
Chapter 24 Decision Making and Risk



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Data Description, inc.

Small businesses are 99.7 percent of all U.S. firms. They generate more than half of the private non-farm gross domestic product and create 60 to 80 percent of net new jobs (www.sba.gov). Here's the story of one such firm.

Data Description was founded in 1985 to develop, market, and support the Data Desk® statistics program.¹ Personal computers were becoming more widely available, and graphical desktop interfaces offered new and exciting opportunities for data analysis and graphics. Data Desk was introduced in 1986 for the newly released Macintosh computer and released for the PC in 1997, with expanded capabilities for analysis, and the ability to work efficiently with large (several million case) datasets. Data Description then launched *ActivStats*, a multimedia education product, which pioneered multimedia teaching in statistics. Data Description also supports the DASL library (dasl.datadescription.com) that holds the datasets for this text and the Active Stats tools (astools.datadesk.com) that provide interactive tables and tools for introductory statistics.

¹Because Data Description was founded by Paul Velleman, one of our co-authors, we have been able to gain access to business decisions that would ordinarily not be publicly available.

Data Description employs both a local staff and programmers who work remotely from other parts of the country and “telecommute.” In these ways, it is typical of many technologically centered small businesses relying on the Internet for development, marketing, and customer support and competing with larger firms by staying fast and flexible.

Company president John Sammis notes that the Internet has enabled small businesses such as Data Description to compete with larger international firms and that decisions about how best to use the Internet are key to competing successfully. By its thirtieth anniversary, Data Description (datadescription.com), based in Ithaca, New York, was providing software and services to education and business clients throughout the world.

We make decisions every day, often without knowing how they will turn out. Most of our daily decisions have no serious consequences. But the decisions a business makes determine the success or failure of the venture. The consequences of business decisions can often be quantified in monetary terms, but the costs and benefits themselves often depend on events beyond the control or foresight of decisionmakers. Decisions must be made nevertheless. How can people make intelligent decisions when they don't know for certain what the future holds?

One decision facing Data Description (as with many high-tech companies) is how best to provide technical support for its customers. In the past, Data Description has relied on its thorough documentation, a built-in help system, and free telephone support. But as its user base has grown, telephone-based customer support has become a significant expense. Data Description's president, John Sammis, must decide whether to invest in developing an online FAQ (Frequently Asked Questions) help system as the first line of defense for customer support, to continue free telephone support through the help desk, or to hire and train additional telephone support staff and charge customers for it. For a small business, decisions such as these carry significant costs, but making the right decision can be the difference between keeping customers happy and losing them to larger competitors.

24.1 Actions, States of Nature, and Outcomes.

We refer to the alternative choices we can make for a decision as **actions** ⓘ. Actions are mutually exclusive; if you choose one course of action, you haven't chosen the others. We'll call Data Descriptions' choices:

- Online FAQ
- Free Help Desk
- Pay Help Desk

The facts about the world that affect the consequences of each action are called **states of nature** ⓘ, or sometimes just **states** ⓘ. We often simplify the states to make it easier to understand the decision alternatives. We know, for example, that the economy isn't just "good" or "bad," and the number of customers can be any value in some reasonable range. But we'll simplify by grouping the states of nature into a few categories and treating them as discrete possibilities.

For Data Description, the *states of nature* concern the type of question coming into the Help Desk. Management classifies them into two basic types:

- Simple
- or
- Complex

A simple question is one that can be answered with an online FAQ system alone. A complex question requires either human technical support by telephone or backup e-mail support for FAQ users.

Each *action* has consequences that depend on the *state of nature* that actually occurs. These consequences are called the **outcomes** ⓘ or **payoffs** ⓘ (because usually in business the consequence can be measured in money).

To make informed decisions, Data Description president John Sammis must estimate the costs and benefits of each action under each state of nature. According to his estimates:

- The FAQ system can answer a simple question for about \$3.50. A complex question can't be answered by the FAQ system and needs additional resources. Unfortunately the back-up system is slow and the marketing manager estimates that this would cost about \$15 in goodwill and future business. Adding that to the FAQ system cost gives a total cost of \$18.50 for a complex question.
- A live telephone support person costs about \$10 per question whether it is simple or complex.
- Charging the customer \$3 for the telephone support could defray some of the cost, but it might upset a customer with only a simple question. That resulting ill will will cost the company an estimated \$15 for each simple question. On the other hand, customers with a complex question might be happy to pay for the telephone support, so the net cost for them would be \$7.

In Practice 24.1 Actions, states of nature, and outcomes

Pat needs to purchase airplane tickets to fly home at the end of the term. The last exam schedule slot is Friday at 3 pm. Exams are scheduled centrally at Pat's school, and there is no alternative time to take exams. Pat simply must be there. A ticket to fly out on Thursday costs \$750. An advanced-purchase ticket for Saturday morning costs \$900, but, the end of term being a busy time, Pat doubts this option will be available for many more days. If the exam is scheduled on Thursday or Friday, Pat would have to sacrifice the ticket and purchase a new one for \$1200. So Pat goes to the Statistics Consulting Lab to seek help.

PAT How should I think about this problem?

What are the actions in this decision process?

What are the states of nature?

What are the outcomes?

CONSULTANT The actions are purchasing a ticket for Thursday or Saturday.

The states of nature are the exam being scheduled before Thursday or afterwards.

The outcomes are \$750 for a Thursday ticket and early exam, \$900 for a Saturday ticket, and \$1950 for a Thursday ticket but late exam.

24.2 Payoff Tables and Decision Trees

We can summarize the actions, states of nature, and corresponding payoffs in a **payoff table**. **Table 24.1** shows the payoff table for Data Description's decision about customer support. Customer support is an expense, so all the entries in the payoff table are costs, which Data Description hopes to keep to a minimum. The table shows the costs for a single tech support request.

Table 24.1

A payoff table showing costs of actions for two states of nature. Note that these are costs and not profits. As "payoffs," they might be written as negative values, but it is simpler to just remember that we want to *minimize* costs. Payoff tables of profits look to *maximize* values.

		State of Nature	
		Simple Question	Complex Question
Action	FAQ	\$3.50	\$18.50
	Free Help Desk	\$10.00	\$10.00
	Pay Help Desk	\$15.00	\$7.00

The payoff table is easy to read, but it doesn't display the sequential nature of the decision process. Another way to display this information that shows the dynamics of the decision-making process is with a **decision tree**. The decision tree mimics the actual decision-making process by showing actions first followed by the possible states of nature and finally the outcomes that would result from each combination (**Figure 24.1**).

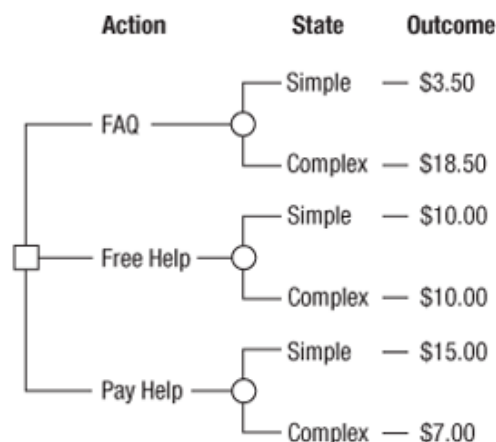


Figure 24.1

A decision tree for the customer support decision.

The decision process moves from left to right through the decision tree. The decisionmaker chooses an action (indicated by a square node), determining which branch of the tree to follow. The circle nodes indicate

branches due to the state of nature, which lie outside the control of the decisionmaker. The tree can expand to show decisions with any (reasonable) number of actions and states of nature.

Node Shapes

The square node, or decision node, indicates that a decision must be made. The circular node, or chance node, indicates a choice made by nature.

In Practice 24.2 Payoff tables

PAT What is my payoff table? (See previous In Practice.)

CONSULTANT

		Exam date	
		Wed or before	After Wed
Ticket	Thursday	\$750	\$1950
	Sat	\$900	\$900

24.3 Minimizing Loss and Maximizing Gain

A conservative approach to decision making would look at the worst possible loss and try to minimize it.

Table 24.2 shows the outcomes for each decision and the greatest cost for each.

Table 24.2

The greatest cost for each decision.

		State of Nature		
		Simple Question	Complex Question	Greatest Cost
Action	FAQ	\$3.50	\$18.50	\$18.50
	Free Help Desk	\$10.00	\$10.00	\$10.00
	Pay Help Desk	\$15.00	\$7.00	\$15.00

The decision to go with a FAQ could cost the company as much as \$18.50 when complex calls come in, and the decision for a pay help desk could cost up to \$15.00. The safe choice—the one that minimizes the maximum cost—is the free help desk. This is known as the **minimax choice**. (If we are maximizing the minimum return, this can be called a maximin strategy.)

Of course, one could take the other extreme position and try for the maximum gain (or, equivalently here, the minimum cost). In this table, that would call for committing to a FAQ system (and hoping that the calls were simple). Such a choice is known as the **maximax** (when maximizing return) or the **minimin** (when minimizing cost) choice.

Choosing actions based on worst and best case scenarios rarely leads to the best business decision. Instead, successful small business executives rely on knowing their market so they can make less absolute decisions. A more realistic modeling approach takes into account how frequently the decisionmaker expects to experience each of the states of nature, and finds the optimum under that model.

In Practice 24.3 Minimizing loss and maximizing gain

PAT OK, so given that payoff table (see previous In Practice), what's my minimax choice?

What is my minimin choice?

CONSULTANT Your minimax choice, minimizing the worst cost, is to purchase a Saturday ticket.

Your minimin choice, minimizing the minimum cost, is to purchase a Thursday ticket.

24.4 The Expected Value of an Action

How can Data Description choose an action to maximize profit (or minimize loss)? They can be pretty sure that they'll get a mix of both simple and complex questions. Decisionmakers often estimate the *probability* of a state of nature based on their understanding of their business. Such probabilities can be *subjective* probabilities or can be grounded in data, and viewed as the *frequentist* probabilities we've used earlier in this text. In either case they express the expert's opinion of and belief in the relative likelihood of the states. We'll write $P(s_j)$ for the probability of the j th state of nature.

As with all probabilities, we need to check that the probabilities are *legitimate*. If there are N states of nature, then we require that:

$$P(s_j) \geq 0 \text{ for all } j, \sum_{j=1}^N P(s_j) = 1.$$

If the probabilities are legitimate, then we can find the **expected value (EV)** of action a_i in essentially the same way as we found the expected value of a discrete random variable in **Chapter 6**:²

In **Chapter 6** we computed the EV for one action, such as investing in a CD. This chapter extends this concept by computing and comparing EVs for different actions.

$$EV(a_i) = \sum_{j=1}^N o_{ij} P(s_j),$$

where there are N possible states of nature and o_{ij} is the outcome or payoff of action i when the state of nature is s_j .

At Data Description, about 40% of the questions are simple, so managers assigned a probability of 0.4 that a support question will be simple and a probability of 0.6 that it will be complex. To compute the expected value, we start by placing the probabilities on the decision tree in the appropriate place. With these values in place, we can find the expected value of each of the actions. The probabilities are associated with each state of nature and are the same regardless of the action. We place these values on the branches associated with each state of nature, repeated for each one of the possible actions (the circle nodes).

How Much Risk Are You Willing to Take?

There are three general types of decisionmakers:

- a risk-averse individual will sacrifice EV for lower variation
- a risk-neutral individual will try to maximize EV
- a risk-tolerant individual may be willing to absorb greater variation in return for the chance of a higher payoff

For each combination of outcome and probability, we calculate its contribution to the expected value $P(s_j) \times o_{ij}$. Because only one state of nature can occur for each call, the states of nature are disjoint. We can therefore find the expected value for each action by summing the contributions over all the states of nature, in this case Simple and Complex (see [Figure 24.2](#)).

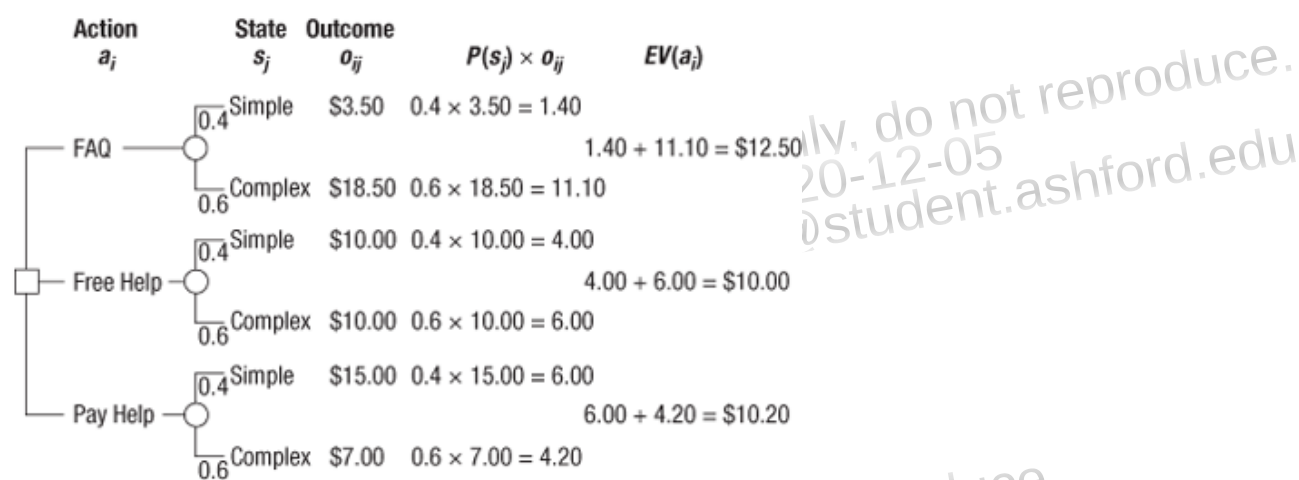


Figure 24.2

Calculating the expected value of each action using a decision tree.

From the expected values in [Figure 24.2](#), it appears that expanding free telephone support may be the best action because it costs Data Description the *least*. The expected value of that action is a cost of \$10.00.

In Practice 24.4 Expected value of purchasing a ticket

PAT Based on previous years, I guess that the course in question has an exam scheduled on the last 2 days of the exam period only about 20% of the time (see [In Practice 24.1](#)).

What is the expected value of purchasing a Thursday ticket?

CONSULTANT I'd compute that this way:

$$0.8 \times 750 + 0.2 \times 1950 = \$990$$

24.5 Expected Value with Perfect Information

Unfortunately, we can't predict the state of nature with certainty. But it can be informative to consider what it costs us to live with the uncertainty. If we knew the true state of nature—rather than just the probable state of nature—how much might that be worth to us? To help quantify that, let's consider a single customer support question. Knowing whether it was simple or complex would enable us to take the optimal action in each case. For a simple question we'd offer online FAQ support and the "payoff" would be \$3.50. For a complex question we'd provide paid telephone support costing the company \$7.00.

Using the probabilities of the two states of nature, we can calculate the expected value of this optimal strategy as:

$$0.6 \times \$7.00 + 0.4 \times \$3.50 = \$5.60$$

This is called the **expected value with perfect information** ⓘ and is sometimes denoted *EVwPI*.

By contrast, the expected value of the optimal strategy that we calculated without knowing the state of nature was \$10.00. The absolute value of the difference between these two quantities is called the **expected value of perfect information** ⓘ.

$$EVPI = |EVwPI - EV|$$

In our example, this difference is $|\$5.60 - \$10.00| = \$4.40$. (Notice the absolute value in that calculation. Information should increase profit or, as in our example, reduce costs. Either way, the *value* of information is positive.) Our lack of perfect knowledge about the state of nature costs us \$4.40 per call. The expected value of information, EVPI, gives the maximum amount the company might be willing to pay for perfect information about the outcome.

In Practice 24.5 EVwPI and EVPI

PAT Based on the payoff table on page 24-4 □ for my airline ticket purchase, what is my EVwPI? What is the EVPI?

CONSULTANT With perfect information, you could purchase the early ticket for \$750 80% of the time and the late ticket for \$900 20% of the time for an EVwPI of $0.8 \times 750 + 0.2 \times 900 = \780 .

The EVPI is then $|\$780 - \$990| = \$210$.

24.6 Decisions Made with Sample Information

Usually the costs and profits—the payoffs—of alternative actions under various states of nature can be estimated fairly well, because they depend on business-related events and actions that are well understood. By contrast, the probabilities assigned to the states of nature may be based only on expert judgment. These probabilities are sometimes called **prior probabilities** because they are determined before obtaining any additional information on the states of nature. A survey of customers, however, or a planned experiment might provide information that could bring the probabilities closer to reality and make for a more informed decision. Revised probabilities are also called **posterior probabilities**. Should the decisionmaker first gather data to help estimate the probabilities of the states of nature? That's a decision in itself. Surveys and experiments cost money, and the resulting information may not be worth the expense. We can incorporate the decision to gather data into the overall decision process. First, it is worthwhile to ask whether useful information is even possible. If the states of nature in the decision process are about the future health of the economy or the future value of the Dow Jones Industrial Average, it is not likely that we can learn very much new. But market research surveys of customers and trial marketing incentives can often provide useful data.

To improve their estimates of the probabilities making up the mix of simple and complex questions, Data Description could collect data about their customers. Would the added expense of that work be worthwhile? It depends on whether the information about customers helps to predict the likelihood of each type of question. Suppose they could classify their users into those who are *technically sophisticated* users and those who are *beginners*. That information might be useful because for *technically sophisticated* users, Data Description thinks that 75% of the questions will be complex but for *beginners*, that percentage is only 40%. Knowing how to classify their customers will help them make the right decision.

These probabilities are *conditional* probabilities of the kind we first saw in **Chapter 5**. We write:

$$P(\text{Complex} | \text{Sophisticated}) = 0.75; P(\text{Simple} | \text{Sophisticated}) = 0.25 \quad P(\text{Complex} | \text{Beginner}) = 0.40; P(\text{Simple} | \text{Beginner}) = 0.60$$

In each case, we know the missing probability from the requirement that the probabilities sum to one.

Now our decision tree must include both the decision of whether or not to conduct the study and the possible outcomes of the study (if it is conducted), each with its appropriate conditional probability. **Figure 24.3** shows the results. The costs in **Figure 24.3** are the same ones we've used all along from **Table 24.1**. The expected values when there is no study are those worked out previously in **Figure 24.2**.

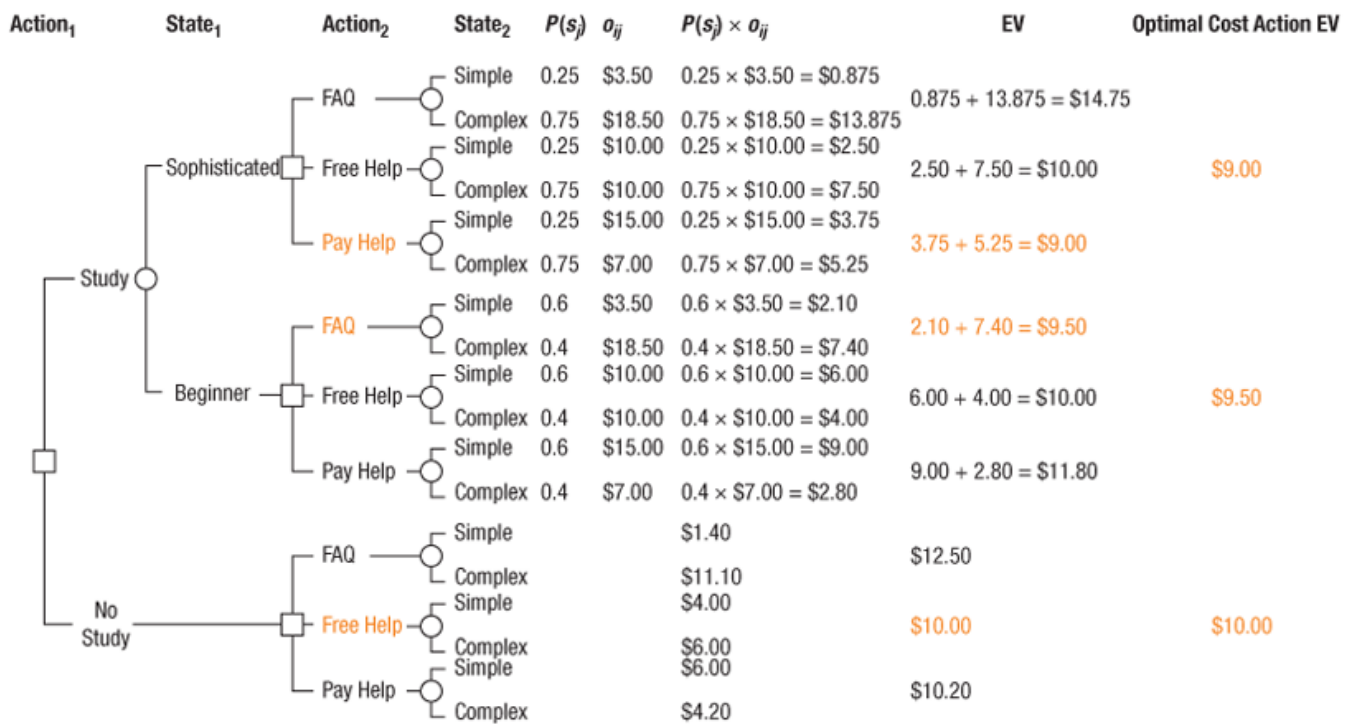


Figure 24.3

A decision tree including a customer history study. For each decision node under each circumstance, the optimal (in this example, lowest cost) alternative is indicated in color, and the corresponding consequence is assigned as the expected value for that alternative. EV's for the No Study branch are from Figure 24.2.

This decision process has two sets of decision nodes. The first decision is whether to conduct the study. The second is what action to take given the information from the study (if available). The outcome of the study is a chance node because we don't know *a priori* what the study will tell us.

To determine a decision strategy we compute the expected payoff at the end of each branch of the tree following the same methods we used before and now using the estimated probabilities that might come from the study. In this example, if we perform the study and it shows that sophisticated users are more common, we'll choose a pay help desk at a cost of \$9.00. If we perform the study but it shows that beginners are the norm, we'll choose the FAQ system, at a cost of \$9.50. If we don't perform the study at all, our optimal choice was the free phone help at a cost of \$10.00. In this example, both alternatives following the study are less costly than the nonstudy choice, so it appears that any information the study may provide will save the company money. To be more precise, however, the company can go further and estimate the likelihood of the study's outcome. This will give the company an estimate of the **expected value with sample information** and help them estimate the potential worth of the study.

For example, if they think there's a probability of 0.8 that the study will show that most users are now technically sophisticated (and, correspondingly, a probability of 0.2 that it would find that beginners are the norm), then the expected value of the decision with that sample information would be:

$$EV_{wSI} = 0.8 \times \$9.00 + 0.2 \times \$9.50 = \$9.10$$

The absolute value of the difference between this payoff and the payoff without the study is the **expected value of sample information**.

$$EV_{SI} = |EV_{wSI} - EV| = |\$9.10 - \$10.00| = \$0.90$$

An analysis like this can help us understand the value of sample information. It tells us that a study of this sort is likely to be worth about \$0.90 per technical support question in its ability to help the company choose the optimal action.

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24.7 Estimating Variation

In [Chapter 3](#), we said that means should always be reported with an associated standard deviation, but thus far we've found expected values (which are, after all, means) without finding the corresponding standard deviations. The expected values tell the decisionmaker which action is likely to be worth the most. But to assess the *risk* of the decision, a decisionmaker must understand whether the likely outcome of the decision will always be close to that expected value or whether it might be quite different. We assess that risk by finding the standard deviation of the outcome.

Recall that the calculation of the expected value of an action is:

$$EV(ai) = \sum_{j=1}^N o_{ij} P(s_j),$$

where there are N possible states of nature, o_{ij} is the outcome or payoff of action i when the state of nature is s_j , and $P(s_j)$ is the probability of the j th state of nature. We saw the equivalent formula for expected value in [Chapter 6](#). The corresponding formulas for variance and **standard deviation** (also seen in [Chapter 6](#)) are:

$$Var(ai) = \sum_{j=1}^N (o_{ij} - EV(ai))^2 P(s_j), \text{ and } SD(ai) = \sqrt{Var(ai)}.$$

To calculate some values, we'll need the outcomes and probabilities we saw earlier and the expected values we calculated for the actions. Recall that Data Description thinks the probability of a simple question is 0.40 and of a complex question is 0.60. The payoffs for each state of nature and action were first given in [Table 24.1](#). Now we also have expected values found from those payoffs and probabilities. [Table 24.3](#) summarizes them.

Table 24.3

The payoff table for the customer support decision along with the expected values computed earlier. Recall that these are costs and thus could be written as negative values. Of course, for finding a standard deviation, writing these as negative numbers would give the same result.

		State of Nature		
		Simple Question	Complex Question	
Action	FAQ	\$3.50	\$18.50	\$12.50
	Free Help Desk	\$10.00	\$10.00	\$10.00
	Pay Help Desk	\$15.00	\$7.00	\$10.20

Now, for example, the standard deviation of the outcome for the FAQ action is $SD(FAQ) = (3.50 - 12.50)^2 \times 0.40 + (18.50 - 12.50)^2 \times 0.60 = \7.35 and the standard deviation of the Pay Help Desk option is $SD(\text{Pay Help}) = (15.00 - 10.20)^2 \times 0.4 + (7.00 - 10.20)^2 \times 0.6 = \3.92

The standard deviation of the Free Help Desk option is zero. (Can you see why?)

In the customer support example, the choice to rely on an online FAQ system has higher variability. That may make it a less desirable alternative even in situations where its expected value seems to be optimal.

One way to combine the expected value and standard deviation is to find their ratio, the **coefficient of variation** ⓘ:

$$CV(ai) = SD(ai)/EV(ai).$$

For the customer support example, the CVs are 0.588 for online FAQ, 0 for Free Help, and 0.384 for Pay Help. Actions with smaller CVs are generally seen as less risky, and may be preferred for that reason by some people. You can see why Data Description may prefer Free Help even though it may be more expensive; the company can predict its cost regardless of the state of nature.

One action may dominate another if its worst outcome is still better than the best outcome for the other. In such cases, the better action should be chosen regardless of how much variation it may have.

Dominance ⓘ is defined as the situation in which one decision alternative is never an optimal action regardless of the state of nature. A dominated action can be eliminated as a variable option or strategy.

Some discussions of risk prefer to concentrate on the expected value rather than the standard deviation, so they look at the reciprocal of the CV and give it the name **return to risk ratio** ⓘ

$$RRR(ai) = 1/CV(ai) = EV(ai)/SD(ai).$$

The RRR can't be computed for actions with zero standard deviation, because they have no risk. Generally, actions with higher RRR are favored because they are less risky for their expected return. The units of RRR are dollars returned per dollar at risk.

In Practice 24.6 Estimating variation

PAT I paid attention in statistics class, so I know that knowing the standard deviation of my outcome will help me make a better decision. What is the standard deviation of my outcome? What is the RRR of purchasing a Thursday ticket?

CONSULTANT For Thursday ticket:

$$(750-990)^2 \times 0.8 + (1950-990)^2 \times 0.2 = 480$$

For Saturday ticket, $SD=0$

$$RRR(\text{Thursday}) = EV(\text{Thursday})/SD(\text{Thursday}) = 990/480 = 2.06$$

24.8 Sensitivity

One weakness of the methods we've discussed here is that they require that you estimate—subjectively or by research—probabilities of states of nature. You may wish to assess the *sensitivity* of your conclusions about the expected value and standard deviation of alternative actions to the probabilities in your model. One way to do this is to re-compute those values with slightly (or even substantially) different probabilities. If the decision advised by the model doesn't change, you can be more confident in it. But if small changes in the probabilities result in large differences in the estimated value of the action alternatives, you should take great care and not rely too heavily on your decision analysis.

3 If you completed the Brief Case at the end of [Chapter 6](#), you have already conducted a small sensitivity analysis.

For example, if the probability of a complex question were 0.8 rather than 0.6, would that change the decision? [Table 24.4](#) shows the calculations.

Table 24.4

Alternative calculations (compare with [Table 24.3](#)) with different probabilities for the states of nature.

		State of Nature		
		Simple Question	Complex Question	
Action	FAQ	\$3.50	\$18.50	\$15.50
	Free Help Desk	\$10.00	\$10.00	\$10.00
	Pay Help Desk	\$15.00	\$7.00	\$8.60

It seems that the best decision would change if the probability of a complex question were as large as 0.8. The decisionmakers at Data Description should consider how sensitive these expected values are to their probabilities by finding the SD and EV for a plausible range of probabilities and then think about how certain they are about those estimated probabilities.

In Practice 24.7 Assessing sensitivity

PAT How sensitive is my decision? Suppose, for example, that the probability of a late exam were only 0.1. How would that change the expected values?

CONSULTANT The EV of the Thursday ticket would now be \$870, which is less than the EV of the Saturday ticket (which would still be \$900).

24.9 Simulation

Another alternative to assessing the sensitivity of a decision model to the choice of probabilities is to simulate the model for a variety of plausible probability values. Rather than specify single probabilities, you can specify a distribution of plausible values. You can then run a *simulation* in which the computer draws states of nature at random according to your distribution of probabilities and evaluates the consequences. This approach can deal with much more complex decision models than those we've discussed here. The result of the simulation is not a single decision but a distribution of outcomes. Such a distribution may be a more appropriate description for a decisionmaker than any single expected value.

Programs such as @Risk (www.palisade.com/) and Crystal Ball (www.oracle.com/us/products/applications/crystalball/overview/index.html) provide ways for you to specify actions, states of nature, and the associated probabilities and outcomes and then use simulation methods to generate distributions of outcomes.

Guided Example Insurance Services



BCFC/Shutterstock

InterCon Travel Health is a Toronto-based company that provides services to health insurers of foreign tourists who travel to the United States and Canada.⁴ The primary focus of InterCon is to act as an interface between local health providers and the overseas insurance company who insured the tourist should the traveler find himself or herself in need of medical attention. The customer base of sick or injured tourists is potentially profitable because most tourists who fall ill require only minor treatment and rarely come back for expensive follow-up visits. So InterCon can pass savings along to the foreign insurer by facilitating claim management and payment and can collect processing fees from these insurance companies in return.

⁴This example is based on the case by G. Truman, D. Pachamanova, and M. Goldstein entitled "InterCon Travel Health Case Study" in *Journal of the Academy of Business Education*, Vol. 8, Summer 2007, pp. 17–32.

Currently, InterCon charges a processing fee of 9.5%, collected partly from the medical providers and partly from the foreign insurers. It has experienced an average annual growth of 3%. However, to help with rising costs, they may consider increasing the processing fee from 9.5% to 10.5%. Although this would generate additional revenue, they would also incur the risk of losing contracts with insurers and health care providers. **Table 24.5** gives the company's estimates of the impact of a change in rates on the annual growth in claims depending on the strength of foreign tourism.

Table 24.5

InterCon's estimates of the impact on the annual growth in claims for two different actions (changes in rate) under two possible states of nature (strong or weak tourism).

		State of Nature	
		Weak Tourism	Strong Tourism
Action	9.5% Fee	\$54.07M	\$56.23M
	10.5% Fee	\$52.97M	\$54.56M

What would be the best choice for the company?

Define and state the objective of the study. Identify the variables. Model Think about the assumptions and check the conditions.	We want to evaluate the two alternative actions the company is considering. We have estimates of the outcomes and the probabilities of two states of nature: we The only condition to check is that the probabilities are legitimate; $0.40 + 0.60 = 1.0$, a																										
The calculations of expected value and standard deviation are straightforward. It can help to diagram the	9.5% fee 10.5% fee 0.4 0.6 Weak Strong 0.4 0.6 Weak Strong <table><thead><tr><th>Action</th><th>P</th><th>State</th><th>Outcome</th><th>$o_{ij}P(s)$</th><th>$EW(a_i)$</th></tr></thead><tbody><tr><td rowspan="2">9.5% fee</td><td>0.4</td><td>Weak</td><td>\$54.07M</td><td>\$21.63M</td><td rowspan="2">\$55.37M</td></tr><tr><td>0.6</td><td>Strong</td><td>\$56.23M</td><td>\$33.74M</td></tr><tr><td rowspan="2">10.5% fee</td><td>0.4</td><td>Weak</td><td>\$52.97M</td><td>\$21.19M</td><td rowspan="2">\$53.93M</td></tr><tr><td>0.6</td><td>Strong</td><td>\$54.56M</td><td>\$32.74M</td></tr></tbody></table> For example:	Action	P	State	Outcome	$o_{ij}P(s)$	$EW(a_i)$	9.5% fee	0.4	Weak	\$54.07M	\$21.63M	\$55.37M	0.6	Strong	\$56.23M	\$33.74M	10.5% fee	0.4	Weak	\$52.97M	\$21.19M	\$53.93M	0.6	Strong	\$54.56M	\$32.74M
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	0.6	Strong	\$54.56M	\$32.74M																							

decision process with a tree diagram.	$0.4 \times \\$54.07M = \\21.6 Standard deviations: For 9.5% fee: $(o_{ij} - EV(a_i)) \quad (O_{ij} - EV(a_i))^2 p(s_j) \quad (54.07 - 55.37) = -1.30 \quad (-1.30)^2 \times 0.4$ For 10.5% fee: $SD = \$0.774MRRR(9.5\% \text{ fee}) = 55.37$
Communicate and Present Summarize your results and state any limitations of your model in the context of your original objectives.	Memo Re: Recommendations for processing fee rate The expected value of the alternative with the lower processing fee rate is slightly higher than the expected value of the alternative with the higher processing fee rate of 10.5% is 55.37. Because one action has the better expected value but the other seems less risky, the decision maker should choose the alternative with the lower processing fee rate based on the probability estimates for the strength of the foreign tourism industry.

24.10 More Complex Decisions

The methods of this chapter can be extended to decisions that are more complex and that may have second or third stages conditional on the outcomes of the first decisions. For example, customer support questions might be handled best by an initial online FAQ system that then offers customers with complex questions a choice of free e-mail support or paid telephone support. To work out the expected values for these choices, we'd need to estimate the probabilities of a customer with a complex question choosing free e-mail or paid telephone support—something with which the company has no prior experience.

Or the probabilities may be changed by a change in circumstances. When the company releases an upgraded version, technical support calls increase, but there's a higher probability of simple calls. As the customer base learns the new version, their questions generally become more sophisticated.

What Can Go Wrong?

- **Decision trees do not tell the decisionmaker the correct decision.** Models can be useful, but they are based on assumptions. Decision trees model the expected outcome and risk for each decision. The best decision depends on the level of risk the decisionmaker is willing to accept, as well as the state of nature that occurs.
- **The computation of the expected values and standard deviations are sensitive to the probabilities.** The probabilities required by the calculations of expected value and standard deviation may be reliably based on past experience or data, or they may just represent the subjective judgment of the decisionmaker. Don't trust them blindly. Using a decision model and ignoring the sensitivity of the model to different probabilities can lead to poor decisions and misleading conclusions. One way to address the problem is to solve the model with a range of plausible probabilities to assess how sensitive the conclusions are to the choice of probabilities. Another way is to use software that simulates the results for randomly generated probabilities from an appropriate distribution.
- **Be sure that the probabilities are legitimate and that the action choices are disjoint.** The calculations in this chapter depend upon both of these being true.

Ethics in Action

Nelson Greene develops real estate in the southwestern United States. His next planned project is to build a housing development on a parcel of land in New Mexico, not far from Santa Fe. However, with the recent decline in housing prices, particularly in areas of the southwest like Las Vegas, Nelson is reconsidering his decision.

He set up a meeting with some key individuals, including Tom Barnick, a representative from the township supervisors. Tom and the township council were positive about the proposed development since it would provide increased tax revenue. So Tom wanted to influence Nelson to go forward with the development.

Tom had some analysis prepared, which he presented at the meeting. Based on several assumptions, including the probabilities associated with different housing market conditions in New Mexico (improving, worsening, or staying the same), the analysis showed a positive expected payoff for going forward with the project. Tom mentioned that the probabilities were obtained from a small group of housing market experts, although they had difficulty reaching consensus. Nelson noticed that not all the payoffs associated with going forward with the project were positive for each possible market condition, but the positive expected payoff made him view the project more favorably.

- **Identify the ethical dilemma in this scenario.**
- **What are the undesirable consequences?**
- **Propose an ethical solution that considers the welfare of all stakeholders.**

Chapter 24 From Learning to Earning

Learning Objectives

Assess costs and benefits of various actions given possible states of nature.

- Use judgment or data.

Estimate the likelihood of the possible states of nature.

- Use data, if they are available.
- Confirm that probabilities are legitimate.

Evaluate likely outcomes (costs and benefits) of decisions when faced with uncertainty about the state of nature.

- Make a decision tree and find the expected value of actions.
- Evaluate the relative risk of alternative decisions.

Terms

Action

Alternative choices that one can make for a decision.

Coefficient of variation

The coefficient of variation (CV) of each decision shows the “\$ at risk” for each “\$ returned”:

$$CV(ai) = SD(ai) / EV(ai).$$

Decision tree

A decision tree organizes the actions, states of nature, and outcomes to display the sequence of the elements in a decision.

Dominance

An alternative dominates when it pays off at least as much as (or costs less than) the alternative it dominates in all states of nature.

Expected value (EV)

The expected value of an action under uncertain states of nature is:

$$EV(ai) = \sum_{j=1}^N o_{ij} P(s_j)$$

where there are N possible states of nature and o_{ij} is the outcome or payoff of action i when the state of nature is s_j .

Expected value of perfect information (EVPI)

The difference between the expected value with perfect information (EVwPI) and the expected value (without perfect information) of the strategy (EV):

$$EVPI = |EVwPI - EV|$$

Expected value with perfect information (EVwPI)

The expected value of a hypothetical strategy assuming that the states of nature are known.

Expected value of sample information (EVSI)

The difference between the expected value with sample information (EVwSI) and the expected value (without sample information) of the strategy (EV):

$$EVSI = |EVwSI - EV|$$

Expected value with sample information (EVwSI)

The expected value of a hypothetical strategy given probabilities of the states of nature estimated from sample data.

Maximax choice (or strategy)

The action that maximizes the maximum possible return across all states of nature in a payoff table.

Minimax choice (or strategy)

The action that minimizes the maximum possible cost across all states of nature in a payoff table.

Minimin choice (or strategy)

The action that minimizes the minimum possible cost across all states of nature in a payoff table.

Outcome (or payoff)

The consequence of an action combined with a state of nature, usually expressed in monetary units (positive or negative).

Payoff table

A table containing the actions, states of nature, and the corresponding payoffs for each combination of the two.

Return to risk ratio

The return to risk ratio (RRR) measures the expected return of an action relative to the risk, represented by its standard deviation:

$$RRR(ai) = 1/CV = EV(ai)/SD(ai).$$

Standard deviation of an action, Variance of an action

The standard deviation of an action measures the variability of possible outcomes, calculated in terms of their estimated probabilities of occurring. The standard deviation is the square root of the variance:

$$Var(ai) = \sum_j = 1N(o_{ij} - EV(ai))^2 P(s_j) SD(ai) = Var(ai)$$

States of nature

The facts about the world that affect the consequences of an action, usually summarized into a few possible values.

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Brief Case

Texaco-Pennzoil



DNY59/GettyImages

“Oil is big business.” A classic example of this is the Texaco-Pennzoil court case, which appeared in the book *Making Hard Decisions* and in a subsequent case study by T. Reilly and N. Sharpe (2001). In 1984, a merger was hammered out between two oil giants, Pennzoil and Getty Oil. Before the specifics had been agreed to in a written and binding form, another oil giant—Texaco—offered Getty Oil more money. Ultimately, Getty sold out to Texaco.

⁵Clemen, R. T., and Reilly, T. (2001), *Making Hard Decisions*, New York: Brooks/Cole.

Pennzoil immediately sued Texaco for illegal interference, and in late 1985 was awarded \$11.1 billion—an enormous award at the time. (A subsequent appeal reduced the award to \$10.3 billion.) The CEO of Texaco threatened to fight the judgment all the way to the U.S. Supreme Court, citing improper negotiations held between Pennzoil and Getty. Concerned about bankruptcy if forced to pay the required sum of money, Texaco offered Pennzoil \$2 billion to settle the case. Pennzoil considered the offer, analyzed the alternatives, and decided that a settlement price closer to \$5 billion would be more reasonable.

The CEO of Pennzoil had a decision to make. He could make the low-risk decision of accepting the \$2 billion offer, or he could decide to make the counteroffer of \$5 billion. If Pennzoil countered with \$5 billion, what are the possible outcomes? First, Texaco could accept the offer. Second, Texaco could refuse to negotiate and demand settlement in the courts. Assume that the courts could order one of the following:

- Texaco must pay Pennzoil \$10.3 billion.
- Texaco must pay Pennzoil's figure of \$5 billion.
- Texaco wins and pays Pennzoil nothing.

The award associated with each outcome—whether ordered by the court or agreed upon by the two parties—is what we will consider to be the “payoff” for Pennzoil. To simplify Pennzoil's decision process, we make a few assumptions. First, we assume that Pennzoil's objective is to maximize the amount of the settlement. Second, the likelihood of each of the outcomes in this high-profile case is based on similar cases. We will assume that there is an even chance (50%) that Texaco will refuse the counteroffer and go to court. According to a *Fortune* article,⁶ the CEO of Pennzoil believed that should the offer be refused, Texaco had a

chance to win the case with appeals, which would leave Pennzoil with high legal fees and no payoff. Based on prior similar court cases and expert opinion, assume that there is also a 50% probability that the court will order a compromise and require Texaco to pay Pennzoil the suggested price of \$5 billion. What are the remaining options for the court? Assume that the probabilities of the other two alternatives—Pennzoil receiving the original total award (\$10.3 billion) or Pennzoil getting nothing—are almost equal, with the likelihood of the original verdict being upheld slightly greater (30%) than the likelihood of reversing the decision (20%).

6Fortune, May 11, 1987, pp. 50–58.

Evaluate the expected payoff and risk of each decision for Pennzoil.

Insurance Services, Revisited

InterCon Travel Health is a Toronto-based company that provides services to health insurers of foreign tourists who travel to the United States and Canada. As described in the Guided Example in this chapter, the primary focus of InterCon is to act as an interface between local health providers and the overseas insurance company who insured the tourist should the traveler find himself or herself in need of medical attention. The customer base of sick or injured tourists is potentially profitable because most tourists who fall ill require only minor treatment and rarely come back for expensive follow-up visits. Therefore, InterCon can pass savings along to the foreign insurer by facilitating claim management and payment and can collect processing fees from these insurance companies in return.

7This case is based on the case by G. Truman, D. Pachamanova, and M. Goldstein entitled “InterCon Travel Health Case Study” in *Journal of the Academy of Business Education*, Vol. 8, Summer 2007, pp. 17–32.

Currently, this Canadian company charges a processing fee of 9.5% (collected partly from the medical providers and partly from the foreign insurers) and has experienced an average annual growth rate of 3%. However, a backlog of claims and a cyclical pattern to the claims (due to high tourist seasons) has caused a delay in filing claims with the foreign insurers, resulting in a number of noncollectible claims. In addition, while the growing company has been trying to keep costs to a minimum, they are considering adding a new information technology system to help them streamline the process. Most of the company’s revenue comes from claims for inpatient hospital stays, which average approximately \$10,000. These claims represent 20% of InterCon’s claims, but over 80% of its claim revenue. The remaining claims arise from clinic and emergency room visits. Currently, the company has about 20,000 annual claims, so the associated revenue is estimated to be as follows.

Claim Class	# Claims by Class	% of Total	Average Claim Amount	Claim Revenue (\$M)	% of Total	Fee Rate	Fees (\$M)
Class A	4000	20%	\$10000	\$40.0	85%	9.5%	\$3.8
Class B	6000	30%	\$1000	\$6.0	13%	9.5%	\$0.57

Class C	10000	50%	\$100	\$1.0	2%	9.5%	\$0.095
Total (Annual)	20000			\$47.0			\$4.465

To help with rising costs, this firm may consider raising the processing fee as high as 11.0%. While this would generate additional revenue, the firm would also incur the risk of losing contracts with insurers and health care providers. Here are estimates of the impact of a change in rates on the annual growth in claims depending on the strength of foreign tourism (reverse of the strength of the U.S. economy) for the 9.5% processing fee rate. Find the payoffs (total revenue) for the 11.0% fee rate based on the preceding table and the growth rates provided.

		Processing Fee Rate at 9.5%		Processing Fee Rate at 11.0%	
Foreign Tourism	Probability	Growth Rate	Payoff (\$)	Growth Rate	Payoff (\$)
Weak	0.40	3%	54069129	1%	??
Strong	0.60	4%	56231894	3%	??

What is the expected revenue for the respective fee alternatives based on the growth rate and total income from claims and fees? Suppose the manager gets new information and revises the probabilities for the strength of tourism to be even at 50-50. What are the new values for expected revenue, CV, and return to risk ratio?

Chapter 24 Exercises

Section 24.1

1. Which of the following are Actions and which are States of Nature?
 - a. Whether Unemployment is above or below 10%.
 - b. Whether a new product should be brought to market before or after the beginning of the fiscal year.
 - c. Whether to tell employees to stay home because of a blizzard.
2. Which of the following are Actions and which are States of Nature?
 - a. Whether to invest in solar energy companies.
 - b. Whether your chief competitor decides to launch a new advertising campaign.
 - c. Whether the decision you made to out-source manufacturing last year turned out to be the cost-saver you thought it would be.