 + 0.80 \times \$-1 \\ &= \$4.00\end{aligned}$$

Now we can replace the chance nodes in the decision tree with their expected values, as shown in Figure 4.4. Finally, choosing between the two tickets amounts to choosing the branch with the highest expected value. As Ticket B pays \$0.50 more on average, the EMV calculations show that on average it is better to select Ticket B. The double slash through the "Ticket A" branch indicates that this branch would not be chosen.

This simple example is only a warm-up exercise. Now let us see how the solution procedure works when we have a more complicated decision

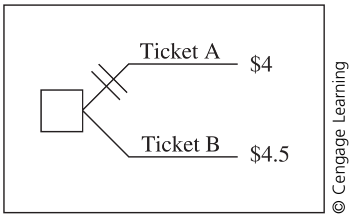


FIGURE **4.4**
Replacing chance nodes with EMVs.

problem. Consider Hugh Liedtke's situation as diagrammed in Figure 4.2. Our strategy, as indicated, will be to work from the right side of the tree. First, we will calculate the expected value of the final court decision. The second step will be to decide whether it is better for Liedtke to accept a $3 billion counteroffer from Texaco or to refuse and take a chance on the final court decision. We will do this by comparing the expected value of the judgment with the sure $3 billion. The third step will be to calculate the expected value of making the $5 billion counteroffer, and finally we will compare this expected value with the sure $2 billion that Texaco is offering now.

The expected value of the court decision is the weighted average of the possible outcomes:

$$\begin{aligned}\text{EMV}(\textit{Court Decision}) &= [P(\textit{Award} = \$10.3) \times \$10.3] \\ &\quad + [P(\textit{Award} = \$5) \times \$5] \\ &\quad + [P(\textit{Award} = \$0) \times \$0] \\ &= [0.2 \times \$10.3] + [0.5 \times \$5] + [0.3 \times \$0] \\ &= \$4.56\ \text{Billion}\end{aligned}$$

We replace both uncertainty nodes representing the court decision with this expected value, as in Figure 4.5. Now, comparing the two alternatives of accepting and refusing Texaco's $3 billion counteroffer, it is obvious that the expected value of $4.56 billion is greater than the certain value of $3 billion, and hence the slash through the "Accept $3 Billion" branch.

To continue folding back the decision tree, we replace the decision node with the preferred alternative. The decision tree as it stands after this replacement is shown in Figure 4.6. The third step is to calculate the expected value of the alternative "Counteroffer $5 Billion." This expected value is:

$$\begin{aligned}\text{EMV}(\textit{Counteroffer}\ \$5\ \text{Billion}) &= [P(\textit{Texaco Accepts}) \times \$5] \\ &\quad + [P(\textit{Texaco Refuses}) \times \$4.56] \\ &\quad + [P(\textit{Texaco Counteroffers}) \times \$4.56] \\ &= [0.17 \times \$5] + [0.5 \times \$4.56] + [0.33 \times \$4.56] \\ &= \$4.63\ \text{Billion}\end{aligned}$$

Replacing the chance node with its expected value results in the decision tree shown in Figure 4.7. Comparing the values of the two branches, it is clear

FIGURE **4.5**
Hugh Liedtke's decision tree after calculating expected value of court decision.

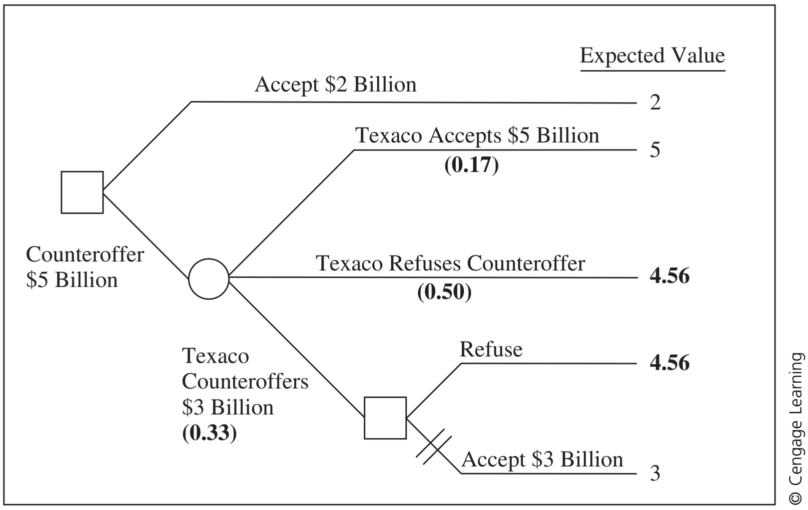


FIGURE **4.6**
Hugh Liedtke's decision tree after decision node replaced with expected value of preferred alternative.

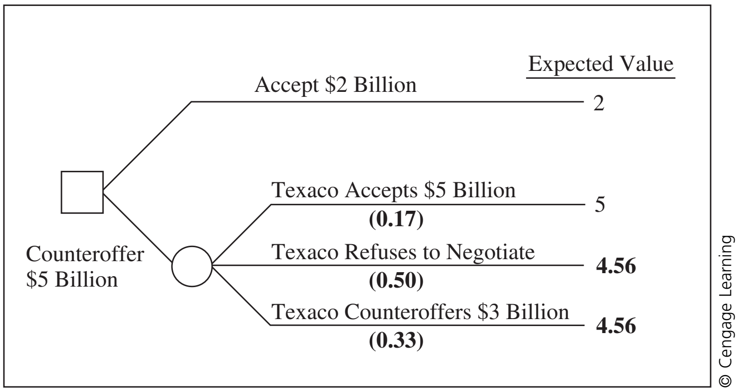
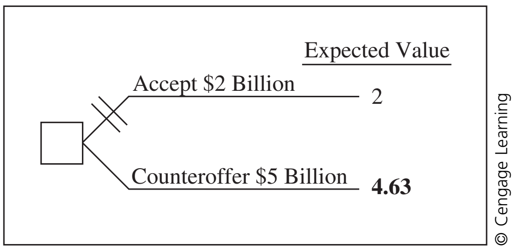


FIGURE **4.7**
Hugh Liedtke's decision tree after original tree completely folded back.



that the expected value of $4.63 billion is preferred to the $2 billion offer from Texaco. According to this solution, which implies that decisions should be made by comparing expected values, Liedtke should turn down Texaco's offer but counteroffer a settlement of $5 billion. If Texaco turns down the $5 billion and makes another counteroffer of $3 billion, Liedtke should refuse the $3 billion and take his chances in court.

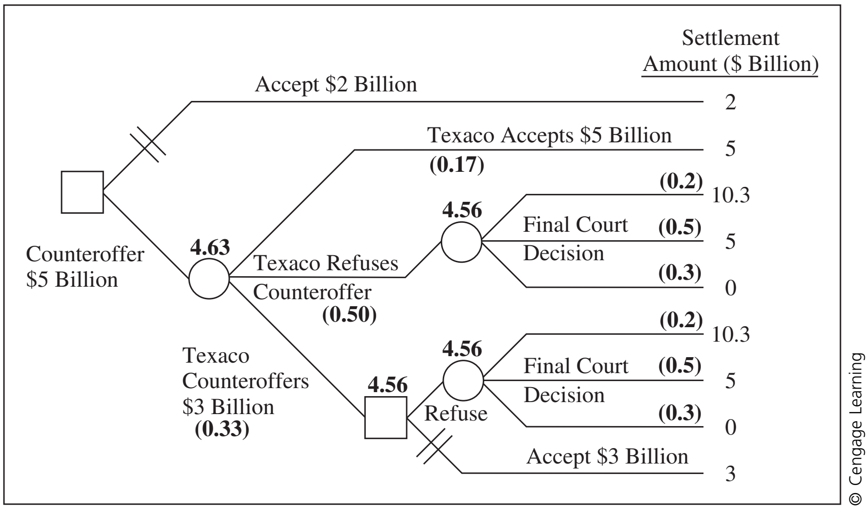


FIGURE **4.8** Hugh Liedtke's solved decision tree.

We went through this decision in gory detail so that you could see clearly the steps involved. In fact, when solving a decision tree, we usually do not redraw the tree at each step, but simply indicate on the original tree what the expected values are at each of the chance nodes and which alternative is preferred at each decision node. The solved decision tree for Liedtke would look like the tree shown in Figure 4.8, which shows all of the details of the solution. Expected values for the chance nodes are placed above the nodes. The 4.56 above the decision node indicates that if Liedtke gets to this decision point, he should refuse Texaco's offer and take his chances in court for an expected value of $4.56 billion. The decision tree also shows that his best current choice is to make the $5 billion counteroffer with an expected payoff of $4.63 billion.

The decision tree shows clearly what Liedtke should do if Texaco counteroffers $3 billion: He should refuse. This is the idea of a contingent plan, which we call a *strategy*. A strategy is a particular immediate alternative, as well as specific alternatives in future decisions. For example, if Texaco counteroffers, there is a specific course of action to take (refuse the counteroffer). We denote this strategy by: "Counteroffer $5 Billion; Refuse Texaco Counteroffer." In deciding whether to accept Texaco's current $2 billion offer, Liedtke must know what he will do in the event that Texaco returns with a counteroffer of $3 billion. This is why the decision tree is solved backwards. In order to make a good decision at the current time, we have to know what the appropriate contingent strategies are in the future.

The folding-back procedure highlights one of the great strengths of decision models. Both decision trees and influence diagrams require us to think carefully about the future, in particular the outcomes that could occur and the consequences that might result from each outcome. Because we cannot predict exactly what will happen in the time horizon of the decision context, we think about and model a representative or requisite set of future scenarios. If we have done a good job, then our model adequately portrays the range of possible future events.

SOLVING INFLUENCE DIAGRAMS: OVERVIEW

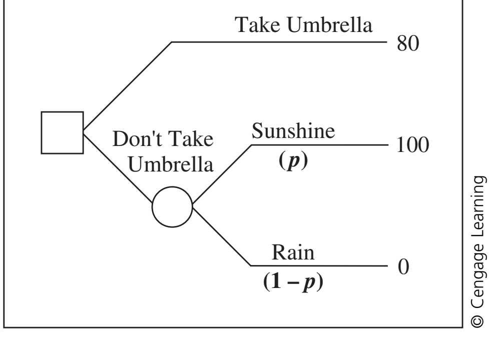
Solving decision trees is straightforward, and EMVs for small trees can be calculated by hand relatively easily. The procedure for solving an influence diagram, though, is somewhat more complicated. Fortunately, computer programs such as PrecisionTree are available to do the calculations. In this short section we give an overview of the issues involved in solving an influence diagram. For interested readers, we have provided a complete solution of the influence diagram of the Texaco-Pennzoil decision at our website. Please go to www.cengagebrain.com to access the solution.

While influence diagrams appear on the surface to be rather simple, much of the complexity is hidden. Our first step is to take a close look at how an influence diagram translates information into an internal representation. An influence diagram "thinks" about a decision in terms of a symmetric expansion of the decision tree from one node to the next.

For example, suppose we have the basic decision tree shown in Figure 4.9, which represents the "umbrella problem" (see Exercise 3.9). The issue is whether or not to take your umbrella. If you do not take the umbrella, and it rains, your good clothes (and probably your day) are ruined, and the consequence is zero (units of satisfaction). However, if you do not take the umbrella and the sun shines, this is the best of all possible consequences with a value of 100. If you decide to take your umbrella, your good clothes will not get soaking wet. However, it is a bit of a nuisance to carry the umbrella around all day. Your consequence is 80, between the other two values.

If we were to represent this problem with an influence diagram, it would look like the diagram in Figure 4.10. Note that it does not matter whether the sun shines or not if you take the umbrella. If we were to reconstruct exactly

FIGURE **4.9**
Umbrella problem.



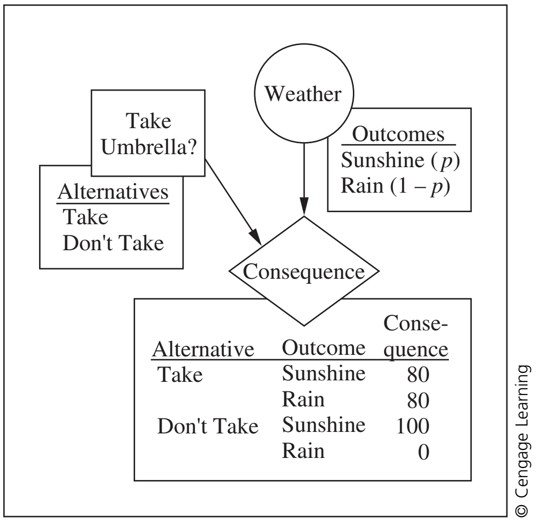


FIGURE **4.10** Influence diagram of the umbrella problem.

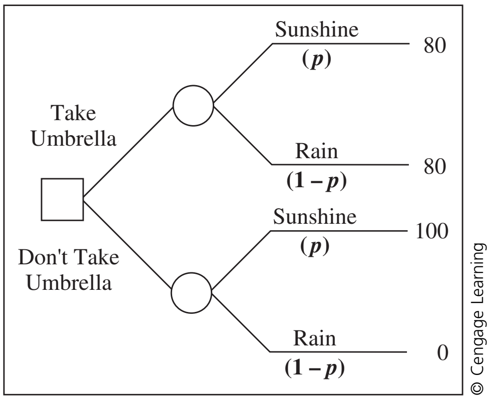


FIGURE **4.11** How the influence diagram "thinks" about the umbrella problem.

how the influence diagram "thinks" about the umbrella problem in terms of a decision tree, the representation would be that shown in Figure 4.11. Note that the uncertainty node on the "Take Umbrella" branch is an unnecessary node. The payoff is the same regardless of the weather. In a decision-tree model, we can take advantage of this fact by not even drawing the unnecessary node. Influence diagrams, however, use the symmetric decision tree, even though this may require unnecessary nodes (and hence unnecessary calculations).

With an understanding of the influence diagram's internal representation, we can talk about how to solve an influence diagram. The procedure essentially solves the symmetric decision tree, although the terminology is somewhat different. Nodes are *reduced;* reduction amounts to calculating expected values for chance nodes and choosing the largest expected value at decision nodes, just as we did with the decision tree. Moreover, also parallel with the decision-tree procedure, as nodes are reduced, they are removed from the diagram. Thus, solving the influence diagram in Figure 4.10 would require first reducing the

"Weather" node (calculating the expected values) and then reducing the "Take Umbrella?" node by choosing the largest expected value.

RISK PROFILES

Up to this point, we have discussed only one way to choose the best alternative. That is, choose the alternative that maximizes EMV (or minimizes EMV if we are calculating costs). This decision rule is both straightforward and appealing. Straightforward because it is easy to implement and appealing because the EMV is a useful measure for comparing different alternatives.

However, the EMV alone does not tell us the whole story; it does not inform us about how much variation there is in the consequences. For example, Liedtke's expected values are \$2 billion and \$4.63 billion for his two immediate alternatives. But this does not mean that if Liedtke chooses to counteroffer, he can expect a payment of \$4.63 billion. Rather the expected value is a weighted average, and thus summarizes the set of possible consequences. It does not specify the exact amount or consequence that will occur for Liedtke. Thus, to help us choose the best alternative, we should consider both the EMV and the set of possible consequences for each alternative. Table 4.1 shows the EMV and consequences for Liedtke's two immediate alternatives, thereby providing a more in-depth look into what actually could happen than the EMV alone.

That Liedtke could come away from his dealings with Texaco with nothing indicates that choosing to counteroffer is a risky alternative. In later chapters we will look at the idea of risk in more detail. For now, however, we can investigate and discuss the relative riskiness of each alternative by studying the set of possible consequences for each alternative. For Liedtke, there is only one possible consequence for "Accept \$2 Billion," which, of course, is a \$2 billion payment, showing that there is no risk if he accepts. In contrast, the possible consequences for "Counteroffer" range from zero to over ten billion dollars, indicating much more risk. If, in addition, we know the probability of each consequence value, as in Table 4.2, then we have a more complete picture of what could happen for each alternative.

TABLE **4.1**
The EMVs and possible consequences facing Hugh Liedtke when deciding to accept the \$2 billion offer or to counteroffer \$5 billion.

Alternative	EMV	Possible Consequences
Accept \$2 Billion	\$2 Billion	\$2 Billion
Counteroffer	\$4.65 Billion	\$0 \$5 Billion \$10.3 Billion

TABLE **4.2** Liedtke's two alternatives along with their associated EMVs, consequence values, and probabilities.

Alternative	EMV	Consequence Values	Consequence Prob.
Accept $2 Billion	$2 Billion	$2 Billion	100%
		$0	24.9%
Counteroffer	$4.65 Billion	$5 Billion	58.5%
		$10.3 Billion	16.6%

Table 4.2 shows that there is only a one out of six chance that the consequence would be $10.3 billion. Knowing the probability values can be very helpful when choosing the best strategy. For example, Liedtke would evaluate the "Counteroffer" alternative more favorably if the probability of the $10.3 billion consequence were to jump from 16.6% to 80%.

Note that the probabilities for the two sets of consequences in the above table sum to one. Interestingly, the probabilities for a given alternative or a strategy must always sum to one. Problem 4.21 asks you to show that the probabilities associated with the consequences of each alternative must always add to one.

For any alternative, the consequence values together with their associated probabilities constitute the risk profile for that alternative. The risk profile provides a complete picture of what could happen when we choose an alternative or strategy. We typically display a risk profile as a graph with the consequence values along the x-axis and their associated probabilities along the y-axis.

Risk profiles are very helpful when deciding which alternative we most prefer. Whereas the EMV summarizes each alternative into a single number, risk profiles graphically display the range of possible results, and as such, convey more of the complexity of the alternative. We will see that we can compare the relative merits of each alternative by comparing risk profiles, and that there is special meaning when two risk profile graphs do not cross each other. For now, we know that a risk profile graphs the consequences and their probabilities, providing a comprehensive snapshot of an alternative.

The risk profile for the "Accept $2 Billion" alternative is shown in Figure 4.12 and the risk profile for the "Counteroffer $5 Billion; Refuse Texaco Counteroffer" strategy is shown in Figure 4.13. Figure 4.13 shows there is a 58.5% chance that the eventual settlement is $5 billion, a 16.6% chance of $10.3 billion, and a 24.9% chance of nothing. These probabilities are easily calculated. For example, take the $5 billion amount. This can happen in three different ways. There is a 17% chance that it happens because Texaco accepts. There is a 25% chance that it happens because Texaco refuses and the judge awards $5 billion. (That is, there is a 50% chance that Texaco refuses times a 50% chance that the award is $5 billion.) Finally, the chances are 16.5% that the settlement is $5 billion because Texaco counteroffers $3 billion, Liedtke refuses and goes to court, and the judge awards $5 billion. That is, 16.5% equals 33% times 50%. Adding up, we get the chance of $5 billion = 17% + 25% + 16.5% = 58.5%.

In constructing a risk profile, we collapse a decision tree by multiplying out the probabilities on sequential chance branches. At a decision node, only

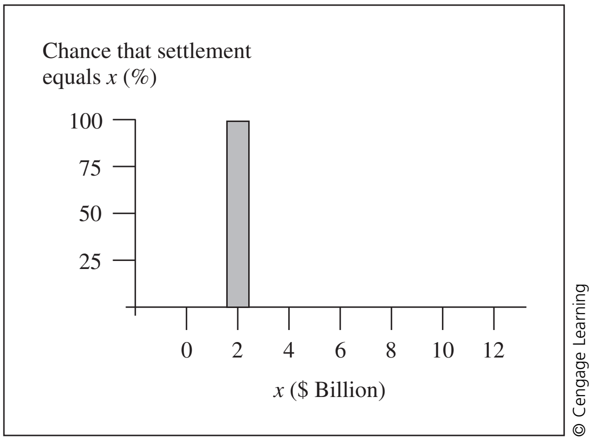


FIGURE **4.12** Risk profile for the "Accept $2 Billion" alternative.

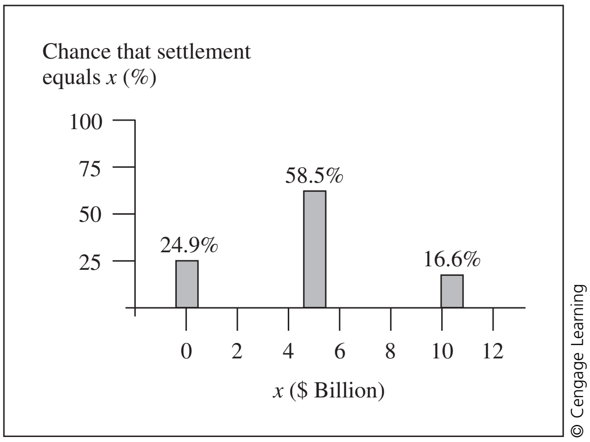


FIGURE **4.13** Risk profile for the "Counteroffer $5 Billion; Refuse Texaco Counteroffer" strategy.

one branch is taken; in the case of "Counteroffer $5 Billion; Refuse Texaco Counteroffer," we use only the indicated alternative for the second decision, and so this decision node need not be included in the collapsing process. You can think about the process as one in which nodes are gradually removed from the tree in much the same sense as we did with the folding-back procedure, except that in this case we keep track of the possible outcomes and their probabilities. Figures 4.14, 4.15, and 4.16 show the progression of collapsing the decision tree in order to construct the risk profile for the "Counteroffer $5 Billion; Refuse Texaco Counteroffer" strategy.

By looking at the risk profiles, the decision maker can tell a lot about the riskiness of the alternatives. In some cases a decision maker can choose among alternatives on the basis of their risk profiles. Comparing Figures 4.12 and 4.13, it is clear that the worst possible consequence for "Counteroffer $5 Billion; Refuse Texaco Counteroffer" is less than the value for "Accept $2 billion." On the other hand, the largest amount ($10.3 billion) is much higher than $2 billion. Hugh Liedtke has to decide whether the risk of perhaps coming away empty-handed is worth the possibility of getting more

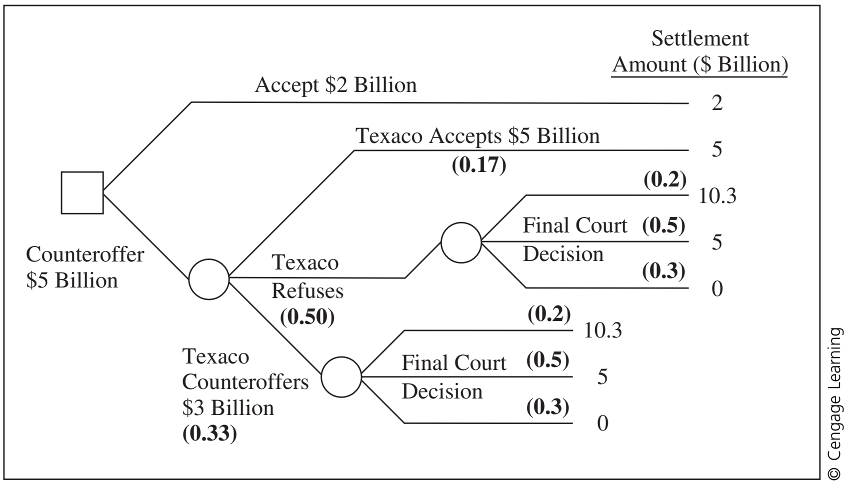


FIGURE **4.14** First step in collapsing the decision tree to make a risk profile for "Counteroffer $5 Billion; Refuse Texaco Counteroffer" strategy.

The decision node has been removed to leave only the outcomes associated with the "Refuse" branch.

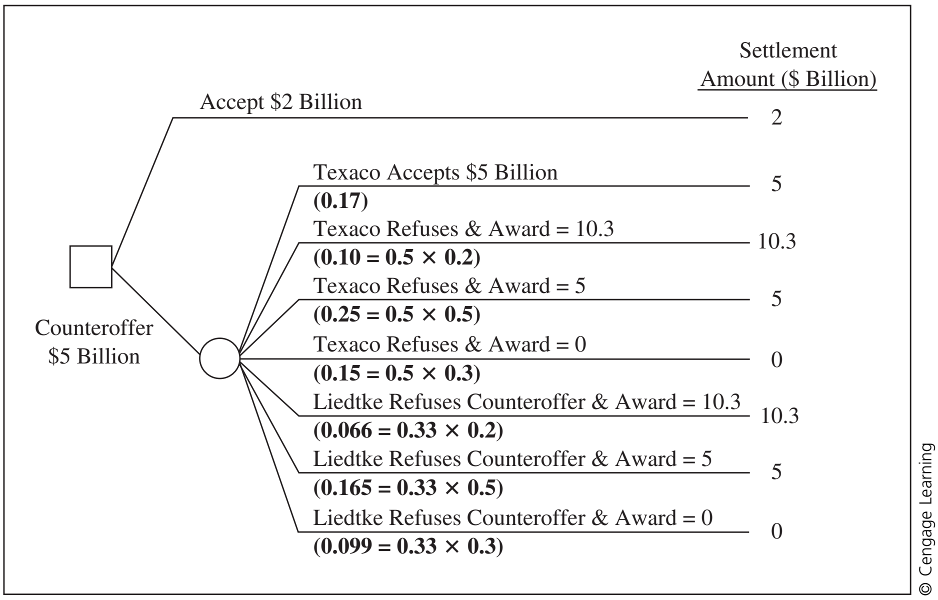


FIGURE **4.15** Second step in collapsing the decision tree to make a risk profile.

The three chance nodes have been collapsed into one chance node. The probabilities on the branches are the product of the probabilities from sequential branches in Figure 4.14.

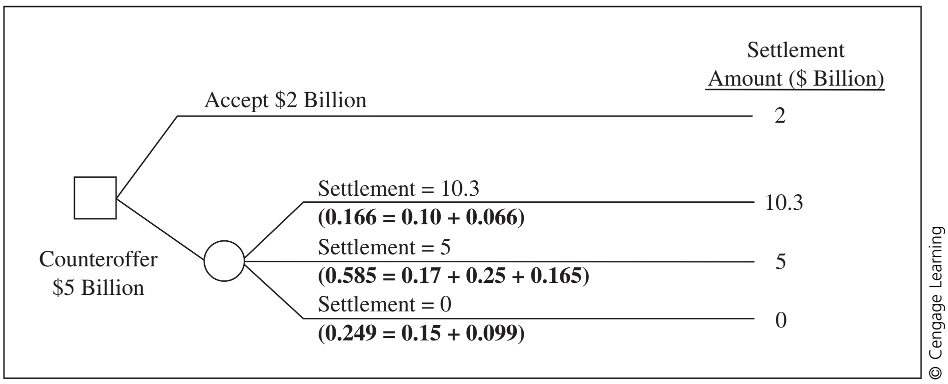


FIGURE **4.16** Third step in collapsing the decision tree to make a risk profile.

The seven branches from the chance node in Figure 4.15 have been combined into three branches.

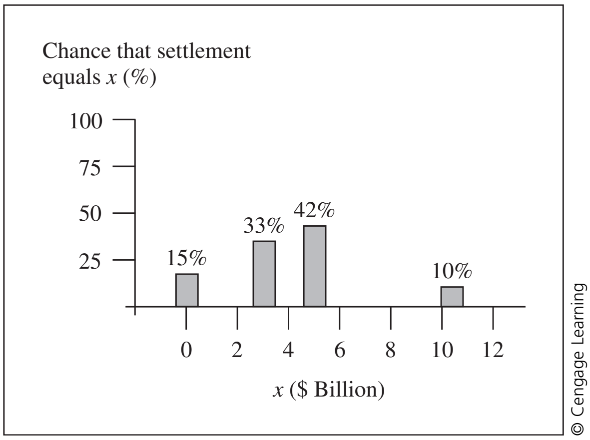


FIGURE **4.17**
Risk profile for the "Counteroffer $5 Billion; Accept $3 Billion" strategy.

than $2 billion. This is clearly a case of a basic risky decision, as we can see from the collapsed decision tree in Figure 4.16.

Risk profiles can be calculated for strategies that might not have appeared as optimal in an expected-value analysis. For example, Figure 4.17 shows the risk profile for "Counteroffer $5 Billion; Accept $3 Billion," which we ruled out on the basis of EMV. Comparing Figures 4.17 and 4.13 indicates that this strategy yields a smaller chance of getting nothing, but also less chance of a $10.3 billion judgment. Compensating for this is the greater chance of getting something in the middle: $3 or $5 billion.

Although risk profiles can in principle be used as an alternative to EMV to check every possible strategy, for complex decisions it can be tedious to study many risk profiles. Thus, a compromise is to look at risk profiles only for the first one or two decisions, on the assumption that future decisions would be made using a decision rule such as maximizing expected value, which is itself a kind of strategy. (This is the approach used by many decision-analysis computer programs, PrecisionTree included.) Thus, in the Texaco-Pennzoil example, one might compare only the "Accept $2 Billion" and "Counteroffer $5 Billion; Refuse Texaco Counteroffer" strategies.

Cumulative Risk Profiles

We also can present the risk profile in cumulative form. Figure 4.18 shows the *cumulative risk profile* for "Counteroffer $5 Billion; Refuse Texaco Counteroffer." In the cumulative format, the vertical axis is the chance that the payoff is less than or equal to the corresponding value on the horizontal axis. This is only a matter of translating the information contained in the risk profile in Figure 4.13. There is no chance that the settlement will be less than zero. At zero, the chance jumps up to 24.9%, because there is a substantial chance that the court award will be zero. The graph continues at 24.9% across to $5 billion. (For example, there is a 24.9% chance that the settlement is less than or equal to $3.5 billion; that is, there is the 24.9% chance that the settlement is zero, and that is