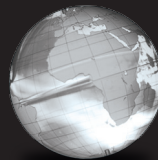


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Foundations of Decision Analysis

Ronald A. Howard • Ali E. Abbas

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Foundations of Decision Analysis

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PREFACE

Decisions are the only means you have to change your future life. We make decisions every day. Some decisions are routine, like choosing a television program to watch. Occasionally we make decisions that have profound effects on us and those around us. Gaining competence in decision making is a highly desirable attainment. Although many of the principles of good decision making have been known for centuries, there is little emphasis on this subject throughout our educational lives. The important concepts in this book could be taught in grade school and in high school. Yet when we ask graduate students about having taken previous courses in decision making, few say that they have. Students in professional courses from major companies with global interests have the same response.

The purpose of this book is to provide an opportunity to gain this mastery; to be able to achieve clarity of action in making any decision on which you focus your attention. One of the biggest obstacles in gaining decision competence is that most of us think we are pretty good at making decisions. Yet it is easy to demonstrate that even in relatively simple decision situations people make decisions that they see as unwise when they carefully review them.

Let us preview the major conceptual lessons that we will share. The most challenging phenomenon we face in decision making is uncertainty. Suppose for each alternative we face in making a decision we had a video showing the future course of our lives in as much detail as we wished. Then we could easily make the decision. Uncertainty is inseparable from all significant decisions. To become masters of decision making we must become competent in dealing with uncertainty. We must learn to surf on the sea of uncertainty rather than to drown in it. We must build clear thinking about uncertainty as a precursor to making a decision; we call this achieving clarity of thought.

Learning how to deal with uncertainty does not mean that we do not relish it in our lives. Who would want to live a life with a future calendar that is completely filled out so that, for example, you would know years in advance on each day when, where, and with whom you would be having lunch.

The most important distinction of decision analysis is that between a decision and the outcome that follows it. This distinction, once thoroughly understood, is a powerful aid to achieving clarity of action. Though it is common for people who make a decision followed by an unfortunate outcome to see the decision as bad, this is not clear thinking. Good decisions can have bad outcomes; bad decisions can have good outcomes. The quality of the decision depends only on the quality of the thought and analysis that you have used in making it.

The amount of analysis appropriate to a decision can range from virtually none to extensive computer modeling. Everyone will have extensive conversations about making important decisions—sometimes with others, sometimes with oneself. Mastering the concepts of decision analysis will increase the focus and usefulness of these conversations. While few decisions will warrant the extensive analysis possible using these methods, merely thinking using the concepts in this book can improve many of the choices we make every day. We find that as students become acquainted with decision analysis it changes their conversation with friends and colleagues.

An important distinction about any decision is its degree of revocability. Some decisions are very revocable, like changing the movie you will see once you arrive at the multiplex; other

decisions have limited revocability, such as amputating your leg for a medical purpose. The irrevocability of an important decision is a sign to invoke the power of decision analysis.

There is no point in valuing an outcome after the decision is made. You will be living the rest of your life beginning with that outcome or, as we prefer to call it, prospect. Once you commit yourself to making good decisions there is no place in your life for regret or guilt. *Good decisions never become bad; bad decisions never become good.*

Consider how evolution has prepared us for the modern world. What will befall an airplane pilot if he flies into the clouds and has no instruments? Soon he will think he is upside down when he is not, or not turning when he is. Without intervention he is likely to die. This is not a matter of his training or experience as a pilot, but rather that he is human. Humans never developed the ability to operate an aircraft without visual reference. Why not? Because before the invention of aircraft there was no evolutionary advantage to this ability. As long as you are standing on earth or swimming in the water, you know which way is down. Notice that birds that fly have no such problem. Duck hunters watching a flock fly into the clouds do not say, "Drop the guns, we will catch them as they fall." The many pilots of aircraft flying in bad visibility somewhere at this moment also have no difficulty, because the aircraft are equipped with instruments and the pilots are trained to read them. Even if a pilot feels he is upside down, his instruments show him that he is not.

Consider another example. For thousands of years, humans have been able to dive into deep water successfully for food or pearls. They would take a deep breath and hold it till they reached their goal and then return to the surface with their spoils. The development of scuba—self-contained underwater breathing apparatus—equipment has allowed people for many decades to do what only the most athletic of our ancestors could achieve. Suppose you are using scuba equipment and you have dived to a depth of 100 feet, about 3 atm, and then find that your equipment does not function. You are now far below the surface with only a lungful of air, air that is now extremely precious to you: you can't breathe. Your instinct is to head to the surface as quickly as possible and preserve what air you have. Unfortunately, following this instinct will probably kill you, for the lungful of air that you have will expand threefold by the time you reach the surface. This expansion will destroy the alveoli in your lung that allow you to breathe and admit air to your bloodstream. Following your instinct will kill you. Instructors point out that in this situation that as you slowly ascend, no faster than your smallest bubbles, you must blow out the air as you rise to avoid this misfortune. You must give up what is precious to you according to your instinct to save your life. (Of course it is even better to dive with a buddy who can assist you in these circumstances.) Here again before the invention of scuba there was no evolutionary advantage in having this be our natural behavior.

Finally, as you sit reading this, it is possible that under your chair there is a highly radioactive substance whose emissions will kill you by tomorrow. You have no alarm, since the ability to sense radiation was not of evolutionary value to our ancestors. If in our modern world you are concerned about the presence of radiation, there are many instruments that will warn you of its presence.

Now let us consider the evolutionary influence on decision making. While evolution has sensitized us to deal with judging the intentions of those we meet for millions of years, there is not any evolutionary knowledge of dealing with uncertainty. If each of us suddenly heard the roar of a live lion we would immediately react, though the noises of everyday life cause no alarm. There was an evolutionary advantage to being aware of dangers from other predatory forms of life that we have, fortunately, little reason to use frequently today. Yet someone can

sign a paper having profound effects on his future welfare without alarm since making marks on a paper does not inspire the natural fear induced by the lion's roar.

Just as knowledge and proper instruments have helped us overcome our evolutionary disadvantages in these areas, so also can they help us in becoming better decision makers. The essential commitment is to use our instruments rather than trusting our intuition.

It is easy to show, and we do so in several occasions in this book, that our intuition on matters of uncertainty is severely flawed. Using our instruments is essential for clear thinking. No matter how long you have studied the subject, solving probability problems intuitively is as likely to be successful as a pilot flying in bad weather without visible reference and without instruments. The list of people who have made reasoning errors about uncertainty looks like the roll call of famous scientists.

Once uncertainty has been mastered, the next step is to use our instruments for making decisions in the face of uncertainty to arrive at clarity of action. The decision procedure will apply to virtually every decision that you face. Once a student in decision analysis said that he could see using the methods we were presenting for financial decisions, but not for medical decisions. We replied that if we had to choose between using it for financial decisions and for decisions about the health of a family member, then we would hire a financial advisor to manage money and use decision analysis for family medical decisions. The reason is that we would want to use the best decision method for the health of family and we know no better method than the one we present in what follows.

This book summarizes what we have learned by teaching decision analysis to thousands of people in the United States and around the world in university classes and special professional educational programs. Dozens of doctoral students and colleagues have contributed to its development. We intend for this book to extend the appreciation and application of this field, with roots in centuries past, to the decision-makers of the future.

HOW TO USE THIS BOOK

Decision making in our daily lives is an essential skill, whose fundamentals should not rely on knowing much more than arithmetic. Often you can make the decision using easily explained concepts without any calculations. We have therefore written the early chapters of this book and certain later chapters to be accessible to a general audience. Readers with more mathematical and computational preparation can benefit from the remainder of the book after understanding the fundamentals.

To be specific, Chapters 1 through 17, Chapters 26, 29, and 33, as well as Chapters 37 through 40 provide the foundations of decision analysis using reasoning. The story is not in the math: a decision maker can, step by step, transform confusion into clarity of thought and action.

Other chapters in this book are intended to expose readers to problems that require a higher level of analysis, such as problems that may appear in organizations. They are covered in Chapters 18 through 25, Chapter 27, Chapter 28, Chapters 30 through 32, and Chapters 34 through 36. While the analyses in these chapters require a higher level of computation, they rely on the basic principles presented in Chapters 1 through 17. No knowledge of calculus is essential to proper understanding of any of these chapters.

The "Decision Analysis Core Concepts Map" at the end of this book is a useful tool to help you understand some of the main concepts presented. You can use this map in several ways. First, it summarizes some of the important concepts, and so it can be used as a checklist

for things you need to know. Second, it tells you the chronological order of concepts you need to understand before learning about another concept. An arrow from one concept to another helps you identify what you need to know before understanding a particular concept.

We do not require the reader to use any software for the analyses carried out in this book. Our purpose is to provide the foundations needed to solve the problems from fundamental principles. While software packages and spreadsheets undergo change in versions and upgrades, the concepts needed to solve these problems remain the same. An analyst should understand and know how to analyze problems from the first principles. We have presented much of the sophisticated analysis in tabular form to give the reader exposure to solving these problems numerically. To gain a better understanding of these chapters, we suggest that the reader repeat the tabular analysis on their own instead of just reading the chapters. The replication of these tables in spreadsheets or other current tabular forms can be assigned as homework problems in classes.

Chapter 37 provides an informative case study (The Daylight Alchemy) that has been used in many decision analysis classes as a final take-home exam. It captures many of the tools presented throughout the book.

Below are some suggestions for using this book in a classroom:

When teaching to an audience that has an interest in the foundations of decision making but less emphasis on the math or computations, the following chapters could be covered:

Chapters 1 through 17 introduce the foundations of decision analysis without requiring significant mathematical sophistication. Topics include characterizing a decision, the rules of actional thought, u -curves, sensitivity analysis, probability encoding, and framing.

Chapter 26 discusses multi-attribute decision problems with no uncertainty. The presentation prepares the reader to address multi-attribute problems where uncertainty is present.

Chapter 29 presents a fundamental notion about probability: when two people have differences in beliefs, we can construct a deal that both will find attractive, and we can also make money out of constructing those deals.

Chapter 33 analyzes decisions that involve a small probability of death, such as skiing or driving a car.

Chapters 37 through 39 explain how to use the decision analysis approach when there are large groups involved. They also discuss some impediments to quality decision making in organizations.

Chapter 40 discusses ethical considerations in decision making. Like any tool, decision analysis is amoral: you can use it to determine the best way to rob a bank. The ethics must come from the user.

Other chapters in the book are also relevant when teaching to a technical audience that would like to learn about large-scale problems and the computations involved. For example, seniors in an undergraduate engineering curriculum, MS students, or MBA students. For this audience, the instructor may wish to add any of the following chapters to the chapters listed above:

Chapters 18 through 25 discuss advanced information gathering from multiple sources, the concept of creating options in our daily lives, other types of u -curves that describe risk aversion, using approximate formulas for valuing deals, and the concept of probabilistic dominance relations that, when present, facilitate the determination of the best alternative.

Chapters 27 and 28 analyze multi-attribute problems where a value function for cash flows is determined and explain how to handle multiattribute decision problems with uncertainty.

Chapter 30 shows how to update probability after observing the results of an experiment.

Chapter 31 examines several auction types and illustrates how to use the basic concepts of decision analysis to determine the best bid and the value of the bidding opportunity.

Chapter 32 presents the concepts of risk scaling and sharing: how a decision maker can determine the best portion of an investment, how a partnership can share an investment, and how to establish the risk tolerance of a partnership.

Chapter 34 analyzes situations where a person is exposed to a large probability of death, such as may be faced in medical decisions.

Chapters 35 and 36 illustrate how to solve decision problems numerically by simulation and discretization.

We hope you enjoy reading the book and then applying this powerful way of thinking about decisions in your daily life.

Introduction to Quality Decision Making

CHAPTER CONCEPTS

After reading this chapter, you will be able to explain the following concepts:

- Normative vs. descriptive pursuits
- Reactive vs. proactive decision making
- Thought vs. action
- Decision vs. outcome
- What constitutes a good decision
- Stakeholders of a decision
- The six elements of decision quality
- The decision basis

1.1 INTRODUCTION

We all make decisions every day, but few of us think about how we do it. Psychological research has shown that people make decisions that after reflection they regard as wrong. Our purpose in this book is to provide a systematic process that enables quality decision making.

1.2 NORMATIVE VS. DESCRIPTIVE

To begin, it is important to distinguish between descriptive and normative pursuits. Descriptive fields do what the name implies; namely, describe reality and actions as they are, while normative fields identify how they should be. For example, it sometimes happens that when we add a column of numbers from the bottom up using pencil and paper, we obtain a different sum than when we add the same column of numbers from the top down. When this occurs, we say that we have made a mistake because we have an arithmetic norm requiring that the sum of numbers be the same regardless of the order in which we add them. If we have no norm for what we are doing, we cannot say descriptively that we have made a mistake. The rules of arithmetic provide norms for arithmetical computations. Similarly, the foundations of decision analysis provide the norms for decision making.

Consider the various fields of study at the University. Is physics a descriptive or a normative field? Although many results in physics have the names of laws, in fact, these findings are models of reality that aim to describe what is so. To confirm their descriptive ability, they must be tested by experiment. Even today, scientists still perform expensive, sophisticated experiments to see whether Einstein's model describes the physical behavior of the universe. While

Newton's model has been used for centuries and continues to be used today, Einstein's model is more descriptive of physical behavior at velocities approaching the speed of light.

In this book, our primary focus will be on normative decision making—how we should make decisions, rather than how we actually make them. Yet for three important reasons, we shall also address descriptive decision making. The first reason is motivational: If we do not learn through demonstration that we are faulty decision makers, we will not see the point of learning a powerful normative process. The second reason is practical: Descriptive models of human behavior may allow us to predict the natural conduct of the people affected by our decisions. Just as the results of a normative process like addition are no better than the numbers entered, the results of our normative decision process will be no better than its inputs. We need to understand that these inputs come from humans displaying various biases and distortions, and we must learn to control for such factors. Finally, our descriptive knowledge of how people receive information will enable us to present our results and have them understood.

You might wonder about the difference between what we naturally do in making decisions and what we would like to do upon reflection. In other words, why is there a difference between descriptive and normative behavior? One possible explanation is that in evolutionary terms, we still have the bodies and brains of our caveman ancestors. Even in the business district of a major city, hearing the roar of a lion will alarm us. For millions of years, this instinctual sense of alarm was critical for survival, but today it is of little value.

One consequence of our origins is that in many cases, our natural capabilities are better suited to the challenges of our ancestors than to the challenges of modern life. Examples abound:

- We cannot sense a highly radioactive environment, even though it could kill us in a matter of hours.
- If we lose visual reference while flying an airplane in bad weather, without instruments, we crash.
- If we are scuba diving and we lose our air supply at depth, our natural instinct to hold our breath and dash for the surface might end up killing us.

Though we do not have these capabilities, we have developed compensations for them all:

- We use Geiger counters to sense radiation.
- We use instruments to fly in bad weather.
- We learn through instruction that the unnatural act of releasing air gradually as you surface is the proper procedure when scuba diving.

Another consequence of our origins is that we have capabilities that once helped us to survive, but now may even lead us to harm.

- Millions of years ago if you had food before you, you ate it before it could spoil or be taken from you by another creature. Now this instinctive behavior at the buffet table can be ultimately harmful if it leads to diabetes or heart disease.
- Millions of years ago if someone challenged you, aggressive behavior toward him could save your life. Now, road rage can lead to injury and death.

Figure 1.1 presents a way to visualize the effects of our nature on decision making. Here we picture our choice of action as determined by the interaction between two decision systems: One **deliberative**, or reasoned; the other **affective**, or emotional. The **affective decision system** is the “hot emotional system.” This system existed within the 6+ million year old brain, and was motivated by sex, fear, and hunger stimuli that were directly related to survival. It focused on stimuli that are here and now; proximate and immediate.

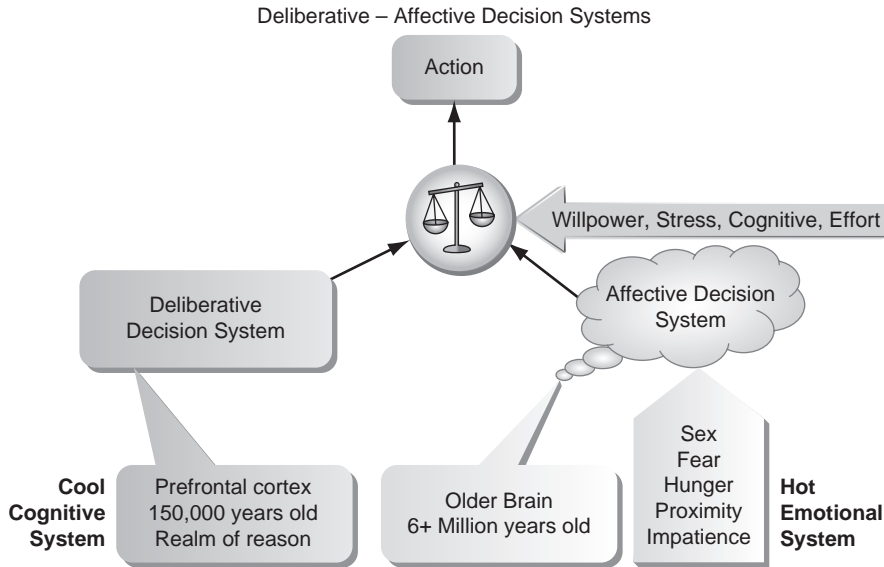


FIGURE 1.1 Deliberative-Affective Systems

In contrast, the **deliberative decision system**, or the realm of reason, is the “cool cognitive system.” The final evolution of the human brain some 150,000 years ago resulted in the development of the prefrontal cortex, and along with that, the deliberative decision system. The prefrontal cortex enhanced, but did not replace, our “old” brains: As a result, the two systems coexist, often creating considerable internal conflict.

The pull of each system in determining action is influenced consciously, by willpower, and unconsciously, by factors such as stress and cognitive effort. We usually think of hard work as some kind of physical activity that will leave you exhausted. However, another kind of work, the cognitive effort involved in thinking, can end up exhausting your deliberative decision system, thereby increasing the influence of the affective decision system.

You might use willpower to avoid the tempting high calorie dessert by remembering that eating it will not serve your desire to lose weight. However, the jet lag you experience by flying through several time zones may create stress that will tip the scale toward the “hot” emotional system, resulting in poor reasoning during the next day’s business conference.

Perhaps the simplest example of the struggle between the systems is to observe someone at a party eating handful after handful of peanuts and saying “I know I am going to regret this tomorrow.”

We were not evolutionarily equipped to make many of the decisions we face in modern life. For example:

- Choosing among medical treatments that have uncertain and long run consequences.
- Making financial decisions, as individuals or companies, that will produce uncertain futures of long duration.

Making such decisions by “gut feel” is to hand them over to the affective decision system. As we proceed, we shall see many examples of affective decision making gone wrong. The purpose of this book is to develop our deliberative decision system and to increase its role in our decision making.

Learning normative decision making poses special challenges. We have all made thousands of decisions in our lives, and most of us think we are good at making them. If we offered

a course in breathing, a prospective student might say, “Why do I need a course in breathing? I breathe quite well already. I suppose you are going to tell me that if I am lying on the couch watching TV I can breathe at a slower rate than if I am running upstairs.” Yet many people do have coaches for breathing: Singers, competitive swimmers, and even meditators.

While some of us may not need breathing coaches because we are not singers or competitive swimmers, none of us can escape making decisions. We know we have made decision mistakes, and that we may have developed flawed decision making habits. Increasing our ability to think clearly about decisions will benefit us throughout our lives and the lives of those we affect.

Since we are examining a human faculty in which most of us feel very competent, demonstrating the inadequacy of our present decision behavior may be discomfiting. If you take a course in calculus or Chinese history, you will rarely have to make a major change in how you think about yourself. You have a general idea of the subject, and you are going to learn much more about it. However, the content of the course will only occasionally challenge the way you are thinking about all the choices you make, major and minor, in your everyday life. In our subject, the challenge is continual. The benefit of grappling with that challenge is learning a powerful way to make decisions.

We sometimes describe the result of mastering this subject as installing a new operating system in your brain. You can now run powerful programs you could not run before, and you can no longer run the old programs. Do not embark lightly on this journey. There is an Eastern saying, “Better not to begin, but if you begin better to finish.”

As Samuel Butler put it, “A little knowledge is a dangerous thing, but a little want of knowledge is also a dangerous thing.” This book is not about making decisions only in a specific field, such as business or medicine. The concepts apply everywhere and are useful in all fields, as our examples will show.

1.3 DECLARING A DECISION

Decisions do not arise in nature. No one walks through a forest and says, “I have just spotted a wonderful decision.” Decisions are declared by human beings. Sometimes they arise when we have what philosophers call a break in our existence—some change in our circumstances—that impels us to declare a decision. We can consider these decisions as reactive to the change. Whether we experience a change for the worse, like losing a job or falling ill to a disease, or a change for the better, like inheriting money, we face declaring a decision.

We can also declare decisions proactively, without any external stimulus. You can declare a decision about quitting your job or about taking up skydiving just because you want to. Figure 1.2 illustrates the different types of declarations.

Some of the most important decisions you can make are those you declare proactively. When Warren Buffett¹ was asked about the worst decision he ever made, he said, “The things I could have done and didn’t do have cost us billions of dollars...” He viewed his worst investment failures as errors of omission, rather than commission—errors arising from a lack of proactivity.

Whether the decision is reactive or proactive, it is yours. The alternatives you have belong to you. You have total power over the alternative you select, but seldom over the consequences of selecting that alternative. We are using the word “alternative” in the American sense, rather than in the European sense. Saying, “We have one alternative” is understandable to an American, but a European might ask, “Alternative to what?” So when we say you have only one alternative,

¹Warren Edward Buffett (born August 30, 1930) is an American investor, businessman and philanthropist. Buffett has been one of the richest men in the world and has given most of his fortune to charity.

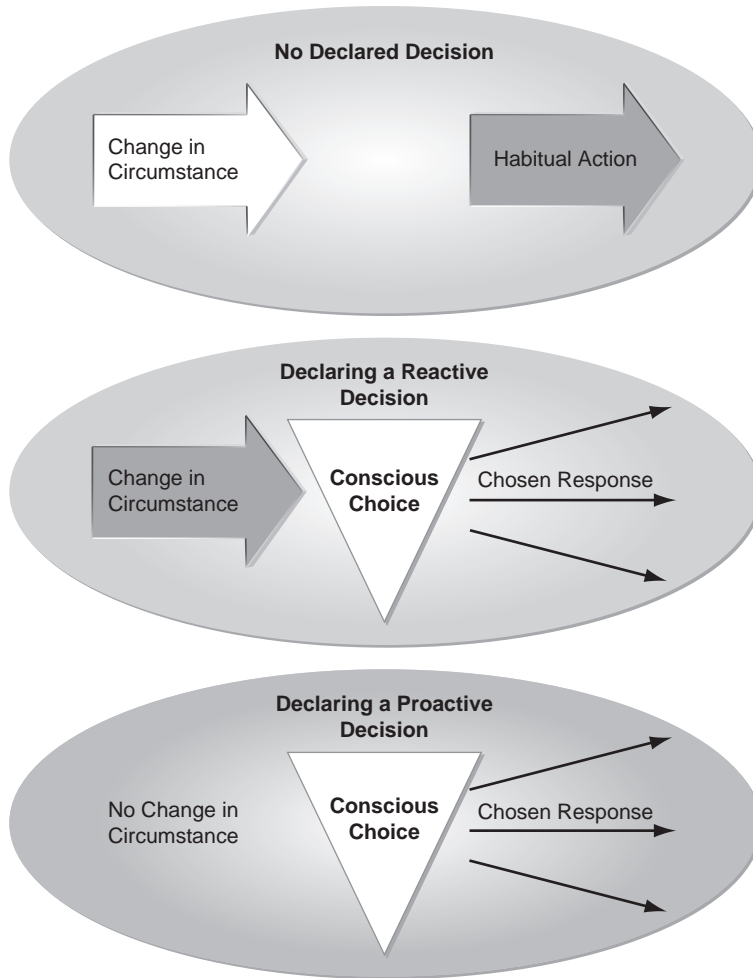


FIGURE 1.2 Declaring a Decision: Reactive vs. Proactive Decision Making

we mean that you have no choice. A cartoon once showed a chaplain offering comfort to a convict about to be executed in an electric chair. The caption was, “My advice is to pray to a saint who helps the wrong people by mistake.”

Doing nothing is always an alternative. Suppose you go to a restaurant for dinner. The waiter presents the menu and then awaits your order. You say, “I will need a few more minutes.” Shortly thereafter, he returns and you again request more time. Whenever the waiter returns, you repeat your request. What happens? The last time you see the waiter, he tells you that the kitchen is closed and that no more food will be served. You have chosen the “do nothing” alternative, and you have suffered the consequences.

To truly have alternatives in making a decision means that they are completely under your control. For example, you may say you have the alternative of getting a job with company ABC, but you do not. You have the alternative of applying for a job with company ABC. You may say you have the alternative of going to graduate school, but your real alternative is to apply to graduate school. Taking care in understanding alternatives is an important step in thinking clearly about decisions.

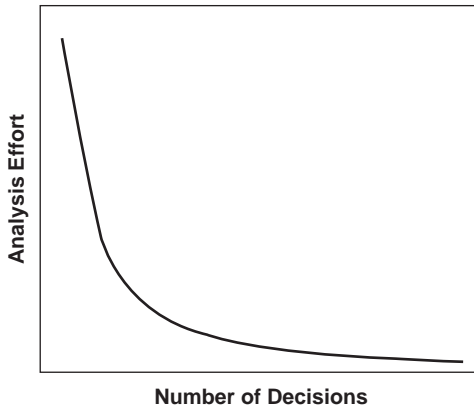


FIGURE 1.3 Number of Decisions vs. Analysis Effort

Once a decision is declared, knowing what to do may require little effort or extensive analysis. Most everyday decisions, such as what to have for breakfast or what clothes to wear, seldom require analysis. Other decisions, such as the purchase of a new home or car, may require more analysis, but are also less frequent. Figure 1.3 shows the number of decisions we face and the analysis effort they require.

Decision analysis works for all types of decisions. However, you can deal with simple decisions in a few minutes using common sense or some rules of thumb. You do not need an extensive analysis to decide what to have for breakfast.

More complicated decisions, however, are worthy of more thought. Using a simple checklist to remind us of things to consider and to help us identify common decision making errors might make the process easier. Examples of more complicated decisions are where to spend a vacation, or whether to buy a new television set.

The most important decisions we face deserve a much more refined analysis. They may involve elements of complexity, dynamics, and far-reaching consequences. They are worthy of, but frequently do not receive, the structured, rigorous decision process we will describe in later chapters.

Figure 1.4 shows the types of decisions we may face and methods to approaching them.

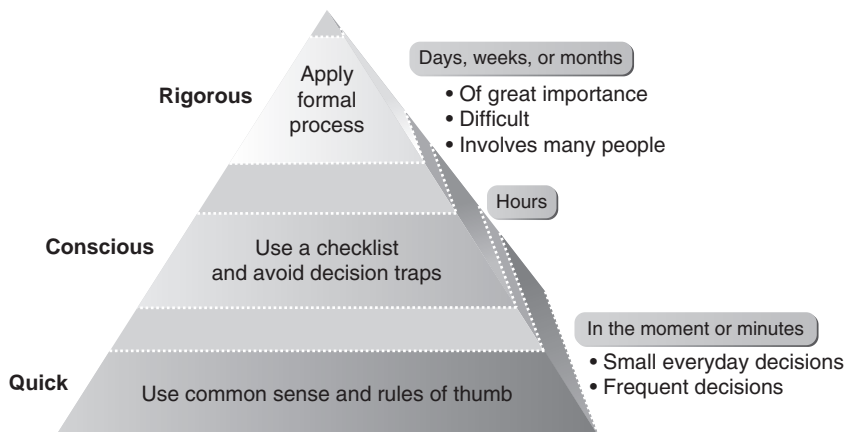


FIGURE 1.4 Hierarchy of Decisions

1.4 THOUGHT VS. ACTION

The mere idea of thinking about something does not mean we have made a decision. To better understand our decisions, we first make a distinction between “thought” and “action.” Figure 1.5 illustrates all possible combinations of actions and thoughts. The diagram identifies four different regions.

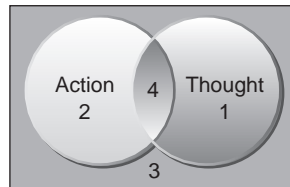


FIGURE 1.5 Regions of Thought and Action

REGION 1: THOUGHT WITHOUT ACTION Consider what you do in your daily life. Are there times when you have thought without action? A little reflection shows that the answer is “Yes.” For example, we can think “What a beautiful cloud!,” or “I should quit this job!,” or “I am bored.” This region also includes feelings you may have towards someone or something. Much of our self-talk is thought without action, and perhaps that is a good thing.

Reflection

Think of other situations where you may have thought but not acted.

REGION 2: ACTION WITHOUT THOUGHT Is there action without thought? Once again, the answer is “Yes.” A simple example is a reflex response to a stimulus, like crying after cutting an onion. A more thought provoking example is riding a bicycle. Can you imagine trying to use an instruction manual for riding a bicycle? The manual would describe things like steering head angles, tire contact areas, and the center of gravity of the combined human-bicycle system. We learn to ride a bicycle automatically without thinking, so a manual like this would be of little use.

Walking is another great example of an inborn ability or a trained skill. No explanation involving muscle contraction will help.

Reflection

To illustrate the advantage of coaching even when a skill has been learned and performed automatically without thinking, consider the following question:

Suppose you are riding fast on your bicycle and wish to turn to the left around a curve as quickly as possible. In what direction do you turn the handlebar?

The common answer is that you turn the handlebar to the left. Very experienced bicycle and motorcycle riders know that the correct answer is to turn the handlebar to the right. This is clear if you observe motorcycles racing counter clockwise around a circular dirt track. They all have their handlebars turned to the right, away from the center of the circle.

For this to be the correct answer, what must be true of cycle design?

Even without instincts or training, you can take appropriate action in new situations, without thought, by acting on your inner knowledge. Buddha would call it “right action.” Just do it. However, it is often difficult to make spontaneous and correct decisions in our personal or professional lives. Complexity, uncertainty, or conflicting values may confuse us.

Reflection

Think of other situations where there is action but no thought.

REGION 3: NO THOUGHT-NO ACTION Are there situations where there is no thought and no action? One example is being in a coma. The state of consciousness produced by proper meditation might be another.

Reflection

Think of other situations where there is no action and no thought.

REGION 4: THOUGHT AND ACTION—“ACTIONAL THOUGHT” Finally, we may want to think about what to do, which we call **actional thought**. When we think about a decision, we are practicing actional thought. But what constitutes high quality actional thought? One answer is decision analysis, our present endeavor.

1.5 WHAT IS A DECISION?

We now need to ask a fundamental question, “What is a decision?” A frequent answer is that it is a choice, or a choice among alternatives. But we want more precision in our understanding. The following is our definition of a **decision**:

A decision is a choice between two or more alternatives that involves an irrevocable allocation of resources.

Suppose a friend tells you that he has decided to buy a new Rolls-Royce. How will you know when he has actually made the decision? Is it when he has visited the dealer to look at Rolls-Royces, or when he has made an appointment to return to buy the car? You will know he has bought a Rolls-Royce when he gives the dealer his cashier’s check for the purchase price and the dealer has given him the registration and the keys. If your friend drives around the block in his new car and decides that he does not like it after all, can he just ask the dealer for his money back? The dealer may well say, “I see, you want to sell us a pre-owned Rolls-Royce in excellent condition. Here is our offer.” His offer will typically be less than the number on the cashier’s check he recently received. The difference is the monetary resource that your friend has committed in making the purchase.

A resource deserves its name if it is something that is scarce and valuable. Money is a resource; the time in our lives is a resource. Thinking about a decision takes time: The decision to think about a decision is an irrevocable use of that time. The decision to buy the Rolls-Royce by handing over the cashier’s check represents an irrevocable loss of resources—the difference between what you pay for it and what you could sell it for after accepting ownership. Every decision, then, is irrevocable in the sense that the resources committed to it will be at least partially lost.

1.5.1 A Mental Commitment or Intention is Not a Decision

You can say that you have decided to diet, but you will not have made a decision until you do not order your customary dessert at a meal. Even if you abandon your diet tomorrow, today's meals are different.

The roots of the word “decision” are consistent with this interpretation. The Latin word corresponding to decide means “to cut off.” As long as you are just thinking about the decision, you are not cutting off anything except the time you might have spent doing something else. As soon as you sign the contract, choose not to fasten your seatbelt before driving, or start down the expert-rated ski trail, you have cut off some possible futures and created the possibility of others. As a radio commentator once said, “The past is a canceled check and you have no claim on the future.”

As we have seen, the resource allocation of a decision can be irrevocable in whole or in part. For example, if you are merely thinking about where to spend your vacation, you have not yet made a decision. Time spent is irrevocable at the current level of science, so while thinking about your vacation you have indeed decided to spend some time, you have not yet committed monetary resources. You make a decision when you book the tickets, make the hotel reservations, and thereby commit some resources that are at least partially irrevocable due to fees for cancellation or change.

The moment of decision is the moment when changing your mind costs something. If, in anger, you write an email to your boss saying you quit, your moment of decision is when you hit “send.” Up until that moment, you can change your mind with little consequence. Once you hit “send,” however, you begin a chain of events that will be difficult, if not impossible, to reverse.

Resources are scarce, and we use our methods to allocate them. Love is not a resource because it is not finite. We do not recommend using the methodology of decision analysis when allocating love. This is more a matter of wisdom than engineering.

Reflection

Which of the following represents a decision?

- a. I have decided that I do not like vanilla ice cream.
- b. I have decided that the stock market will go up.
- c. I have decided that the stock market will go up, so I will invest right away. Here is a check for my purchase.
- d. I have decided to ace the test.
- e. I have decided to diet, and I have thrown away the ice cream in the freezer.

1.5.2 What Makes Decision Making Difficult?

Now let us look back at some of the decisions we have made and think about why they were difficult. Sometimes decisions are difficult because they require making trade-offs among several factors. They may be difficult because of other people who are involved. We call such people stakeholders. We define a **stakeholder** as someone who can affect, or will be affected by, the decision. In personal decisions, stakeholders may be friends or family. For example, suppose you are interested in buying a motorcycle, but you know this will worry your mother. Your mother is a stakeholder in this decision. You will have to balance upsetting her and your personal enjoyment of the motorcycle. Stakeholders in business decisions can be shareholders, employees, and customers. Stakeholders in medical decisions can be the patient, doctors, nurses, and the patient's family.

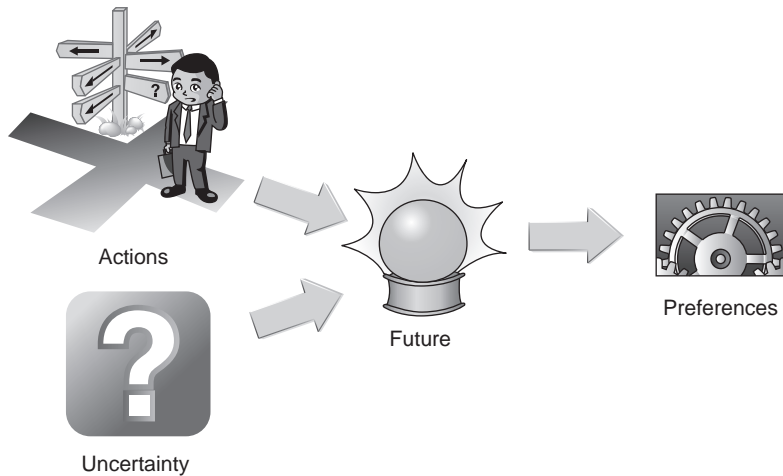


FIGURE 1.6 Decision Making with Uncertainty

Sometimes decisions are difficult because of fear of a bad outcome, or fear of regret, or even fear of blame. In all these cases, the difficulty is our uncertainty about the outcome. Suppose no matter what alternative you chose, there was no resulting uncertainty about the future. Imagine you could magically and instantly play a movie to illustrate your future, based on each potential alternative. After seeing the movie, you choose the best alternative. This opportunity to foresee the future would make decision making easy and free of any regrets or worries. By viewing the movie, you would learn more about your preferences and the types of tradeoffs you would be willing to make to substitute one vision of the future for another. Sometimes people say decision making is difficult because of time pressure or constraints, but even those situations would be simple if you saw the movie of your future lives resulting from each alternative.

Unfortunately, these movies of our future lives do not exist. Consequently, we can only choose the best course of action at a certain moment in time. Our futures are always uncertain, but we do have preferences. What we want to do is choose the best alternative given our preferences by properly considering uncertainty, as depicted in Figure 1.6. Creating the normative process for doing this is the subject of this book.

1.6 DECISION VS. OUTCOME

Suppose you had a choice between two deals (shown in Figure 1.7).

Deal A gives you \$100 if a tossed coin lands on heads and \$0 otherwise;

Deal B gives you \$100 if a rolled die lands on 5 and \$0 otherwise.

Which deal would you choose? Most people would choose deal A.

Suppose you choose deal A and your friend chooses deal B. The coin is tossed and it lands tails, and the die is rolled and it lands on 5. You do not get the \$100 but your friend does. Did you make a bad decision? The answer is no. If you faced this decision situation again, would you still choose deal A? Most people would say yes.

This example, shown in Figure 1.7, illustrates the most fundamental distinction in decision analysis, the difference between the quality of a decision and the quality of its outcome. The distinction implies that we can make good decisions but still get a bad outcome due to uncertainty. Observing the outcome tells us nothing about the quality of the decision—just about the quality of the result.



FIGURE 1.7 Coin vs. Die (Coin photo: Imagedb/Fotolia; dice photo: Piai/Fotolia)

Using the distinction between a decision and its outcome, we can think of four eventualities:

- Making a good decision and getting a good outcome.
- Making a good decision and getting a bad outcome.
- Making a bad decision and getting a good outcome.
- Making a bad decision and getting a bad outcome.

To illustrate using Figure 1.8, imagine you are at a party and you have had a few alcoholic drinks. At the end of the party, you are drunk and must decide whether to drive home in this state. A good decision would be not to drive and to stay at your friend's house until the morning when you can drive home sober. A bad decision would be to drive while drunk.

We consider possible outcomes following each decision. If you decide to stay and drive sober, you could have a car accident on your way home the next morning. A bad outcome has followed a good decision. If you decide to stay and drive sober, and arrive home safely, a good outcome has followed a good decision. On the other hand, if you decide to drive drunk and arrive home safely, a good outcome has followed a bad decision. Finally, if you decide to drive drunk and have an accident, a bad outcome has followed a bad decision.

Ambrose Bierce² uses a poem to describe this idea of not judging a decision by its outcome:

"You acted unwisely" I cried, "as you see
By the outcome" . . . He calmly eyed me:
"When choosing the course of my action," said he,
"I had not the outcome to guide me."

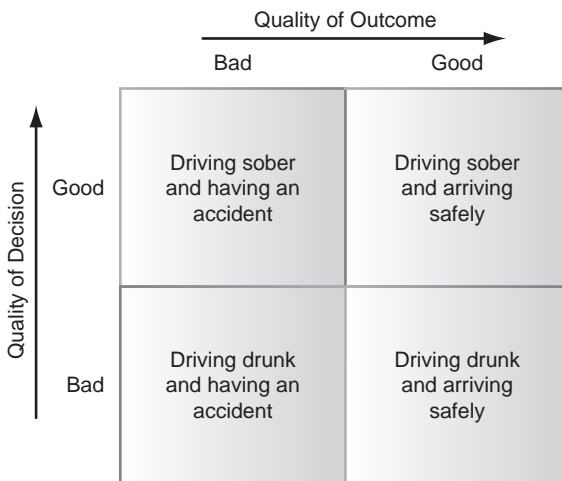


FIGURE 1.8 Decision vs. Outcome

²Ambrose Gwinnett Bierce (June 24, 1842–1914) was an American satirist, critic, poet, short story (horror) writer, editor, and journalist.

Ambrose rushes to tell a person that he acted unwisely “made a bad decision” based on the outcome that he received. The response highlights the distinction between a decision and an outcome: the person did not have the outcome available at the time of making the decision to guide his decision making.

Some people may live their lives feeling guilt or regret about something they did when, in fact, they had made a good decision at the time. We often hear statements like, “This did not work last time, so we cannot do it again” or, “This project turned out to be a bad investment, it was a very bad decision.” Careful thinking about this statement shows that they are judging the quality of the decision by the past outcome.

On the other hand, people may also make a bad decision, receive a good outcome, and live thinking that they did the right thing. When this happens, we may hear, “We tried this last time and it worked, so it was a good decision and we should just do it again.”

Reflection

Reflect on the distinction between a decision and an outcome.

Do you confuse the two in your own decision making? Have you judged the quality of a decision you made based only on the outcome? Have you been judged by the quality of a decision you made based on its outcome?

We see the need for the distinction between a decision and an outcome in understanding the daily news. The following piece aired April 12, 2004 on CNN.

*Gambler: Roulette Play “Just a Mad Thing to Do”*³

(CNN)—Ashley Revell, a 32-year-old man from London, England, sold everything he owned, even his clothes, to try his luck Sunday on one spin of a roulette wheel in Las Vegas, Nevada. He put \$135,300 on red, and with friends and family watching, the ball hit the mark, giving Revell \$270,600. The event was filmed by Britain’s Sky One television as a short reality series called “Double or Nothing.” CNN’s Anderson Cooper asked Revell what was going through his mind when the wheel was spinning.

REVELL: I was just...pleading that I’d pick[ed] it and that it would come in red. Before I actually walked up to the wheel, I was thinking about putting it on black, and then suddenly the guy was spinning the ball around and all the Sky viewers said...they [had] voted that I should put it on red. So suddenly I just put it all on red. But...I was just pleading that it would come in and I’d get lucky this time. What I was really worried about was that I’d lose and my parents would be upset and my family would, you know, all my friends would be upset. So...I was obviously just so happy when it came in.

COOPER: So you were going to put it on black, but people back in England were voting, and they said you should put it on red? You decided to do that?

REVELL: Yeah, that’s right. I mean, with all those people sort of hoping that it would be red, I thought I’ve got to go red, so that’s what I did.

COOPER: Your father was opposed to this whole concept all along. This is what he had to say. He was quoted in an interview as saying: “I told him he was a naughty boy, he was a bad boy, he shouldn’t do it. He should work like all other kids do.” How does he feel now? I mean, has he changed his mind?

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- REVELL:** Yeah, I think so. I mean, I obviously went and shook his hand before I did it, and after he was just hugging me and jumping up and down. So, you know, I think most all dads are just concerned, and he's seeing all my friends being married off and having kids and stuff, and he's like any father, he just wants me to settle down and make sure I'm secure.
- COOPER:** Now, why did you do this? I mean, is it true that you sold all your possessions, even underwear, everything you had, and then put all the money on this? Why? Was it all just to be on TV?
- REVELL:** Looking back on it now, I mean, at no point before I did the bet did I think about losing. I just felt positive and thought about just going ahead and winning. But now I've actually won, I can think about what would have happened if I'd lost. And to be honest, I was crazy to do this bet. It was the maddest thing. I mean, this is really about all I've got left, the tuxedo, which I'm not allowed to keep. So it was just a mad thing to do. And I'm thinking back now about what would have happened if I lost. I'd have nothing to go back to, nothing to wear. But I'd still have my friends, my family, and they'd always be there for me. So they gave me the security to be able to do this. But you know, never again. I mean, that's – it was mad.

Reflection

Keeping in mind the roulette player's decision, consider the following questions:

- Did Revell make a good decision by playing this game?
- Did he have a good outcome?
- Does the outcome he received change the quality of the decision he made?
- Should his father have a different view of the situation because the outcome was good?
- If you were in Revell's place, would you have made the same decision?
- Do you think Revell would be willing to repeat the same gamble again with his current wealth of \$270,600?

1.7 CLARITY OF ACTION

We have discussed the difference between a decision and an outcome, and determined that a good decision does not guarantee a good outcome. What, then, is the role of decision analysis?

The purpose of decision analysis is to enable a decision maker to achieve clarity of action in his decision and, even more fundamentally, to achieve clarity of thought. Furthermore, knowing that we have made the best decision provides peace of mind, since that is all we can do to influence the future.

We can make an analogy between decision making and flying a plane. When the weather is clear, we do not need to rely on all available instruments. However, when the weather is cloudy, we need to rely on our instruments. In a similar manner, when decisions are simple, we can make decisions using our own judgment. When decisions are more complicated, however, our judgment may fail, and we need to rely on rules to help us identify the best course of action.

Continuing the analogy, relying on instruments when flying in bad visibility is necessary not just for beginning pilots, but for the most experienced ones. When deprived of the familiar cues provided by seeing the ground, even an experienced pilot will soon believe, incorrectly, that

he is, in fact, upside down, and will make the wrong corrective adjustments to the controls. The same is true for decision makers acting in an uncertain world. Unless they use the instruments we will build, they may also make grievous errors.

A Story by Ron Howard

Many years ago, I had a medical condition that caused occasional debilitating flareups. By taking some medications continually and other medications during flareups, I could control the condition. However, the medications had long run serious negative effects. My doctor recommended a major operation that, if successful, would cure the condition. Yet success was uncertain, and I could die in the operation. I demurred; my doctor thought I was indecisive.

Since this was a major important decision with great uncertainty and with implications for the rest of my life, I did an extensive six-month long analysis with the help of two medical doctors who were in my class. We did dynamic probabilistic modeling of the future. The doctors sent my x-rays to a specialist across the country for advice. We found that my best alternative was to see whether I had another flareup. If I did, then I should have the operation. If I did not, then I should keep postponing it. A flareup occurred and I called my doctor to schedule the operation. He asked when, and I replied “right away.” He had difficulty understanding why his indecisive patient was now so decisive. On the day of the operation, just before going under anesthesia, a kind nurse assured me that everything would be fine. I thanked her, told her I had a 2% chance of dying on the operating table, and that I was ready to go.

This story makes three points. First, that I had clarity of action in having the operation in the face of uncertainty about the consequences. Second, that the most irrevocable part of the decision was to allow myself to be anesthetized rather than to get up and leave the hospital. Third, I had a good outcome.

1.8 WHAT IS A GOOD DECISION?

We have probably used this term “good decision” in many of our daily conversations. But what is a good decision? And how do we know that we have made one?

1.8.1 Common Misconceptions about What Makes a Good Decision

There are many common misconceptions about what constitutes a good decision. In graduate classes or in executive seminars, people often answer,

“A good decision is one that produces a desired outcome.”

As we have seen, there is a clear distinction between a decision and its outcome, so this cannot be the correct definition.

Another common response is,

“A good decision is one that has the highest chance of getting the best outcome.”

Once again, this answer has a problem since this definition takes into account neither the absolute desirability of the best outcome nor the chances of very bad outcomes. Consider a deal with an 80% chance of gaining you \$1,000,000 and a 20% chance of costing you \$10. Another deal may provide you with a 90% chance of gaining \$100 and zero otherwise. Most people would agree that the first deal is more attractive than the second, yet it has a lower chance of the best possible outcome, and a higher chance of the worst outcome. The example also illustrates the problem with the response,

“A good decision is one that has the lowest chance of getting the worst outcome.”

Arno Penzias,⁴ a Nobel Laureate, was asked how he knew a good project when he saw one. His response was,

“Simple, imagine that what you’re going to do will be 100% successful; find out how much money it’s going to be worth; multiply by the probability of success, divide by the cost, and look at the figure of merit.”

While this approach may sound like a reasonable criterion for project selection, closer examination reveals that it focuses only on the monetary outcome of 100% success and ignores other levels. In some cases, this answer would correspond to the best project, but in others, it may not. Using a ratio does not take into account the actual monetary values involved.

For example, consider two projects that will either succeed or fail. They each have a 90% chance of success. The first project will either cost \$10, and, if successful, will yield \$100. The Penzias figure of merit is 0.9 times 100 divided by 10, or 9. The second project will either cost \$150,000, and, if successful, will yield \$1,000,000. Its Penzias figure of merit is 6. Choosing based on the figure of merit would lead us to choose the first project, yet most companies would prefer the second project to the first.

There are still more ways of looking at this same example. Does the company have only two available projects? Can the company do both? Are there other considerations besides monetary reward, such as legal or ethical issues?

1.8.2 The Six Elements of Decision Quality

To answer the question of what constitutes a good decision, we first need to understand the main elements of a decision:

1. The decision-maker;
2. A frame;
3. Alternatives from which to choose;
4. Preferences;
5. Information; and
6. The logic by which the decision is made.

First, every decision requires a **decision-maker**, the person who will act. As we have discussed, decisions are never found in nature: A person speaks them into existence. For example, anyone who says “I am going to decide whether to make this investment... have the operation... set the research budget at \$200 million...” must be committed not only to thinking about acting, and but also to deciding. Otherwise, the analysis is useless. Commitment to actional thought is the first element of good decision making.

Next, the person must provide a way of viewing the decision. We call this view a **frame**. For example, a person’s frame may be deciding which car to buy from a certain category of cars. The frame could also be whether to buy or lease a car, whether to own a car in the first place or to use public transportation, or even whether to commute to a job or work at home. Each frame presents a different view of the decision problem to be addressed.

The choice of a particular frame will lead to the creation of **alternatives** appropriate to that frame. These alternatives are available courses of action that the person believes would lead to different futures. Making a high quality decision will involve consideration of several

⁴Arno Penzias joined Bell Labs in 1961. He conducted research in radio communication and won the Nobel Prize in 1978 for research that enabled a better knowledge of the origins of the universe. He later became Chief Scientist, and continued to search for innovative and new product ideas by visiting small companies around the country.

substantially different alternatives. Note that by an alternative, we mean a choice that is actually available and is under the decision maker's control. You can choose to apply for many different jobs; however, your alternative cannot be to accept a job offer unless you have a job offer available. If you have no alternatives, or, in the American sense, only one alternative, then you have no choice in what to do and you have no decision to make.

Can you have too many alternatives? While a new alternative can sometimes be better than any that you recognize, finding alternatives takes time and effort. For example, suppose you had gone to a carpet store and spent two hours selecting a carpet for your living area. You have found one that is very attractive and reasonably priced, so you are about to buy it. The salesperson then says, "I should mention that we have a warehouse of carpets just behind the store with 10,000 other carpets you could look at." Many of us would say we had made our choice and would rather spend our time in another way.

A decision maker will also have **preferences** on the futures that arise from different alternatives. The preferences describe what the person wants. If the decision maker were indifferent to the possible futures, there would be no need to make a decision, but merely to live in acceptance of what will be. A wise saying from the east is, "The great road is not difficult for he who has no preference." However, many of us prefer pleasure to pain; success to failure; health to illness; wealth to poverty; youth to old age; chocolate to vanilla; and so we have preferences. A high quality decision will have clear, carefully specified preferences.

The linking of what we can do to what we want to do is provided by what we know, also known as our **information**. This information may leave us uncertain about what the future will follow; we must often make the decision in the face of uncertainty. We are always tempted to get more information, but information costs resources. A high quality decision process ensures that information acquisition is neither overdone nor underdone.

Finally, we must use some process to derive the action we should take, from what we can do, what we want, and what we know. If we desire to use a systematic process, such as **logical reasoning**, then we will want to use the best rules we know for this reasoning. We shall soon present such a set of rules for your consideration.

We can depict the six essential elements of decision quality using the metaphor of a three-legged stool, as shown in Figure 1.9. The stool metaphor is useful because it makes clear to anyone working on a decision precisely which aspect of the decision is currently under consideration. The three legs of this stool represent the three essential elements of any decision. One leg is what

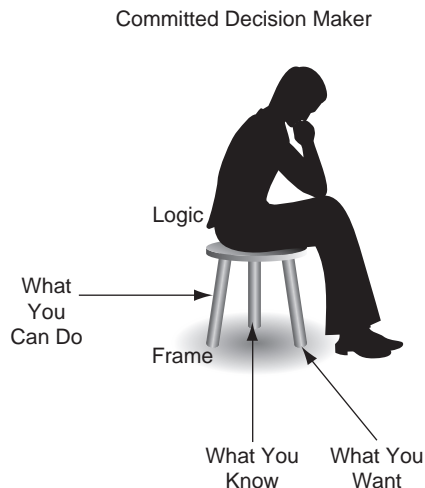


FIGURE 1.9 The Decision Quality Stool

you can do: Your alternatives. The second leg is what you know: The knowledge that relates your alternatives to possible consequences. The third leg is what you want: Your preferences on consequences. The three legs constitute the **decision basis**: The complete description of the decision problem you face. A seat, the logic that will determine your best action for this decision basis, holds the legs together. We shall have much to say about the nature of this logic in what is to come.

One important thing to understand about the stool metaphor is that the stool will collapse if you remove any of its legs. You have no decision to make if you have only one alternative, if you see no connection between any of your alternatives and the future, or if you are indifferent to the possible consequences.

The location of the stool represents your decision frame, which determines the alternatives, information, and preferences that will be germane to your decision. For example, if you need a place to live, you could frame the problem as one of finding a new rental apartment or house. You could also use a larger frame that includes buying a home as an additional alternative. The choice of a frame, then, determines the decision basis and is the most fundamental aspect of making a decision. Later in this book, we will have a much more complete discussion on the subject of framing.

Finally, the most essential element is the person sitting on the stool. There is no decision without the person who constructs the other elements of the stool and is committed to using it for support in making the decision. The person making the decision establishes the frame, seeks and creates alternatives, assembles pertinent information, states preferences, and uses proper reasoning to select the most desirable alternative. That person is, therefore, responsible for placing the stool, fashioning its legs, constructing the seat that connects them, and, finally, sitting on the stool—following the clear course of action.

Another metaphor that contains the six elements of a decision is the chain shown in Figure 1.10. The notion here is that the chain is only as strong as its weakest link. To achieve decision quality, you must assure the quality of each link.

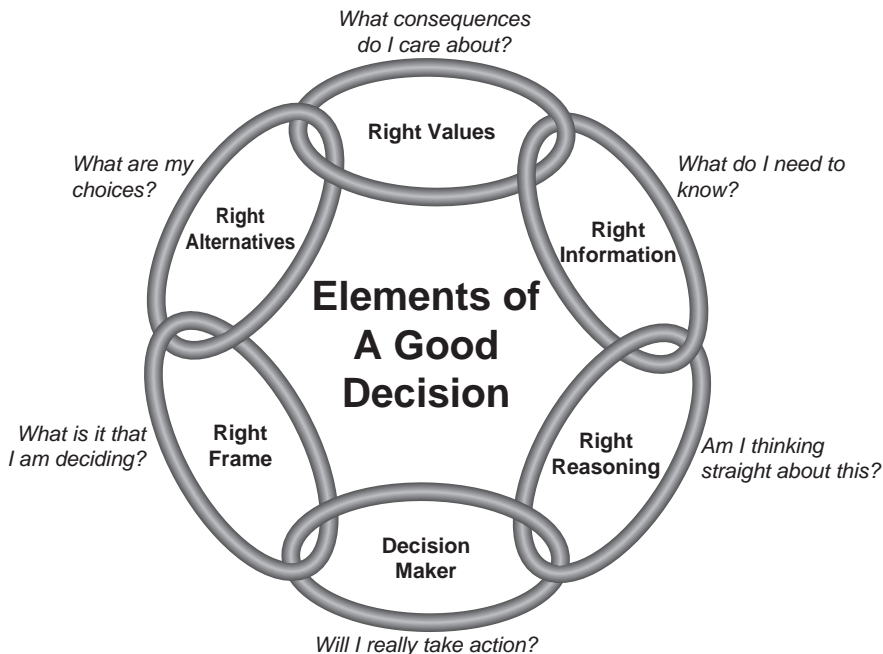


FIGURE 1.10 Decision Quality Chain

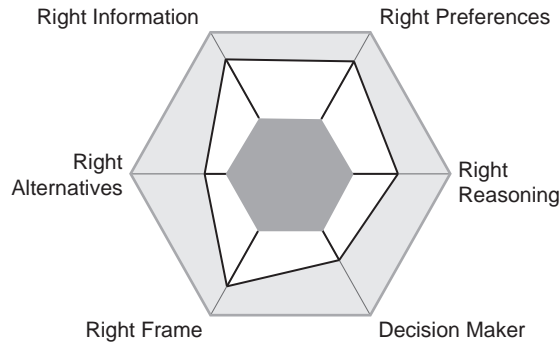


FIGURE 1.11 Decision Quality Spider Web

1.8.3 Graphically Representing Decision Quality

The decision quality spider web shown in Figure 1.11 graphically represents the qualitative attainment of decision quality. It can be a useful tool for individuals and for groups engaged in decision process assessment.

The distance from the inner hexagon to the outer one represents the degree of achievement for each element. The outer hexagon represents the proper balancing of elements for this particular decision. If the line for an element extends beyond the outer hexagon, that element is requiring too much effort. Figure 1.12 depicts an unbalanced analysis because too many alternatives are being considered and too little valuable information of reasonable cost is being gathered. The resulting picture displays the deficiencies or excesses in any of the elements of decision quality.

1.9 SUMMARY

If you decide not to read further in this book, then take away its most important message.

The most fundamental distinction in decision making is that between the quality of the decision and the quality of the outcome.

Once you understand this, you know how to deal properly with two useless concerns: Regret and worry.

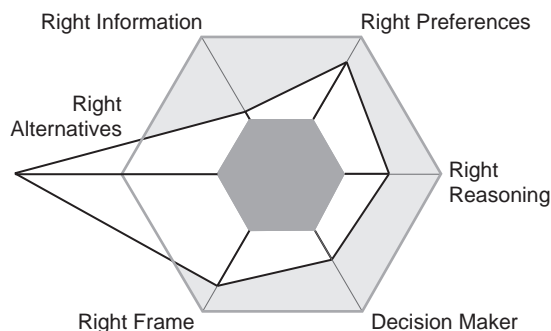


FIGURE 1.12 An Unbalanced Analysis

If you make good decisions, there is no place for regret in your thinking. Just continue to make good decisions. Why regret if you made a good decision and the outcome was out of your control?

If you find you are worrying about a decision before making it, transfer your energy to making sure it is the best decision you can make.

Annie Duke, a very successful professional poker player, described how she exhibits this wisdom in her playing. She uses all her abilities to make good decisions and pays no attention to whether they actually yield good outcomes or bad outcomes. This behavior often confuses opponents who expect her game to change when she has had a very bad outcome or a very good outcome. In future sections, we will develop the structure of thought necessary for making good decisions.

KEY TERMS

- Normative vs. descriptive
- Recognizing a decision is an essential first step to good decision making
- Declaring a decision
- Thought vs. action
- The importance of actional thought
- The definition of a decision as an irrevocable allocation of resources
- The need to deal with uncertainty in decision making
- The difference between a decision and its outcome
- The role of decision analysis in helping the decision maker achieve clarity of action
- The six elements of decision quality
- The decision basis
- The stool metaphor
- The decision chain
- The spider web diagram

PROBLEMS

Problems marked with an asterisk (*) are considered more challenging.

1. What is a decision? What makes decision making difficult? What goal do we pursue in decision analysis? Is decision analysis a normative or descriptive discipline? Explain.
2. Name the six elements of decision quality.
3. From your readings of this chapter, explain the following terms in decision analysis:
 - a. Actional thought
 - b. Clarity of action
 - c. Decision
 - d. Outcome
 - e. Normative versus descriptive
 - f. Decision basis
4. Which of the following situations represents a decision?
 - a. I am thinking of going to Tahoe during the break.
 - b. This is a beautiful star.
 - c. I need to buy an umbrella.
 - d. I have decided to become President.
 - e. I have decided that breathing is good for me.
5. Select a newspaper article describing someone facing a decision. Who is (are) the decision makers and what is (are) the decision(s)? What are the uncertainties present? What does (do) the decision maker(s) like or dislike? If you were a consultant hired to help the decision maker(s), what kind of warranty could you give them?
6. Write a brief answer to each of the following.
 - a. What is the difference between a decision and its outcome?
 - b. Give an example of a good decision followed by a good outcome.
 - c. Give an example of a good decision followed by a bad outcome.
 - d. Give an example of a bad decision followed by a good outcome.
 - e. Give an example of a bad decision followed by a bad outcome.
7. Take some time to think about an important decision situation you are currently facing or will be facing in the near future. Describe your decision situation.
 - a. What makes this decision hard? List some of the issues involved in your decision.
 - b. Which of these issues describe something that you can control?
 - c. Which of these issues describe something over which you have no control?
8. Write a page on a decision that most changed your life. In looking back, how did your decision making fare on each of the six elements of decision quality?
- *9. Write a short paper on what you did today—how you spent your time, what you ate, etc. Do you feel like today was well spent? Did you get the things done that you wanted to? Did you make good choices about how you spent your time? Why or why not? If you had \$10 million in the bank, what would you do differently with your time? What is preventing you from doing this right now—is it really the money or is something else holding you back?
- *10. Mohammad is considering whether to go to college for a PhD in decision analysis and is figuring out which schools he should consider. Which of the following considerations should be a part of his decision basis?
 - a. Mohammad believes that decision analysis will give him the opportunity to find a good job after graduation.
 - b. Mohammad has a preference for schools which have historically successful football teams.
 - c. Mohammad will choose among the top three US universities that accept him.
 - d. All of the above should be considerations for his decision basis.

- *11. You are considering buying stock in a Silicon Valley startup. Which of the following statements should not be a part of the decision of whether or not to invest in the company?
 - a. You examine the balance sheet for the company, and are encouraged by the slow rate at which they are spending their venture capital.
 - b. You attend a presentation by the CEO and CTO, and are greatly impressed by their exciting vision for the future of the company.
 - c. You decide that you would rather invest in a conservative mutual fund which pays regular quarterly dividends than take a large risk of losing all of your investment in the company.
 - d. All of the above should be parts of the decision basis.
- *12. Give other examples of normative and descriptive fields.
- *13. Consider the following quote from Gandhi talking about the British occupation: “They cannot take away our self-respect if we do not give it to them.”
Explain this phrase and show how it relates to Decision Analysis.

Experiencing a Decision

CHAPTER CONCEPTS

After reading this chapter, you will be able to explain the following concepts:

- Analysis of a simple decision
- What role probability plays in the decision-making process
- Why the thumbtack is a better deal than the medallion in our example
- The sunk cost
- Decision vs. outcome
- The clairvoyant and the value of clairvoyance

2.1 INTRODUCTION

In the last chapter, we presented our definition of a decision and discussed what is meant by having high quality actional thought. In this chapter, we present and analyze a simple decision that has all of the elements of more complex decisions, and will enable us to think about the way we make decisions in our daily lives. To benefit from this exercise, as we go along, imagine yourself facing this decision and think of the choices you would make. As we have discussed, a decision is a choice that involves an *irrevocable allocation of resources*, and is often difficult to make because some degree of *uncertainty* is present. Both of these elements (resources and uncertainty) are part of the demonstration described below.

2.2 ANALYSIS OF A DECISION: THE THUMB TACK AND THE MEDALLION EXAMPLE

In the following situation, an instructor is speaking to his students about decision making.

Note: “I” refers to instructor and “C” refers to one or more individuals in the class.

- I:** To illustrate a decision, we need both resources and uncertainty. For resources, I have here \$100 in U.S. currency. Would anyone like that?
- C:** (Chorus of *Yes!*)
- I:** O.K., it is not surprising that you would like this \$100 bill. This seems like an easy decision, but now for some uncertainty. I have here something we can toss. (*Instructor withdraws a coin-like object from his pocket.*)
- C:** Is that a coin?



FIGURE 2.1 Two Faces of the Medallion
(Courtesy of the authors)

I: No, but it is very similar. It is a medallion with “60th Snap-On Anniversary” and a box wrench on one side and “The Master’s Choice” in large script on the other. (*He holds up the object illustrated in Figure 2.1.*)

(*The medallion is being passed around the class.*)

I: Take a look at it, but don’t toss it. Notice that it is as heavy as a large coin, very well made, embossed on both faces, and has a milled edge. Is that right?

C: Yes.

I: Fine, but I wouldn’t try to spend it. (*Instructor retrieves the medallion.*) I could toss this medallion to introduce uncertainty, and someone could try to call which face would come up. What do we wish to call the faces of the medallion?

C: Heads and tails.

I: How do you know which face is “heads?”

C: A head usually has a person on it; a tail doesn’t.

I: Yes, that works in many countries of the world, but not all. You have to check before you wager. In this case, that rule won’t help us because there is no person on either face. (*Instructor selects a volunteer.*) How would you like to name the faces?

Volunteer: I name the one with the wrench as “heads,” and the one with the script as “tails.”

I: O.K., now we all know what calling the toss of the medallion means. Whenever I refer to the possible outcomes of the toss I will now refer to them as either heads or tails. Clear?

C: Clear.

I: I will now construct a deal. If the owner of the deal calls the toss of the medallion correctly, the owner receives the \$100; otherwise, the owner receives nothing. This picture shows a certificate that gives the bearer the right to call the flip of the medallion. (*He presents Figure 2.2 as shown below.*) The certificate is worth \$100 only if the owner calls the

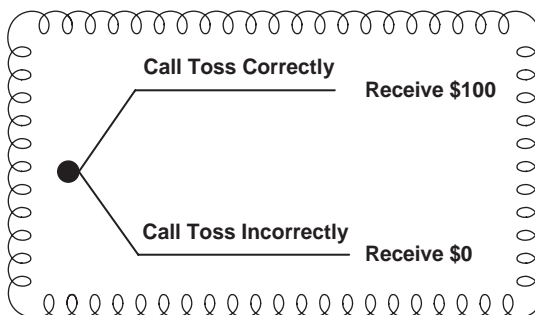


FIGURE 2.2 The Certificate with
Scrollwork Around the Edge

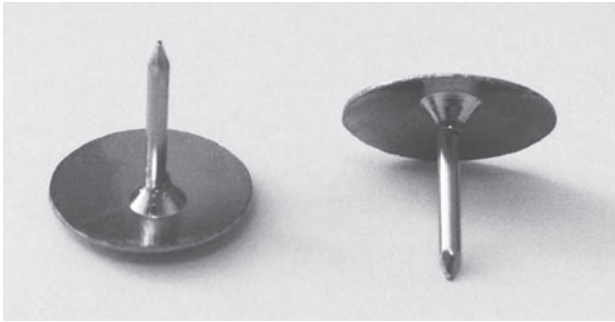


FIGURE 2.3 Two Sides of the Thumbtack: Pin Up and Pin Down
(Rachel Youdelman/Pearson Education, Inc.)

toss of the medallion correctly and nothing otherwise. The scrollwork around the edge of the certificate shows that it is a valuable piece of paper. Who would like this certificate?

C: (Chorus of *I'll take it!*)

I: Of course! Who wouldn't? But first, let's consider another "uncertainty-generating" device. I have here a jar (*opens an opaque, 1-liter plastic jar.*) Into the jar I am going to put a thumbtack. Next, I will screw on the lid, turn it upside down, shake the jar vigorously up and down, and, finally, set it down on the desk on its lid. When I hold the lid and carefully unscrew the jar, we shall see whether the thumbtack has landed "pin down" or "pin up." (*He holds up tack shown in Figure 2.3.*)

To simplify our discussion, we will designate "pin down" as *heads* and "pin up" as *tails*. (*He presents Figure 2.4 as shown below.*) "Pin down" is the way you would prefer to have it fall if you are just about to sit on it.

To provide the uncertainty in this decision, we might toss either the thumbtack or the medallion. If you call the outcome of the thumbtack toss correctly, you get the \$100; if not, you get \$0. Who would like the certificate with this uncertainty device?

C: (Chorus of *I'll take it!*)

I: Of course, everyone wants the certificate, but since we have only one we shall have to auction it off and sell it to someone through a bidding process. I get to choose whether the medallion or the thumbtack will be used, and you get to call its outcome—either heads or tails. However, for an additional \$3, you can decide which device you want to use. Now these are escrow rules. That means that the bid amount for the highest bidder will be collected upfront before we call the outcome.

2.2.1 Rules for the Bidding Process

I: To summarize the rules of the bidding process:

1. This is a closed bid auction. You will bid a dollar amount for the certificate: *The highest bidder acquires the certificate.* If you get the certificate, once you pay the specified amount, in cash upfront, you own it and get the chance to call.



FIGURE 2.4 Heads or Tails for Thumbtack

2. If you are the certificate acquirer, the instructor will choose whether you will call the medallion or the thumbtack. However, at the time of making your bid you can specify which device will be used by agreeing to pay an extra \$3 should you become the acquirer. If you acquire the certificate, you will receive either \$100 or \$0, depending on your call. You will receive the payoff after the demonstration lesson is complete.
3. Any ties between the bids will be resolved by tossing a U.S. 25 cent coin. To avoid ties, you may want to bid including cents.
4. No collusion is allowed. That means you may not collude with a classmate to bid as a group and then divide the possible winnings.
5. The certificate is not transferable (non-negotiable); it cannot be resold.
6. Should you decide to withdraw after making the highest bid, but before making any payment, you must pay a penalty of \$10 cash. At that point, the second-highest bidder will be designated the highest bidder, and the process will continue.

I: The rules are summarized here. (*He presents Figure 2.5 as shown below.*)

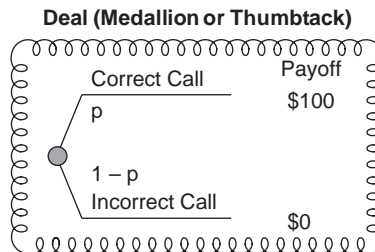
2.2.2 Starting the Bidding Process

(*At this point, the instructor passes out index cards.*)

- I:** On your card, please write your name and indicate what you are willing to pay for the certificate. To decrease the chances of having a tie, you may wish to include cents in your bid. It will be in your best interest not to disclose your bid to anyone else. If you want to specify the device for an additional \$3, be sure to indicate that as well. The person whose name appears on the card with the largest amount of money will acquire the certificate.

Rules for Bidding on the Certificate:

- Closed bid.
- Bid specifies \$ you will pay.
- Device: Medallion or thumbtack.
- We choose the device.
- For an additional \$3, you can choose the device.
- Highest \$ bidder acquires the certificate.
- Ties resolved by coin tossing.
(Suggest bid using cents.)
- Payment is by cash or by check.
- \$10 fee for highest bidder to withdraw.
- No Collusion, no syndicates.
- Deal not transferable.
- Acquirer will receive deal payoff after class discussion.



On the Index Card:

Write your

First name, Last name, \$bid

Optional: If you would like to pay \$3 for the choice of the device, write

"If I am the acquirer, I will pay \$3 for choice of device. I choose device"

First name: Bill
Last name: Gates
My bid: \$xxxx.xx

I will pay \$3 to use the ...

FIGURE 2.5 The Rules of the Bidding Process

2.2.3 The “Fair Coin” Fallacy

C: Is this a “fair coin?”

I: First, we need to remember that this is not a coin. It is a medallion. Now, to answer your question, what does the word “fair” mean? I assume you mean it is equally likely to land heads or tails. Correct? (*Student nods.*) Now I am pretty sure that the designer of the medallion did not take any such consideration into account. What chance does the person who owns the certificate have of receiving \$100 if he chooses the medallion?

C: 50/50.

I: If this is the case and this is your belief, then perhaps you can rephrase your question as “is the probability of heads or tails 0.5?” You may have a belief that it is equally likely to land either way, but this is just your personal belief. Have any of you tossed a medallion like this before?

C: No.

I: Why, then, do you assign 50/50, or probability one-half, to each face?

C: Because it has only two possible outcomes.

I: The existence of life on Mars has only two possible outcomes: Either there is life or there is not. Do you think there is a 50/50 chance of life on Mars?

C: No.

I: Why, then, do you believe the probability is 50/50?

C: Because the medallion is symmetric.

I: Actually, the medallion is not symmetric at all. As you have seen, both faces of the medallion are, in fact, very different in three dimensions.

C: I believe the probability is 50/50 because I don’t think that one face is more likely to come up than the other.

I: You mean that if you chose the medallion and called heads, but then I told you we were going to reverse our definitions of heads and tails before seeing whether you had called it correctly, you would be indifferent to this change.

C: Yes.

I: In this case, then, you would assign a 50/50 chance, but this probability is not a property of the medallion. Rather, it is your belief about how the medallion will land when I toss it. Your indifference to reversal of the definition of heads and tails means that you believe it is equally likely to land either way. Others may have a different view.

Reflection

Take a minute to consider the situation. Think about the three questions below, and the decisions you might make.

1. What device (medallion or thumbtack) would you prefer to call if you had the choice?
2. How much would you bid for the certificate?
3. Would you pay \$3 to choose the device you want?

For comparison, we show some statistics on the answers to these questions in Appendix A that is located at the end of this chapter. The data is taken from a graduate class at Stanford University that had an enrollment of 270 students. About 30% of the students chose the medallion and 70% chose the thumbtack. Furthermore, 30% of the students were willing to pay \$3 for the choice of the device. Of those, 25% preferred the medallion over the thumbtack.

2.2.4 The Acquirer Revealed

I: Now we have the bids. The acquirer is Sally at \$42. Congratulations Sally. Please pay me \$42 and the certificate is yours. Thank you Sally. I now write Sally's name on the certificate to acknowledge her ownership. Before we go on, Sally, I see that you have chosen to pay \$3 to choose the device. So I will need another \$3 from you. (*Sally hands Instructor the \$3.*) Thank you. I see that you have chosen the medallion. Why?

Sally: The medallion is like a coin, and I do have some experience in coin tossing, but I know nothing about thumbtack tossing. It is safer to choose the medallion.

I: Your argument may sound appealing and is used frequently by those new to the field, but it is incorrect. In fact, the medallion deal is the worst deal you can get if you believe the probability of heads is one half. No binary device is harder to call than one that is equally likely to come up either way. If you believe that the thumbtack is more likely to fall one way than the other, you are better off using the thumbtack. And I guarantee that it will never be a worse choice than the medallion.

To demonstrate, we can convert the thumbtack deal into a medallion deal at no cost. Does anyone know how to do this?

Sally: Yes. I can simply flip my own coin. If the result is heads, I call heads on the thumbtack. If the result is tails, I call tails on the thumbtack.

I: Correct. To see this, suppose that the thumbtack has already been tossed, but no one had seen how it has fallen. Before calling it, you remove a coin from your pocket and toss it. If it comes up heads, you call heads for the thumbtack; if it comes up tails, you call tails for the thumbtack. Since you believe your coin has a 50/50 chance of coming up heads or tails, you will have a 50/50 chance of winning the \$100. Regardless of how the thumbtack has fallen, you have created the medallion deal.

I: You see, Sally, if you were working in a company, it would be difficult to explain to your manager why you would pay an extra \$3 to choose the medallion. But this was your decision, you now own the certificate, and you will call the medallion toss. As you know, you cannot sell the certificate. But if you were able to sell it, what is the least you would accept for it?

Sally: \$45.

I: Why do you say \$45? (*To the class.*) Should this value depend on what Sally paid for the deal?

C: Sure, she wants to make a profit.

I: Suppose she makes a mistake and bids \$95 for the certificate; then what?

C: She would sell it for the most she could get for it.

I: Why doesn't she sell it for the most she can get for it regardless of what she paid for it?

C: Shouldn't what you paid for something affect your selling price?

I: Not really. What you paid for something may tell you a lot about its market value; for example, when buying a souvenir from an artisan in a foreign country. However, what you originally paid for the item becomes more important if you are paying a tax on the difference between your buying price and your selling price. You now care what you paid for it because it will affect your future tax payment. This difference aside, you should generally sell anything you own for as much as you can get for it.

This is called the **sunk cost principle**: How much you spent to get into the situation you are in does not make any difference to your future.

I: Here's an example. Suppose you inherit a house from your grandmother that she paid \$5,000 for many years ago. The current market price is about \$100,000. Someone approaches you, offers you \$10,000, and says, "That is a 100% profit! What more do you want?" You would say, "About \$100,000."

I: Sally, let us review your present investment in the certificate. Your bid was \$42, plus \$3 to call the medallion, for a total of \$45. You just said that you would be indifferent to selling it for \$45. Is that still true?

Sally: No. Originally, I was thinking that the certificate was worth about \$48 to me and that if I could get it for an investment of \$45, I would have a good deal. I can now see that I was not thinking straight. If I could sell the certificate now, I would be indifferent to selling it for \$44.

I: Sally, here is another way to think about it. With your present understanding, suppose that instead of paying \$45 for the certificate, I had given it to you at no charge. However, on the way to class, you lost \$45 from your wallet and you had just discovered the loss. Your bank account is down \$45 and you own the certificate. Would you be just indifferent to selling it for \$44?

Sally: Yes, I would. With the same bank account, how I received the certificate should not affect my selling price. I should not be thinking of profit.

I: Let's continue. Sally, what is the chance you are going to receive the \$100?

Sally: 50%.

(At this point, without warning, the instructor flips the medallion without looking at it and places a piece of paper over it.)

I: Sally, what is the chance you are going to receive \$100 now?

Sally: Still 50/50.

I: Right. Does everyone else agree?

C: Yes.

I: That is correct. It is interesting that some people may see a difference between the probability of an event in the future or the same event in the past, even when they have no new information about it. Knowing the event has occurred does not change your information about calling correctly.

I: *(Instructor peeks under the paper.)* Very interesting. Sally, what is your chance of receiving \$100 now?

Sally: Still 50%.

- I:** And if I were to call the medallion toss, what is my chance of calling it correctly?
- Sally:** 100%.
- I:** Right. What is my probability that the medallion has fallen one way or the other?
- Sally:** For you it's zero for one face and one for the other.
- I:** So my probability of looking at a head or a tail is not 0.5 on each one, but one for one face and zero for the other.
- Sally:** Right.
- I:** Even though the coin has now been tossed for both of us, my probability of heads or tails is definitely different from yours. So, is the probability out in the world or in our heads?
- Sally:** It's in our heads. It depends on what we know.

2.2.5 The Value of Clairvoyance

- I:** Right. The probability depends on your state of information. Now, Sally, suppose I offered to tell you what I saw under the paper. Is that information valuable to you?
- Sally:** Yes. It guarantees that I will call correctly.
- I:** What is the most you would be willing to pay for it? Class, what do you think she should pay?
- C:** *(Answers all over the place.)*
- I:** Is this a matter of logic or opinion? Think of me as a clairvoyant: One who can tell you anything about the past, present, or future as long as the telling requires no judgment. If Sally obtains my services for nothing, what is the certificate worth to her?
- C:** \$100.
- I:** What if she does not have my services?
- C:** \$44, the lowest price at which she would remain indifferent to selling it.
- I:** So what is the most she would pay to transform a \$44 certificate into a \$100 certificate?
- C:** \$56.
- I:** Right. The most she should pay to know how the medallion has landed, and to call this result, is \$56. We call this the **value of clairvoyance** on the result of the medallion toss. Since you would never pay more than that value of clairvoyance for any information source that does not provide clairvoyance, this concept helps you rule out many information-gathering activities.

Reflection: The Clairvoyant

The Clairvoyant can tell anything physically determinable past, present, or future and can compute with infinite resources. However, the clairvoyant cannot exercise judgment. If you ask the clairvoyant, "How many people in the room are happy?" He will respond that he cannot answer. If you ask him the total age of all the people in the room, he can tell you if you specify exactly what you mean by "age."

The *value of clairvoyance* is a key concept in decision analysis because it shows you the most you would pay to know something uncertain. (See Figure 2.6.)



FIGURE 2.6 The Value of Clairvoyance is a Key Concept in Decision Analysis
(Destina/Fotolia)

- I:** If the clairvoyant wants to be paid less than Sally's value of clairvoyance, she should buy the information, but if he wants more, she should not. Also, note that in this situation, once we know the price at which Sally is indifferent to selling the certificate, the value of clairvoyance is a matter of logic.
- I:** We say that an information source provides imperfect information if it does not yield clairvoyance. Suppose, for example, a person sitting at the back of the room has binoculars and thinks he saw how the medallion fell. If he asks for more than the value of clairvoyance for his information, then Sally should not care how good his eyesight was, since she should not pay any more than the value of clairvoyance for any type of information gathering activity about how the medallion fell. Companies routinely spend many times more than the value of clairvoyance for information that is not as valuable to them as they believe.
- I:** To continue, consider the possibility of my offering Sally this deal. To ensure that I carry this out correctly, Sally can appoint an agent. I have a watch that shows seconds digitally. Suppose I glance at the watch and note the number showing the seconds. If the number is between 00 and 49, I will tell her the face of the medallion that is up. If the number is between 50 and 59, I will tell her the face of the medallion that is down. That is, she has a $5/6$ chance of correct information about the face that is up and $1/6$ chance of incorrect information. Would this imperfect information be worth something to her?
- C:** Yes.
- I:** More than \$56?
- C:** No, less.
- I:** Right, and we have methods to help her figure out what she is willing to pay for such information; we shall present these methods later. Are most of life's information gathering opportunities like clairvoyance, or like the deal with the watch?
- C:** The watch.
- I:** Yes. In every field of decision making, and in most information gathering activities—surveys, pilot plants, test wells, medical tests, and controlled experiments—we encounter imperfect information.

2.2.6 The Call

- I:** Well, Sally, we are almost ready to let you call the toss of the medallion. From this point on, let's be clear about what we are going to learn. Are we going to learn anything about Sally's decision making ability after observing the outcome of the toss?
- C:** No. At the time, she paid \$42 plus \$3 for something she believed was worth \$48. Now, she believes the medallion is equally likely to land either heads or tails, and none of us has any new information.
- I:** So really, we are not going to learn anything. All we are going to find out is whether or not she takes home the \$100. In other words, we know the decisions she has made, but we don't know whether she will get the more desirable outcome. Does the world tend to reward people on their decisions or on their outcomes?
- C:** Outcomes.
- I:** That is something to consider. Now Sally, what do you call?
- Sally:** "Heads" ("or Tails")
- I:** You are right, here's the \$100 (or you are wrong, thanks for being a good sport).

2.3 LESSONS LEARNED FROM THE THUMBTACK AND MEDALLION EXAMPLE

The previous demonstration involved a simple decision, yet presented a challenge to our intuition. There are several lessons we can learn from the thumbtack demonstration and we summarize those below.

2.3.1 Probability is a Degree of Belief

In probability classes, you might be used to seeing terms such as "fair coin" or a "perfectly shuffled deck of cards." These terms often lead us, incorrectly, to believe that probability is a property of the coin since it is fair, or that probability of drawing a card is a property of the deck. In fact, what the instructor really means when he says "fair coin" is that he wants us to assume our belief is equally likely that the coin will land heads or tails.

Reflection: If a Magician Tosses the Coin

We have a magician friend who tosses coins and always makes the coin land heads. If you knew this guy would be tossing a coin for you, would you still believe heads has a probability of 0.5? No. Therefore, probability is nothing more than our degree of belief that a certain event or statement is true.

In many statistics classes, there is a notion of a "long run fraction" of repeated trials that is supposed to represent the probability of an event. However, understanding probability as a degree of belief is much more useful. In real-world decision making, we never encounter infinite repeated trials. For example, consider the probability that it will rain tomorrow in Palo Alto. Suppose you knew the number of times it rained on that day of the month for the last hundred years. Would you use the fraction of times it had rained as your probability of rain tomorrow?

Instead, we would recommend that you consider this data, but also obtain current weather forecasts and then go outdoors to look at the sky. Based on this information, you would assign a probability to represent your belief that it will rain tomorrow. As your state of information changes, your probability assignment may also change. If you look out the window again and see that it is now raining, you would revise your probability based on this new information. Therefore, every probability assignment you make should be conditioned on your *current state of information*.

2.3.2 Probability Comes from a Person

Probability is not a property of the medallion or the thumbtack, but comes from a person. “The medallion has a probability of 0.5 for landing heads” has no meaning. People may feel uncomfortable with the thumbtack demonstration because they are not accustomed to assigning probability. They are used to analyzing data and calculating statistical quantities from data. Probability, however, does not come from data. It represents a person’s state of information about an uncertainty. Therefore, before we can talk about any probability assignment, we need a *person*.

There is no such thing as a “correct probability.” To illustrate, suppose two people are talking about the probability of rain tomorrow. One says the probability of rain is 0.5; the other says the probability of rain is 0.7. Now suppose it rains. Who was correct? They both were. If it does not rain, they are still both equally correct. There is no such thing as the actual probability of rain; each individual presented a belief about the chance of rain.

In the previous demonstration, at the point of calling the result, Sally believed she had a 50/50 chance of calling correctly, but the instructor knew the result of the toss. His probability was 1 and hers was 0.5. The two probabilities were different, since they represented different states of information. Therefore, every probability assignment should specify the person who is making the assignment.

2.3.3 Thumbtacks and Probability

Over the years, many people have presented their reasons for believing the thumbtack is more likely to land one way or the other. Here is a popular one: We call it the “coin-nail” model. Suppose the thumbtack had its pin cut off, leaving just the round head. It would look more like the medallion, and many people would assign a probability of 0.5 for its landing on either side.

Suppose the pin was very long. Then the thumbtack would almost always fall pin down. The actual length of the pin is somewhere between zero length (no pin at all) and the very long pin. This reasoning would require you to assign a higher probability for it to land pin down than pin up (see Figure 2.7).

Another method of reasoning refers to the principle of minimum potential energy, suggesting that the thumbtack is more likely to land with its pin up because the center of gravity is lower when it is pin up. Most of these arguments, however, do not take into account the actual jar, the



FIGURE 2.7 Thumbtack with Long Pin

shaking mechanism of the jar, or even our existing information about thumbtacks. Once again, we need a person to make the probability assignment.

2.3.4 The Thumbtack Deal is at Least as Good as the Medallion Deal

Even though Sally believed she had a 50/50 chance of calling correctly with the medallion, she should never have paid extra. The demonstration showed how to convert the medallion deal into the thumbtack deal by simply flipping a coin and using the result to call the thumbtack. Paying \$3 for the chance to choose the medallion was, therefore, a bad decision. We will refer back to this point in Chapter 6.

2.3.5 The Sunk Cost Principle

The *sunk cost principle* is another fundamental distinction we make in decision analysis. According to the sunk cost principle, a decision is made by considering only the possible futures that it might generate. The historical account of how the situation developed is pertinent only to the extent that it has provided information useful in assessing the likelihood of these futures. Any resources consumed in the past are pertinent to the present decision only through this learning effect. The resources consumed may be things such as money, time, and effort.

Reflection

If you have been working on a “do-it-yourself” plumbing job all day and you still aren’t finished, you may need to decide whether to invest more of your time or to hire someone else.

The only question is whether it is a better use of your resources, time, and money, to continue by yourself or to hire a professional. Note that from the time you have already spent, you have learned something about your degree of competence in carrying out this job. However, the time you have wasted is not otherwise pertinent to the decision.

Saying to yourself, “look at all the time I have spent on this, I have got to finish it” is falling prey to a temptation to violate the sunk cost principle.

Often, the sunk cost principle often conflicts with human nature. That is, we find it hard to avoid blaming ourselves for resources wasted in arriving at the present situation. Imagine, for example, you are present at a Board of Directors meeting, helping to decide whether to abandon a foundering project. Before the meeting is over, you will most likely hear something like this:

“Look at all the time and money we have already wasted.”

Seldom will anyone laugh, and yet laughter would be appropriate. The lost resources are meaningless to the future of this project. The future value lies in the experience gained from the bad outcome.

For several reasons, the sunk cost principle can create confusion. First, people often believe that experience gained from a bad outcome should never be used in making decisions. In truth, learning from experience should always be a part of good decision making. It is the wasted or expended resources that have no real bearing.

Confusion also arises when people consider making a decision that will limit future action. For example, a person who goes on a diet might decide to eliminate tempting foods from the house to increase their chances for success. Similarly, an alcoholic might check into a rehabilitation facility that will restrict opportunities to drink.

Reflection

In this famous excerpt from Homer's *Odyssey*, Ulysses makes a decision in an attempt to limit future action.

Ulysses had to sail near the coast of the Sirens, who were known to tempt mariners to a watery fate by luring them with their cries. Ulysses had his crew stuff their ears with wax and bind him to the mast, with orders not to release him no matter how much he begged them. On hearing the Sirens' calls, Ulysses struggled to get loose and begged to be released, but his crew refused. As a result, they sailed by in safety. (Of course, Ulysses could also have stuffed his own ears with wax, but being tied to the mast makes a better story.)

Like learning from past experiences, mindfully limiting your future actions can improve your chances of making a good decision. None of the examples above violate the sunk cost principle. In fact, limiting your future actions can be prudent.

Finally, people sometimes are not sure whether keeping records of past purchases will help them to make informed decisions about future spending. Such records are useless as any kind of guide to current market prices, due to their constant fluctuation. However, there is one compelling reason to track your purchases: Taxation. What you have paid for a share of stock, or for your home, may have an important bearing on your future cash flows because you will often be taxed on the difference between what you paid for something and what you receive for it when you sell it.

Common maxims advise us to follow the sunk cost principle. One is "Don't cry over spilt milk." More to the point, another warns "Don't throw good money after bad." A more optimistic way of looking at a decision, consistent with the sunk cost principle, would be "Today is the first day of the rest of your life."

2.3.6 The Value of the Certificate

When making a decision, monetary value is often not the only consideration. When participating in the demonstration described earlier in the chapter, a student once bid \$100 for the certificate. He mentioned that the opportunity to get the certificate and be the center of class discussion was worth more to him than the money itself. Furthermore, he explained, the experience would be a nice memory of his learning this material. As a result, he valued the certificate at more than the amount of money he could receive.

Other people may have religious beliefs about not owning such a certificate and would value it at zero; they would refuse it even if they received it at no cost. Still others may be willing to engage in the demonstration and may even have the same beliefs about the probability of heads or tails with the thumbtack, but still place different values on the certificate. In future chapters, we will clarify values for certain and uncertain deals, but for now, understand that, for many reasons, different people may have different values for the same deal.

2.3.7 The Value of Clairvoyance

As we discussed, the value of clairvoyance on uncertainties you face is a key concept in decision analysis. If you knew the future that would follow your choice, the decision simplifies.

The value of clairvoyance on any uncertainty is the most you would pay the clairvoyant to know the outcome of that uncertainty.

The ability to buy clairvoyance is rare in practical decision-making. However, there are many information-gathering activities that will provide imperfect information at a cost: market

surveys, medical tests, pilot plants, seismic measurements, wind tunnel experiments, etc. They can be valued using the same principle:

The value of clairvoyance on any information gathering activity is the value of clairvoyance on the results of that activity.

Calculating the value of clairvoyance does not require the existence of the clairvoyant, but only the concept of one. We shall discuss how to exploit the notion of clairvoyance in more detail in future chapters.

2.3.8 Good Decision vs. Good Outcome

This chapter's demonstration provides an excellent example of the difference between a good decision and a good outcome. Once the decision is made, we will not learn anything about the quality of the decision by observing its outcome. Furthermore, once the outcome is revealed, there is no point in seeing it as good or bad: it is simply the outcome, the starting point for future decisions.

2.4 SUMMARY

- The thumbtack deal is better than the medallion deal.
- Probability comes from a person. It is not a physical property. It depends on the person's information.

KEY TERMS

- Sunk cost principle
- Value of clairvoyance

APPENDIX A Results of the Thumbtack Demonstration

Figure A.1 shows a histogram of bids made by 270 graduate students for the opportunity to call either the medallion or the thumbtack deal. In general, the bids are too low for the decision situation they are facing. As shown here, sometimes students misunderstand the demonstration and make a bid of \$95 or more. These students often choose to withdraw for \$10.

Thirty percent of students were willing to pay \$3 for the right to choose the device. 25% of those, who were willing to pay \$3, preferred the medallion over the thumbtack. Given our previous discussion showing that you cannot be worse off by receiving the thumbtack deal, it would be difficult to explain why you would pay \$3 to get the medallion deal.

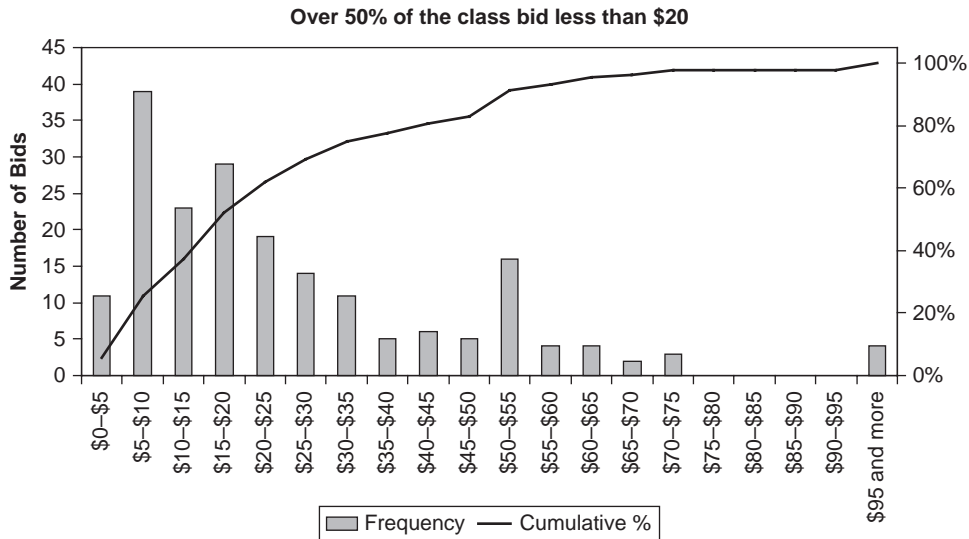


FIGURE A.1 Histogram and Cumulative Histogram of Bids

25% of those who wanted to be able to pick the device preferred the medallion over the thumbtack

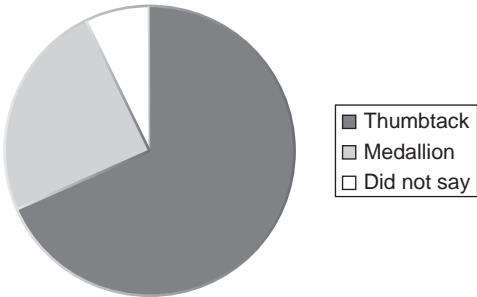


FIGURE A.2 \$3 Choice Pie Chart

PROBLEMS

Problems marked with an asterisk (*) are considered more challenging.

Problems marked with a dagger (†) are considered quantitative.

- *1. What is the result of a high-quality decision analysis?
 - a. Knowledge of what will happen as a result of your decision
 - b. Guarantee of a good outcome
 - c. Clarity of action
 - d. None of the above.
- *2. Suppose that at \$45, you were the highest bidder for the certificate auctioned off during the chapter demonstration. After winning the certificate, you determine that the least you would be willing to sell the certificate for is \$75. The instructor offers to tell you truthfully how the thumbtack has landed before you make your call. What value would you assign to this information?
 - a. \$25
 - b. \$30
 - c. \$55
 - d. You need more information to answer this question.
- *3. In this chapter, we described a fallacy involving the “fairness” of the coin. What was this fallacy?
 - a. A “fair coin” implies a 50/50 chance at heads vs. tails, but we can never be sure of the actual probability of the coin landing heads.
 - b. “Fairness” is not clear, and, therefore, should not be used.
 - c. “Fairness” is not a property of the coin, but of our beliefs about the coin.
 - d. A flipped “fair coin” and a spun “fair coin” have different probabilities of landing heads.
- *4. Yosem has already flipped a new Massachusetts quarter three times, and each time it has come up heads. He then says to his friend Pablo, “I’ll bet you a dollar that the next flip will come up tails.” Pablo agrees to the bet. Yosem flips the coin, it comes up tails, and so he collects a dollar from Pablo. Which of the following best described Yosem’s action?
 - a. The first three coin flips clearly showed that the Massachusetts quarter is not a “fair” coin. Therefore, Yosem’s bet on the coin coming up “tails” was a bad decision.
 - b. Since any ordinary quarter is “fair,” tails was bound to come up eventually. Yosem made a good decision to bet on the next coin flip being tails, and had a good outcome.
 - c. After observing three heads in a row, Yosem should have bet more that tails would come up next. Betting only one dollar was a bad one because it reduced his winnings.
 - d. It is not unusual to observe three consecutive heads when flipping coins. Yosem was just lucky and got the good outcome.
- *5. Which of the following is an example of falling into the sunk cost trap?
 - a. I need to think about how much I paid for the house five years ago, since that affects the taxes I need to pay when I sell it.
 - b. Let’s do some research on the past performance of this company before we invest in it.
 - c. I bought this for \$15; therefore I shouldn’t accept to sell it for anything less than \$15.
 - d. All of the above.
6. Which of these statements necessarily violates the sunk cost principle?
 - a. The engine in my car just broke down. I decided to scrap the car because the costs for repairing the car exceed the amount I paid for it.
 - b. After observing how financial stocks performed last week, I will sell all of my shares of Bank of Amerigo next week.
 - c. I will buy a \$1 book that I would not otherwise want in order to make my online purchase exceed \$25. That way, I can save \$5 on the shipping fees I would otherwise pay.
 - d. I would have paid \$30 for a ticket if it all went to the venue, but I won’t pay it knowing Ticketbuster gets most of the money in fees.

7. How many of the following is an example of a violation of the sunk cost principle?

- I. Let's do some research on the past performance of this company before we invest in it.
- II. I need to think about how much I paid for the house five years ago because I do not want to lose on the sale.
- III. I need to think about how much I paid for the house when I sell it if it will reduce my tax bracket and I will have a higher profit.
- IV. My car transmission just broke down and I decided to scrap the car because the cost for repairing the car exceeds the amount I paid for the car.
 - a. Only one is a violation of the sunk cost principle
 - b. Only two are violations of the sunk cost principle
 - c. Only three are violations of the sunk cost principle
 - d. All of the above are violations of the sunk cost principle

*8. Nathalie is an expert in taxes and she prefers more money to less. She bought a ticket to see *Ariadne auf Naxos* at the opera. It cost her \$50. Unfortunately, she is sick on the day of the performance and she decides not to go. The opera does not reimburse tickets but considers unused tickets as donations. Her friend Robyn offers to buy her ticket for \$15.

- I. She rejects that offer feeling that since she paid \$50, Robyn should pay her no less than \$50.
- II. She rejects that offer because she prefers to donate the unused ticket back to the opera. She knows that a donation of \$50 will provide her a tax credit of \$20.

In which cases is Nathalie violating the sunk cost principle?

- a. I only
- b. II only
- c. Both I and II
- d. None

9. Mary assigns a probability of $1/7$ to a particular die landing on "5" the next time it is tossed. Consider the following two statements about her probability assessments:

- I. Mary's probability must be wrong. The correct probability of a die landing on "5" is $1/6$ th.
- II. Mary can't assign this probability until she has seen at least seven flips.

Which of the statements are true?

- a. I only
- b. II only
- c. Both I and II
- d. Neither I nor II

*10. Jasmine believes that the thumbtack has an 80% probability of landing pin down. Winston believes that this probability is closer to 40%. When the instructor flips the tack, however, it lands pin up. What may we conclude from this event?

- a. Jasmine's belief about the tack's probability of landing pin down was incorrect. It should have been much less.
- b. Winston's belief reflects reality more accurately than Jasmine's.
- c. The probability of landing pin down is actually 80%, but Jasmine just got a bad outcome.
- d. None of the above.

11. Big Game is the annual football rivalry game between Stanford University and UC Berkeley. Jack assigns a probability of 0.6 that Stanford will beat UC Berkeley in Big Game 20XX. Kim believes that the probability is actually 0.4 and challenges Jack to a bet. If UC Berkeley wins, Jack pays Kim \$100 and if Stanford wins, Kim pays Jack \$100.

Which of the following statements is valid?

- a. If Kim wins the bet, we know that she made a good decision.
- b. The objective probability that Stanford wins the game is between 0.4 and 0.6.
- c. The clairvoyant's probability that Stanford will win Big Game 20XX is greater than 0 and less than 1.
- d. None of the preceding statements is valid.

*12. Which of the following statements violates the sunk cost principle?

- I. I called customer support because my digital camera does not work anymore, and I have been on hold for a few minutes. I am wondering whether I should give up and try again the next day, or whether I should stay on the line and keep waiting. As I make that decision, I consider how much time I have already spent waiting, because it helps me think of how much longer I might need to wait before I can speak to a representative.
- II. When selling my small business, I should think about how much I paid to purchase the company 5 years ago because it may change my tax bracket and affect my profit.
 - a. I only
 - b. II only
 - c. Both I and II
 - d. Neither I nor II

*13. How many of the following statements violate the sunk cost principle?

- I. I bought my tennis racket online at \$300, but I found its head was too heavy for me so I choose to put it up for sale. I will not sell it for less than \$300 because that would be a loss to me.
- II. Despite waiting in line for 3 hours for the Black Friday shopping day, Mary decided to go back home before the store opened since she cannot bear the cold wind.
- III. A manager should look at her employee's past performance reviews when deciding whether to grant him a promotion.
 - a. 0
 - b. 1
 - c. 2
 - d. 3

†*14. William is a private equity guru. One year ago, the owners of a troubled retail company accepted William's buyout offer of \$15M. At the time, William's PIBP for the company was \$30M. William worked very hard to restructure the company over the past year, but, unfortunately, the company went bankrupt. The following statements are thoughts that William had after the bankruptcy.

How many of them **do not** violate the principles of decision analysis?

- I. I have the chance to invest an additional \$1M in order to earn \$3M extra on the liquidation of the company's assets. However, I shouldn't make such an investment because it won't fully recoup my \$15M original investment.
- II. I am very unhappy with the bankruptcy, but I still feel like the buyout was a good decision.
- III. I should remember this outcome and learn from it so it will help make future investment decisions.
 - a. 0
 - b. 1
 - c. 2
 - d. 3

*15. How many of the following statements violate the sunk cost principle?

- I. I want to stay until at least the 7th inning stretch so I can hear Cameron sing *Take me Out to the Ball Game*...
- II. I have to finish drinking this beer because I paid \$8 for it!
- III. I prefer to go to the bar rather than pay \$100 for the only baseball tickets left, but since I drove this far to get here, I'll buy the expensive tickets.
- IV. Since you are late getting here, the best thing to do is buy outfield tickets!
 - a. 0
 - b. 1
 - c. 2
 - d. 3

† *16. Theater Tickets

You have made plans to attend the theater alone. The tickets cost \$20 each. Consider the following two scenarios:

- a. You have purchased a ticket for \$20. When you arrive at the theatre you discover you have lost your ticket, and find you have another \$20 bill in your wallet. Would you buy another ticket and attend?
- b. You arrive at the theater only to discover that on the way you have lost one of the two \$20 bills in your wallet. Would you spend the other \$20 bill to buy a ticket and attend?

† *17. Project Funding

As the President of XYZ's largest subsidiary, you have two project proposals on your desk.

Note: All monetary values cited are in today's U.S. dollars.

- I. Last year, we approved Project I. Upon completion, it will generate \$100 M in revenue, and cost \$90M. You spent the \$90M. The proposal before you now states that an additional \$20M is required to complete the project and realize the \$100M in revenue. If you do not spend the additional \$20M, no revenues will be realized.
- II. Project II will generate \$80 M in revenue. A trusted advisor tells you that you can secure this deal at a cost of \$20 MM.

Now consider the following questions:

- a. If you had \$100 MM to invest today, which project(s) would you fund?
- b. If you had \$20 MM to invest today, which project(s) would you fund?
- c. If you had known from the start that there would be the additional \$20MM required to complete Project I, would it still have deserved funding?

Clarifying Values

CHAPTER CONCEPTS

After reading this chapter, you will be able to explain the following concepts:

- Value in use
- Value in exchange
- Personal Indifferent Buying Price (PIBP)
- Personal Indifferent Selling Price (PISP)
- Cycle of ownership
- Effects of wealth, time and information on the cycle of ownership
- Market buying and selling price
- Value around a cycle of ownership

3.1 INTRODUCTION

In the last chapter, we explored the decision making process through our analysis of the medalion and thumbtack demonstration. We asked a student named Sally to consider the value of a certificate she had acquired. We witnessed her confusion as she considered the difference between her purchase price and the actual certificate value to her. The issue of valuation arises in so many decisions that we shall now present the basic concepts in familiar settings that have no uncertainty. Later we shall address the additional complications in valuation created by uncertainty. The ideas introduced in this chapter will support much of our future development.

3.2 VALUE IN USE AND VALUE IN EXCHANGE

To illustrate the concept of valuation, we begin with another discussion between the same instructor and his class.

Note: “I” refers to instructor and “C” refers to one or more individuals in the class.

I: Today, we shall be talking about buying and selling prices. Frank, that is a very nice shirt you are wearing today.

Frank: Thank you.

I: What would you be willing to sell it for?

Frank: \$500.

C: (*Laughs*)

I: I know you would, but let me ask you, what is the least you would be willing to sell it for? I assure you we are not really going to buy it, so you can just tell the truth. What is the least amount of money we could give you that would make you indifferent between owning the shirt without that money and not owning the shirt, but having that money?

Frank: \$30.

I: You would not take \$29, but would definitely take \$31?

Frank: Right.

I: We call the \$30 Frank specified his Personal Indifferent Selling Price (PISP) for the shirt. PISP is an important concept in decision analysis.

I: Who likes Frank's shirt?

Joe: (*Raises his hand*)

I: Joe, if I take care of the cleaning, how much would you pay for Frank's shirt?

Joe: \$5.

I: Joe, I remind you that we are not really going to sell Frank's shirt. So just imagine that we are, and tell me, just between us, what is the most you would pay for it?

Joe: \$20.

I: That means that at \$19 you would definitely buy it and at \$21 you would not.

Joe: Yes.

I: We call the \$20 your Personal Indifferent Buying Price (PIBP) for Frank's shirt. PIBP is another important concept in decision analysis.

I: Now, would Frank and Joe have a deal?

C: No.

I: Correct. For two people to have a deal, the Personal Indifferent Buying Price for the one who doesn't own it has to be higher than the Personal Indifferent Selling Price for the one who does own it.

By the way, Joe, what would you pay for a second identical shirt just after you've bought the first?

Joe: \$5. I want variety.

I: I see. Indeed, there is no reason why a second identical item would have the same Personal Indifferent Buying Price.

Now, it is important to note that what we have been talking about are *values in use*. Frank is not in the shirt-selling business and Joe is not in the shirt-buying business.

Note: Personal Indifferent Selling Price (PISP)

A *selling price* arises when you sell something you own. The word *indifferent* signifies that it is the amount at which you are indifferent about whether you continue to own the item, or give it up to receive that sum. The word *personal* indicates that it depends on the person: The amount can change from one person to another.

Note: Personal Indifferent Buying Price (PIBP)

A *buying price* arises when you buy something you do not own. The word *indifferent* signifies that it is the amount at which you are indifferent about whether you buy something, or continue not to own it. The word *personal* indicates that it depends on the person: it can change from one person to another.

Note: Value in Use

The PIBPs and PISPs reflect the *values in use* of the shirt. They do not reflect the actual cost of the shirt or the potential selling price. Out in the world, however, there are indeed people who are in the business of buying and selling things, such as shirts, to make a living. We call this the *market*.

- C:** And what about brokers, do they have a PIBP and a PISP?
- I:** Brokers are people who put together deals between potential buyers and sellers. If Barbara is a broker, for example, and she knows someone who will pay \$50 for Frank's shirt, she will happily pay Frank his PISP of \$30, or even more. Barbara may think this is the ugliest shirt in the world, but since she can sell it for \$50, she cares only about the profit she can make in this transaction.

Note: Market Buying and Selling Prices

The *market buying price* is what you would have to pay in the market for a particular good. The *market selling price* is what you would receive in the market for selling something you own.

- C:** But why doesn't my PISP for an item depend on the market price? For example, suppose I own a house and I know its market price is a lot more than what I paid for it. Should I not sell it for as much as I can get out of it?
- I:** By all means. Now remember, your PISP is the value you are getting out of the house by living in it and owning it. If the housing market suddenly drops or rises, this value of the house should not change, as long as your use of the house continues to have the same benefit to you. When you are going to sell your house, you should sell it for as much as you can get out of it. *Knowing your PISP does not mean you need to sell it at your PISP.* You would be just indifferent to selling it at that price.
- I:** You should also understand that the market price is not well defined. For example, if I ask a realtor about the market price of my house, she may respond, "That depends on how long you are willing to wait to sell it. If you need cash by next week, we can get x dollars, but if you are willing to wait six months, it could go for as high as y dollars."

Note: Value in Exchange

The market buying price and the market selling price reflect the *market value*, or the *value in exchange*, of a given good or service. The market value is specified by actual market buying and selling prices.

- C:** What about going shopping or buying groceries? In this transaction there is a market, yet you buy something for your own use. Right?
- I:** Yes. When you go shopping, you buy things for which your personal indifferent buying price is greater than the market selling price. Have you noticed when you buy groceries, you leave saying “Thank you” and the cashier also says “Thank you.” You bought things for less than your PIBP, and the storeowner, who is a broker in this case, sold the goods for an amount that is higher than what he paid for it. Both parties are happy with this transaction.
- I:** We’re learning a lot of new terms today, so let’s take a moment to recap.

Your **Personal Indifferent Selling Price**, or **PISP**, is the least you would be willing to accept to forgo the use of something that you own. Your PISP does not depend on the market buying price, but on its value in use to you. It also does not depend on what you paid for it. The PISP is the price at which you become indifferent to losing the item.

Your **Personal Indifferent Buying Price**, or **PIBP**, is the most you would be willing to pay to obtain the use of something you do not own. Your PIBP does not depend on the market selling price, but on its value in use to you. The PIBP is the price at which you become indifferent to buying the item.

The degree of value a good or service creates for you is also known as its *value in use*. It has nothing to do with selling or exchanging, and does not depend on the market price, but only on the benefit derived from owning or receiving the item. Value in use is specified by personal indifferent buying and selling prices.

The **market buying price** is what you would have to pay in the market for a particular item or service. The **market selling price** is what you would receive in the market for selling something you own. Note that these prices are fluid because they are observable only within a fluctuating market. Often, you will only learn the market buying and selling price for a unique item—for example, a particular house or piece of art—at the time of the actual transaction.

The **value in exchange** is the market value of any good or service. Buying and selling prices are what determines the value in exchange of a given item.

Why are these concepts important? Once you have established your PIBP for an item, getting it at a lower price is a good deal for you. This does not mean that you should not try to get it for an even lower price, but paying anything less than your PIBP is a good deal for you, since your value in use will be higher than what you paid for it. Conversely, once you have established your PISP, selling something for anything higher than that price will be a good deal for you.

In principle, we can think of having PISPs for everything in our lives that we currently own, and PIBPs for everything that we do not own, but might buy. We would then go through life selling those things with market buying prices higher than our PISPs and buying those things with market selling prices lower than our PIBPs. Of course, after any exchange that significantly affects our wealth, all of our PISPs and PIBPs may need to be reconsidered.

To illustrate the concepts of PIBP and PISP in this demonstration, we used items that had no uncertainty. Frank knows his shirt quite well, and Joe could see the shirt before he gave it

a PIBP. We introduced these same concepts in the last chapter, during the thumbtack demonstration. We asked Sally for the least she would be willing to sell the certificate for once she acquired it. She said \$45. While the outcome of the certificate was uncertain, the certificate had a definite value for her, which we now refer to as her PISP. We will often refer to the PISP of an uncertain deal, such as the certificate, as the *certain equivalent* of the deal. Sally believed she had made a good deal, since she paid \$42 for something that she would not sell for less than \$45.

Compared to the complex decisions we often face in our actual lives, the thumbtack deal was relatively easy to evaluate. For this reason, Sally was able to quickly calculate her certain equivalent of this deal. In chapter 11, we shall discuss how to calculate your PIBP and PISP for deals with a larger number of possible monetary outcomes.

Now let us continue our class discussion by defining values around a **cycle of ownership**.

3.3 VALUES AROUND A CYCLE OF OWNERSHIP

- I:** Let's get back to Frank and his shirt. Suppose that Frank sells the shirt for \$30—his PISP. After a few minutes, he changes his mind and considers buying it back. What is his personal indifferent buying price?
- C:** \$30.
- I:** Correct. To see why this is the case, suppose that at the time of the transaction, the buyer decides not to buy the shirt. If Frank is selling the shirt at his PISP, then he should be indifferent as to whether he sells it or not. He is, then, indifferent between two situations. One where he owns the shirt, and one where he does not own the shirt, but has extra money equal to his PISP. To maintain that state of indifference, when he sells the shirt at his PISP and buys it back, the amount of money he pays must be identical to his PIBP. We call this notion of an instantaneous buying and selling at your PIBP and PISP a cycle of ownership. Within a given cycle of ownership, buying and selling prices must be the same.

Figure 3.1 identifies the two properties most important to a cycle of ownership: Wealth and ownership. The grey shaded area represents your wealth when you own the shirt. The striped area

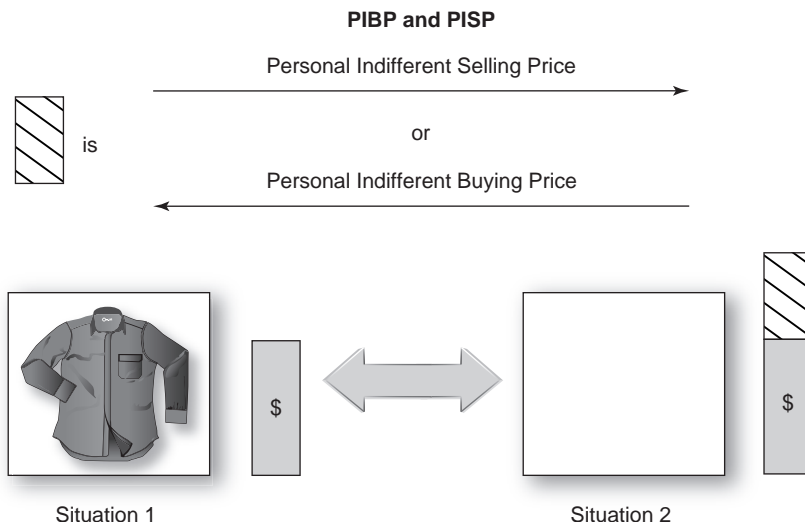


FIGURE 3.1 PIBP and PISP within a Cycle of Ownership

represents either a personal indifferent selling price or personal indifferent buying price at different points in the cycle. Within a cycle of ownership, whether you end up owning the shirt and having less money (equal to the PISP), or passing up the shirt and having more money (PIBP), the personal indifferent selling and buying prices must be the same.

You do not need to actually sell and buy an item at your indifference prices to think about your PIBP & PISP.

The concept of a cycle of ownership simply helps you determine whether you have really indifferent between winning an item and saving less money equal to your PIBP or PISP or not.

Note: Cycle of Ownership

Instantaneous buying and selling at your PIBP and PISP is known as a *cycle of ownership*.

Within a cycle of ownership, the PIBP and PISP must be equal. A cycle of ownership requires no passage of time, no new information, and no change in the state of wealth.

A cycle of ownership only occurs when the price paid for the item is equal to the PIBP for the item. If we pay less or more, there cannot be a cycle of ownership because of our new state of wealth. The cycle of ownership can also change by time or by receiving new information since it can change our values in use.

C: Can my PIBP and PISP include a range of prices?

I: No. The prices must be fixed. By definition, we say the PISP is the least you would be willing to accept to sell an item, while remaining indifferent as to whether you sold it or not. If you had a range, then the PISP is the minimum of that range. The same applies to the PIBP, since it is the maximum you would be willing to pay. If there is a range, the PIBP would be the maximum. There is also another important reason for not having a range. Suppose Frank had a range of PISP from \$25 to \$35 for his shirt. If he is indifferent to any of these values, then he must be indifferent to receiving \$25 instead of \$35. Frank's bank account would not survive for long if he had the habit of considering \$25 equal to \$35.

I: Now, I want you to consider the question of identical items. Joe said his PIBP for Frank's shirt was \$20. What is his PIBP for a second identical shirt? If Joe values having two identical shirts so he can wear either one and have the other washed, it could be higher. If he prefers variety in shirts, his PIBP for the second identical shirt could be less.

C: That sounds reasonable.

I: Here's another example: Suppose I own a gold coin. I can establish my PISP for it. Now suppose someone offers me an identical gold coin. Does my PIBP for the new coin need to be equal to my PISP for the coin that I already own?

C: No.

I: Correct. There is no reason that my PIBP for the second gold coin needs to be equal to my PISP for the coin I already own. It could be less, since my keychain can only hold one. On the other hand, suppose these two gold coins were collectors items, and their value together is far more than either one alone. In this case, a broker might be willing to spend more for the second one in order to make a profit later, by selling them as a set.

C: So, the PIBP of a bundle of two items together is not necessarily equal the sum of their individual PIBP's?

- I:** Correct. The gold coin example illustrates that it can be higher or lower. Consider a matched pair of shoes. If you have two legs, your PIBP for just the left shoe, or just the right, might be zero, since you can't wear either shoe without the other. However, your PIBP for a matching pair of shoes would be much higher.
- C:** Can the PISP be negative?
- I:** Think about that. Are there things in our lives that we own and that we would pay money to get rid of?
- C:** Trash.
- I:** Yes, that's a good one. Any others?
- C:** (*Silence*)
- I:** How about risk? We pay to get rid of risks in our lives in the form of insurance. We sell those risks at a negative PISP. An insurance company may be willing to assume ownership of one of my liabilities for a market buying price, the premium, that is less in magnitude than my PISP.
- I:** Here's another question for you: Can the concepts of PIBP and PISP apply to services, or just to goods?
- C:** Yes, they can apply to services as well. For example, you can have PIBPs for things such as haircuts, manicures, and car washes.
- I:** Correct, and you could be either buying or selling these services. What, then, is the value of clairvoyance?
- C:** The value of clairvoyance would be the price at which you would be indifferent about paying for the Clairvoyant's services: Your PIBP for clairvoyance.
- I:** Correct.

3.3.1 Wealth Effects on Values and the Cycle of Ownership

Now we consider changes in our lives that may affect our PIBP, our PISP, or our cycle of ownership.

- I:** My personal indifferent buying price for a new Rolls-Royce is \$30,000. Remember that I have to keep and use the car. This is my value in use so I am not thinking of reselling it. Since the market selling price is much higher than that, I don't own one. My personal indifferent buying price is relatively low because I don't feel comfortable driving it to the airport, I think maintenance would be expensive, and I have not found them to be much fun to drive. If I did buy the Rolls-Royce for \$30,000, my personal indifferent selling price for it at that instant, as we have discussed, would also be \$30,000.
- I:** Figure 3.2 represents the cycle of ownership using the Rolls-Royce rather than a shirt. I am currently in *Situation 2* in Figure 3.2. (*He presents Figure 3.2 as shown below.*) I do not have a Rolls-Royce and I have a bank account whose level is indicated on the right hand side of the Figure. To be in *Situation 1* and also own a Rolls-Royce, I would have to pay some money out of my bank account. To be indifferent between the two situations, this amount must be my PIBP of \$30,000. Since I am indifferent to the two situations, if I consider returning to Situation 2 from Situation 1, the required increase in my bank account is my PISP, which is the same \$30,000. This is the same analysis we did for the shirt.

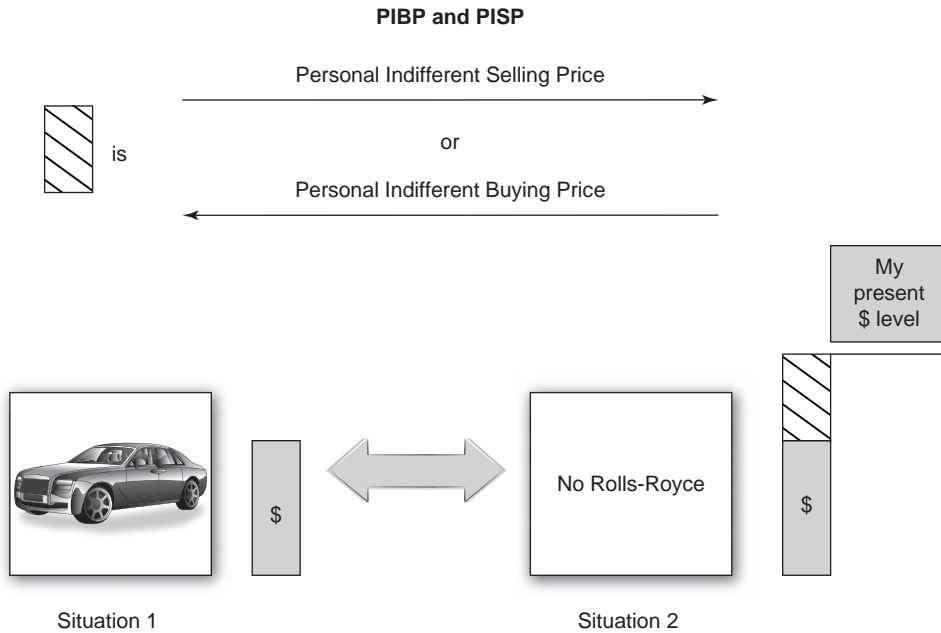


FIGURE 3.2 PIBP and PISP for a Rolls-Royce

- I:** Suppose that instead of buying a Rolls-Royce, I receive one as a gift. Does this mean that my personal indifferent selling price for it, now that I own it, is still \$30,000?
- C:** Not necessarily.
- I:** Correct. As you can see in Figure 3.3, I am now in *Situation 4*: I have my original bank account and I now own the Rolls-Royce. Due to this generous gift, I have become a wealthier man, the inconveniences once associated

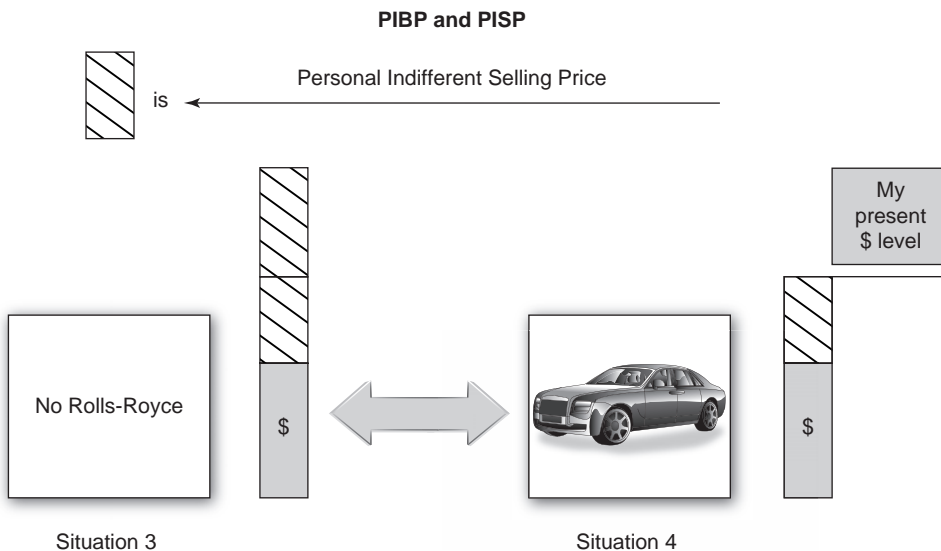


FIGURE 3.3 A New Cycle of Ownership for a Free Rolls-Royce

with the car are now easier to manage, and I might end up using it a lot more frequently. Consequently, my personal indifferent selling price for the Rolls-Royce might now be \$40,000 when I contemplate moving to *Situation 3*. If I do move to Situation 3, with no Rolls-Royce and a higher bank account, then my personal indifferent buying price for the Rolls-Royce would be \$40,000. There is no reason why my personal indifferent buying price for something in a world where I do not have it should be my personal indifferent selling price for the same thing in a world where everything is the same except that I have it.

- I:** Within a cycle of ownership, buying and selling prices are only tautologically the same. This is true both in my original world and in the free Rolls-Royce world. When I receive my free Rolls-Royce, I may have a new PISP for it because I am in a new cycle of ownership. Around this new cycle, my PISP is equal to my PIBP if I sold it and bought it at an instant.
- C:** Does wealth have to increase your PISP (or your PIBP)?
- I:** Not necessarily. It can go either way. For example, you may own a bicycle that you ride to work every day. At a new wealth level, you may have a driver and a new Rolls-Royce, so you will not use the bicycle as often. Your PISP for the bicycle in this new state may be less than your PISP in the previous state.

3.3.2 New Information Effects on Values and the Cycle of Ownership

- I:** Returning to original example where I have no free Rolls-Royce, suppose I learn that the price of gasoline will double. Now my personal indifferent buying price will be less than \$30,000 in this world of higher operating costs – my value in use will be lower. If I bought it at this price, my personal indifferent selling price at this instant would equal my personal indifferent buying price, since they must be equal in this world.

3.3.3 Time Effects on Values and the Cycle of Ownership

- I:** As we discussed, the cycle of ownership always occurs at a particular instant in time. The passage of time can change our resources and our preferences. For example, if I get tired of driving the Rolls-Royce, my PISP will fall. Similarly, my PIBP for a sky diving experience may also change as I age. However, within any cycle of ownership, the PIBP and PISP will always remain the same.

3.3.4 Expansion

- I:** Suppose I have an option to buy a Rolls-Royce that I must drive on a daily basis for the next ten years, but can then opt to sell. In this case, the most I would pay for it would consist of two parts: My PIBP for the ten years of use, and what I believe is today's market value of a used Rolls-Royce ten years from now. Perhaps, if there was a market in used Rolls-Royce futures in which I could sell the decade-later ownership rights today, I could evaluate this second component. This example illustrates that the simple concepts we have been discussing can be extended to

clarify many issues of valuation. As we progress in our discussions, our ability to evaluate will continually expand.

C: Can I have a PIBP for an item even if it is impossible to buy it?

I: Yes you can. You can assess a value for something even if it is not available. This kind of thinking is what drives entrepreneurs to create new products and services.

C: Does a corporation have indifferent buying or selling prices?

I: Yes. Suppose, for example, that a company is thinking about obtaining a patent for its exclusive use. They can think about the value the patent provides in improving their own design and the value of preventing some other company from getting the patent and using it. The company would then assess an indifferent buying price for acquiring that patent. This would be the **Corporate Indifferent Buying Price (CIBP)**. If a company owns a patent, it could also assess can also assess the **Corporate Indifferent Selling Price (CISP)** for its sale. Alternatively, an entity might think about buying a patent not for its use but for later sale, in which case it would be a broker concerned with value in exchange.

3.4 SUMMARY

- A *value in use* is different from a *value in exchange*. The value in use considers how much something is worth to us. The value in exchange considers the value we can get by buying an item and selling it to someone else. Value in exchange depends on market prices. Brokers are concerned with value in exchange.
- My *Personal Indifferent Buying Price (PIBP)* is the most I would be willing to pay for the use of something I do not own so that I would be indifferent to the transaction. It does not depend on market price.
- My *Personal Indifferent Selling Price (PISP)* is the least I would be willing to receive for giving up the use of something I own so that I would be indifferent to transaction. It does not depend on the market price.
- My *certain equivalent* is my PISP for an uncertain deal that I own.
- PIBP and PISP cannot have a range of values.
- The *cycle of ownership* is at an epoch in time and can change by changes in wealth, time, and information.
- Around a cycle of ownership, PIBP = PISP.
- PIBP and PISP can change with wealth, information, and time. In a new state, and new cycle of ownership, the new values of PIBP and PISP will be the same.
- If your wealth state changes, your PIBP and PISP for a given item may also change because your usage of the item may change. For example, if you inherit a large sum of money, your lifestyle may change and you may not use certain items that you would have in your previous state, or perhaps have an interest in new items and services.
- Your PIBP for buying a second item does not need to equal your PISP for selling the first item. Your usage of a second item does not need to be the same as the first.
- Corporations also have indifferent buying and selling prices, the *Corporate Indifferent Buying Price (CIBP)* and the *Corporate Indifferent Selling Price (CISP)*.

KEY TERMS

- Personal Indifferent Buying and Selling Prices (PIBP), (PISP)
- Market buying price
- Market selling price
- Cycle of ownership
- Value in use
- Value in exchange
- Market value
- Corporate Indifferent Buying Price and Selling Price (CIBP), (CISP)

PROBLEMS

Problems marked with an asterisk (*) are more challenging.

- *1. Which of the following is always true?
 - a. PISP is the value in exchange for a deal you own.
 - b. If you buy groceries for \$50, then your PIBP for them is equal to \$50.
 - c. PIBP is your value in use for a deal you own.
 - d. Your PIBP and PISP do not change around a cycle of ownership.
- *2. Which of the following is always true?
 - a. Your PIBP must change over time.
 - b. Your PISP for an object must change with wealth.
 - c. Value of clairvoyance on the medallion toss, if you owned the deal, is equal to your PIBP for the clairvoyant's services.
 - d. Your PISP exceeds market value.
- *3. Mary is selling her car for \$5,000. Ali thinks about it, decides that his PIBP for the car is \$5,000 and buys the car. Immediately after the transaction is completed, what do you know about Ali's PISP for the car?
 - a. It is equal to Mary's PISP for the car.
 - b. The exact value of it.
 - c. Neither (a) nor (b).
 - d. Both (a) and (b).
- *4. Your PIBP for a new Rolls-Royce is \$135,000. Your friend, Ronnie, offers to give you his new Rolls-Royce for free. Three minutes later, you receive a phone call from your friend asking to buy your Rolls-Royce. Which of the following must be true?
 - a. Your PISP must be greater than \$135,000.
 - b. Your PISP must be less than or equal to \$135,000.
 - c. Your PIBP for a second Rolls Royce is \$135,000.
 - d. None of the above.
- *5. Ed bids \$46 for the medallion deal of the last chapter. If Ed is following the principles we've taught so far, what must be true at that moment?
 - a. His PIBP must be equal to \$46.
 - b. His PISP must be equal to \$46.
 - c. His PIBP must be greater than or equal to \$46.
 - d. His PIBP must be less than \$46.
- *6. Vicki is shopping for books. She prefers *Great Expectations* to *The Chosen* and prefers *The Chosen* to *Jurassic Park*. She buys *Great Expectations* and *Jurassic Park* for a total of \$30. Which of the following MUST be true?
 - a. Her PIBP for *Jurassic Park* is greater than \$15.
 - b. Her PIBP for *Great Expectations* is greater than \$15.
 - c. Her PIBP for *Jurassic Park* is less than \$15.
 - d. None of the above.
- *7. Which one of the following statements about *value in use* is true?
 - a. John bought groceries for \$50, so his PIBP for the groceries was \$50.
 - b. My PIBP for two identical items can be, at most, twice my PIBP for one item.
 - c. My PIBP for a ticket to the Big Game must remain constant until game day.
 - d. Xi sold his helmet for \$20, so his PISP for the helmet was at most \$20.
- *8. On Monday, Jeff bought a ticket to the Big Game for \$40. On Wednesday, another friend offered him six tickets, each for the remaining home football games for \$80, but Jeff was able to negotiate him down to \$60. Which of the following statements must be true?
 - a. On Monday, Jeff's PIBP for the Big Game ticket was at least \$40.
 - b. On Monday, Jeff's PIBP for all seven home game tickets was at least \$100.

- c. On Wednesday, Jeff's PISP for the remaining six home game tickets was at most \$60.
 - d. On Wednesday, Jeff's PIBP for each of the remaining six home game tickets was at least \$10.
- * 9. A discount department store has a couple of dresses on sale for \$1000. You choose to buy one and take it home. That evening, your friend Mary sees the dress and offers to buy it from you for \$2000. After calling the store and having the identical dress put on hold for you, you decide to sell the dress you own to Mary. Given this information, which of the following statements must be true at the time you decide to sell the dress to Mary?
- a. Your PISP must be less than or equal to \$2000.
 - b. Your PISP must be greater than \$2000.
 - c. Your PIBP must be greater than \$2000.
 - d. None of the above.
- *10. John sold his used bike for \$75, even though he paid over \$400 for it three years ago. Assuming John follows the principles taught so far, what can we infer from John's behavior?
- a. John's PISP must lie between \$75 and \$400.
 - b. John did not violate the "sunk cost" principle.
 - c. Around a cycle of ownership, the buying price of an item need not equal its selling price.
 - d. John's PIBP for the bike must have been below \$400 three years ago when he bought it.
- *11. Lisa is in the market for a new bass guitar. She sees an Ibanez SR300 Model on sale for \$400 at Guitar Grotto, and an identical one for \$350 at Axe Mart. She gathers her savings and purchases the guitar from Axe Mart. We denote Lisa's PIBP for this guitar at the time of this purchase as b . A year later a friend offers Lisa \$375 for her guitar, but Lisa refuses the offer. If s is Lisa's PISP for this guitar at the time of her friend's offer, which of the following statements must be true?
- a. $b \geq \$400$
 - b. $\$350 \leq b < \400
 - c. $b = s$
 - d. $s \geq \$375$
- *12. Two years ago, Alexandros purchased a television from TV Town for \$500. Last year, he sold it to his friend Jason for \$600. Just yesterday, Jason sold the same television back to Alexandros for \$300. In each case, the television was purchased for the purpose of personal use. Given this information and that both follows the principles taught so far, how many of the following statements must be true?
- I. Jason's PIBP for the television when he purchased it last year was less than or equal to \$600.
 - II. Alexandros's PIBP for the television when he purchased it from TV Town is less than his PIBP for the television when he purchased it from Jason yesterday.
- a. I only
 - b. II only
 - c. Both I and II
 - d. Neither I nor II
- *13. Ben buys an HP computer for \$700. If he follows the principles taught so far, how many of the following are true?
- I. His PIBP for that computer must be less than \$700.
 - II. If Ben received an offer to buy an additional (identical) HP computer at an 80% discount, he would take it.
 - III. If Ben were offered a free computer (either the HP or a Dell), he would definitely prefer the Dell because it costs \$900.
- a. Neither, I, II or III
 - b. I only
 - c. II only
 - d. III only

- *14. The Draeger's grocery store in Menlo Park will buy Parmesan Reggiano cheese from any supplier for \$2,000 per 100-pound wheel.
- State your personal indifferent buying price for getting a 100 pound wheel of Parmesan Reggiano cheese, eating what you want (over time), and throwing away the rest. Briefly explain your choice.
 - A friend of yours owns a 100 pound wheel of Parmesan Reggiano cheese. He invites you to bid on the wheel. State the maximum amount you would bid. Briefly explain your choice.
 - Summarize the differences and similarities in your answers to parts a and b.
- *15. Gerry is shopping for a new car and sees a gorgeous Porsche 911 sitting outside the dealership. "I would love to buy that!" he thinks, but after seeing the sticker price of \$100,000, he realizes that he will not be buying that car. Fortunately, he sees that there is a charity raffle event that day, so he decides to pay \$100 for a raffle ticket. As luck would have it, Gerry wins the car! Which of the following statement(s) are necessarily true?
- Gerry's PIBP for the Porsche was greater than \$100,000.
 - Gerry's PIBP for the raffle ticket was greater than or equal to \$100.
 - Now that he owns the Porsche, his PISP is the sticker price of \$100,000.
 - I
 - II
 - I and II
 - II and III
- *16. Give some examples of items you own where you feel your PISP would go up by receiving a substantial amount of wealth. Identify some other items for which you feel your PISP would go down.
- *17. A friend of yours mentions to you that his PIBP for a shirt is a range of \$40 – \$50. What argument can you give him to explain it is not wise to have a range for his PIBP?

FOOD FOR THOUGHT QUESTION

The purpose of this question is to help you practice determining your PIBP.

Using your web browser, refer to one of the Internet auctions (for example, ebay.com, ubid.com, onsale.com, amazon.com). Select an item that interests you. What is it?

- Establish your PIBP for that item. How much is it?
- Could you determine your PIBP? Why or why not?
- Did you identify just one value, or a range of values?
- Would you bid for that item in a closed bid system with your PIBP?

Assuming you did bid with the value of your PIBP and acquired the item. Do you believe you got a good deal? Repeat this step until you narrow it down to where you will feel indifferent to whether or not you acquire the item.

Precise Decision Language

CHAPTER CONCEPTS

After reading this chapter, you will be able to explain the following concepts:

- Considerations for a precise decision language
- Simple speaking
- Familiar speaking
- Fundamental speaking
- Experts and distinctions
- Mastery of a subject
- Creating your own distinctions

4.1 INTRODUCTION

Becoming an expert in a subject requires making powerful distinctions in that subject. To learn decision analysis, you must master its basic distinctions. Collectively, these distinctions form a precise decision language that allows you to think clearly about any decision you or others are facing. We will show that restricting decision language to particular terms that are accurate, familiar, and fundamental contributes to clarity of thought and understanding. You have already begun to learn the language; that learning will expand as we proceed. In the previous chapters, we identified many powerful terms, including *value of clairvoyance*, *sunk cost*, *Personal Indifferent Selling Price (PISP)*, and *Personal Indifferent Buying Price (PIBP)*.

Note the clarity that these terms bring to our discussion: The term “Personal Indifferent Selling Price,” for example, is a “selling price” because the seller is going to exchange ownership of an item for money. We use the word “indifferent” because the seller would not accept a lower amount; he does not care whether or not he sells it at that price. We use the word “personal” because other people may have other indifferent prices, and because the seller is forgoing the use of the item rather than thinking as a broker and considering other potential selling opportunities. We note that the term PISP did not involve any notion of a market price, gain, or any other price, except the one that represents our indifference to keeping an item or selling it at that price. This is an example of the type of precision we would like to have in distinctions we create and use in our discussion.

4.2 LEGO-LIKE PRECISION

We shall develop the concepts and language of decision making following the design principles of Legos. Building an easily assembled and durable Lego model requires precisely made components. We shall define our decision components precisely so that they will easily fit together, and yet form a structure of thought that can support the challenges it may face.

A Story by Ron Howard

In the 1960's I made a consulting trip to the Netherlands. One day I spotted in a toy store a set of colorful plastic blocks in a wooden case. They could be snapped together to make many toys. I brought the box home to my children and they became some of the first kids in the United States to play with "Legos." When I was a child, I played with Erector sets and Tinker toys. Why not Legos? Plastics existed back then. I considered the performance requirements: The blocks must be easy for a child to snap together, and yet they must adhere well enough that the wings of "airplanes" do not readily fall off. The answer is the later development of "precision plastic molding," for the performance requirements dictate that the dimensions of the blocks must be precise enough for a structure to hold together (Figure 4.1).

4.3 PRECISE DECISION LANGUAGE

There are several considerations in the design of a precise decision language. The foremost is that it be a language for both learning and practicing decision analysis. To be truly precise, decision language should be plain, familiar, and fundamental.

4.3.1 Simple Speaking

Words should be **simple**—that is, they should say what they mean. As Seneca famously states, "When the words are clear, the mind will be also." The reverse is also true.

Terms that we shall avoid are **expectation** or **expected value**. In probability class, the expectation of an uncertain deal that may produce different amounts of money with different probabilities is computed by multiplying each possible dollar amount received by the probability of receiving it, and then summing over all the possible outcomes. For example, in our demonstration, Sally had a 0.5 probability of calling the medallion toss correctly and thereby receiving \$100. A student in probability class would compute the expectation or expected value of the deal to be $0.5 \times 100 + 0.5 \times 0$ or \$50. However, Mary will receive either \$100 or nothing. One thing she can be sure of is that she will not receive \$50, the expected value. How strange it is to say that something is expected when it cannot happen. Yet that is a commonly used terminology, and one that contributes to confusion rather than to clarity.

Therefore, the term "expected value" has a misunderstanding built into it—a misunderstanding that analysts avoid only by their education. According to a popular teaching maxim, "The expected value is seldom expected." We shall have more to say on this topic in later chapters.



FIGURE 4.1 Precision Plastic Molding
(Adriana Berned/Getty Images)

4.3.2 Familiar Speaking

Not only should words be simple, but they should also be **familiar**. Whether you are in a boardroom or on a construction site, your discussions should involve words that people can easily recognize. Words that are strange or overly technical will interrupt the flow of communication, and should be avoided in the context of a precise decision language.

For example, the word "stochastic" often appears in technical conversation as a substitute for the word "probabilistic"—a word that is much more familiar to most of

us. To further complicate matters, the dictionary offers several definitions for stochastic, the first of which is “of, relating to, or characterized by conjecture; conjectural¹.” We doubt anyone would want a client to use this meaning. Whenever possible, try to stick to the words that are most widely recognized and the most easily understood.

4.3.3 Fundamental Speaking

To eliminate any potential confusion, decision language should also be **fundamental**—that is, it should use a limited number of precisely defined words. The language should be rich enough to describe any decision situation, but limited enough that two different people discussing the same situation would have virtually the same description. For example, a doctor was overheard telling one of his patients “there is some kind of a chance of a likelihood of a bad result.” The precise decision language translation is clear and to the point: “There is a probability of a bad result.”

When describing uncertainty, there is no reason to become fuzzy or verbose. When we conduct the conversation about a decision problem in precise decision language, rather than excessive language, our message becomes much stronger.

4.4 EXPERTS AND DISTINCTIONS

Now we have discussed what we mean by precise language, let us explore the meaning of **expertise**. What distinguishes an expert from a non-expert? In practice, we find that an essential characteristic of an expert is the ability to make and use powerful distinctions about a subject that are beyond the knowledge of non-experts.

The following examples will demonstrate this assertion. Suppose your car was not running right and you took it to an auto mechanic. He opens the hood and exclaims, “There’s a lot of metal and wires in there!” How do you evaluate the mechanic’s expertise? You would likely say to yourself, “Even *I* knew that! How can this person possibly help me?” Very likely, you would begin searching for a different mechanic to fix your problem.

For another example, imagine you are facing brain surgery, and you are meeting the surgeon to discuss the procedure. You ask, “Doctor, exactly what are you going to do to me?” The surgeon replies, “You know that gray, goopy stuff in your head? I am going to take some of it out.” How do you feel? If someone is going to operate on your head, you want that person to have long Latin names for everything that is supposed to be inside your skull, and other long Latin names for everything that is not. Furthermore, you want that person to have the skill to remove the latter while doing as little damage as possible to the former.

To illustrate the nature of expert distinctions, let us examine a few paragraphs from the book *The Silence of the Lambs* by Thomas Harris. This novel and its movie spinoff describe the efforts of an FBI agent, Officer Starling, who is trying to solve a series of murders. The corpse of one of the victims is found with an insect in its mouth. To learn more about the insect, Officer Starling consults two entomologists, Pilcher and Rosen.

Excerpts from their conversation appear below, in italics, interspersed with comments relevant to our discussion on distinctions.²

¹<http://www.thefreedictionary.com/Stochastics>

²From SILENCE OF THE LAMBS © 1989 by Thomas Harris. Reprinted by permission of St. Martin’s Press. All Rights Reserved.

From: *The Silence of the Lambs*

The insect was long and it looked like a mummy. It was sheathed in a emitransparent cover that followed its general outlines like a sarcophagus. The appendages were bound so tightly against the body, they might have been carved in low relief. The little face looked wise.

- I:** Up to this point, the discussion uses only terminology that would be familiar to almost everyone.

"In the first place; it's not anything that would normally infest a body outdoors and it wouldn't be in the water except by accident," Pilcher said. "I don't know how familiar you are with insects or how much you want to hear."

- I:** Now the entomologist is asking just how far Officer Starling wants to get into a technical discussion. She tells him:

"Let's say I don't know diddly. I want you to tell me the whole thing."

"Okay, this is a pupa, an immature insect, in a chrysalis—that's the cocoon that holds it while it transforms itself from a larva into an adult."

- I:** Now the discussion has reached the level of high school biology.

"Obtect pupa, Pilch?" Roden wrinkled his nose to hold his glasses up.

- I:** Welcome to the realm of the expert.

"Yeah, I think so. You want to pull down Chu on the immature insects? Okay, this is the pupal stage of a large insect. Most of the more advanced insects have a pupal stage. A lot of them spend the winter this way."

"Book or look, Pilch?" Roden said.

"I'll look." Pilcher moved the specimen to the stage of a microscope and hunched over it with a dental probe in his hand. "Here we go: No distinct respiratory organs on the dorsocephalic region, spiracles on the mesothorax and some abdominals; let's start with that."

"Ummhumm," Roden said, turning pages in a small manual. "Functional mandibles?"

"Nope."

"Paired galeae of maxillae on the ventromeson?"

"Yep, yep."

"Where are the antennae?"

"Adjacent to the mesal margin of the wings. Two pairs of wings, the inside pair are completely covered up. Only the bottom three abdominal segments are free. Little pointy cremaster—I'd say Lepidoptera."

- I:** Later, the discussion continues:

"What about pilifers?"

"No pilifers," Pilcher said. "Would you turn out the light, Officer Starling?"

What, then, are the characteristics of experts? The first and most important one is that they understand powerful distinctions about the subject of interest. This understanding is not merely

knowledge of subject itself, but also knowledge of the most significant distinctions and how those distinctions relate to one another.

A true expert will also have humility based on the awareness of the limits of present knowledge. For example, we once met a combustion expert at the Jet Propulsion Laboratory: An actual rocket scientist. At the end of our conversation, he pulled a book of matches from his pocket and lit one, saying, “It works every time, and yet we don’t know why.” His knowledge of what we were seeing exceeded that of anyone in the room, or maybe anyone in the city, yet he acknowledged its limitations.

True experts usually have other characteristics as well. One is knowledge of the history of the field, and an understanding of how it arrived at its present state of development. The expert will usually know about any wrong directions the field may have taken, as well as any true progress it has made to date.

Sometimes the expert must have physical skill—for example, if the expert is an auto mechanic or a surgeon. However, physical skill is not always necessary. Even a completely paralyzed internist could be an extremely competent diagnostician.

Now that we know what it means to be an expert, we can refine our knowledge of what it means to be an expert in decision analysis. The expert decision analyst must understand powerful distinctions about decision making that transcend the knowledge of lay people. We have already discussed many of these, such as the distinction between decision and outcome, and the value of clairvoyance. Our task now is to develop a set of powerful distinctions complete enough to achieve clarity of action in any decision problem. We call this process characterization of a decision situation and will discuss it further in the next chapter. First, let’s consider another question: What is mastery?

4.5 MASTERY

A master is the ultimate expert. Note that mastery does not reside in the tools of the master. To illustrate, if you require an emergency appendectomy, and faced only these choices, which would you prefer?

- To be operated on in the back of your car by a skilled surgeon using a penknife, needle, and thread.
- To be operated on in the surgeon’s state-of-the-art operating room by your favorite actor.

The choice for us is clear, and so we were not surprised to see a recent news story: A woman involved in what appeared to be a minor traffic accident boarded a plane in Hong Kong directly bound for London. After a few hours of flight, she suddenly had great trouble breathing. A surgeon flying as a passenger knew at once that she had a collapsed lung and was in mortal danger. With no hospital nearby, the surgeon decided to operate on the spot. He used a scalpel from the plane’s emergency kit, sterilized it with brandy, cut into her chest wall, and inserted a shunt made from a section of emergency oxygen mask tubing stiffened with a piece of coat hanger wire. When the plane arrived in London, doctors said his quick and skillful action had saved her life and that she would have a quick and complete recovery.

So, what is **mastery** of a field? We suggest five characteristics:

1. The master understands powerful distinctions about the field, and understands the importance of each.
2. The master sees and appreciates the relationships among these distinctions.

3. If mastery requires physical action in the world, the master possesses the skills and abilities to carry out that action, whether the master is a surgeon, mechanic, or violinist.
4. The master typically possesses a *deep* and *broad* knowledge of the setting of the field—its history, its relation to other fields, and the roles of major contributors. For example, a master mechanic would tell you where the field of a mechanic ends and the field of a master of auto body repair begins.
5. Most fundamentally, the master exhibits a humble awareness of the limits of present knowledge and an associated commitment to perpetual learning.

4.6 CREATING YOUR OWN DISTINCTIONS

We have presented several distinctions and illustrated how they lead to clarity of thought in a decision. When analyzing a given decision, you will also create your own distinctions. Once you create them, you will also need to make sure that they are clear and that everybody involved in the decision situation is aware of their precise meaning. In the next chapter, we will discuss this process of creating distinctions for a given decision situation in greater detail.

4.7 FOOTNOTE

We learned the importance of distinction from George Spencer Brown in his book, *Laws of Form*. There are now many websites discussing this work, including one by Randall Whitaker³, who notes: “In his 1979 book *Principles of Biological Autonomy*, Varela intensively explored (and elaborated upon) the British logician George Spencer Brown’s ‘calculus of indications.’ Spencer Brown’s *Laws of Form* (1969) outlines a complete and consistent logic based on ‘distinctions,’ which Maturana and Varela identify as “the elementary cognitive act.”

4.8 SUMMARY

A precise decision language is a powerful tool for thinking clearly about decision making. Although some of the terminology you encounter may seem subtle and academic, this terminology was created based on decades of experience in the teaching and practice of decision analysis. It has proven its value over time by helping decision makers avoid common decision mistakes. Throughout the rest of this book, you will have an opportunity to see for yourself the confusion that results from common but misleading decision terminology and how a precise decision language, once mastered, quickly clears up these confusions in thinking.

KEY TERMS

- Expectation
- Expected value
- Simple speaking
- Familiar speaking
- Fundamental speaking
- Expertise
- Mastery
- Distinctions

³Whitaker quotation: “In his 1979 book *Principles of Biological Autonomy*, Varela...as “the elementary cognitive act.”, Dr. Randall Whitaker. Reprinted with permission.

PROBLEMS

Problems marked with an asterisk (*) are considered more challenging.

1. Think about any misunderstandings you may have had due to imprecise language use.
2. Think of some conversations you have had with people you believe are experts in their field. Recall some of the distinctions they used, and the types of conversations that led you to believe they were experts.
- *3. List the five characteristics of mastery. Can you think of other characteristics to add to the list?