# CHAPTER 1
# Introduction to Decision Analysis

**Notes**

This chapter serves as an introduction to the book and the course. It sets the tone and presents the basic approach that will be used. The ideas of subjective judgment and modeling are stressed. Also, we mention some basic aspects of decisions: uncertainty, preferences, decision structure, and sensitivity analysis.

In teaching decision analysis courses, it is critical to distinguish at the outset between good decisions and good outcomes. Improving decisions mostly means improving the decision-making process. Students should make decisions with their eyes open, having carefully considered the important issues at hand. This is not to say that a good decision analysis foresees every possible outcome; indeed, many possible outcomes are so unlikely that they may have no bearing whatsoever on the decision to be made. Often it is helpful to imagine yourself in the future, looking back at your decision now. Will you be able to say, regardless of the outcome: "Given everything I knew at the time — and I did a pretty good job of digging out the important issues — I made the appropriate decision. If I were put back in the same situation, I would go through the process pretty much in the same way and would probably make the same decision." If your decision making lets you say this, then you are making good decisions. The issue is not whether you can foresee some unusual outcome that really is unforeseen, even by the experts. The issue is whether you carefully consider the aspects of the decision that are important and meaningful to you.

Chapter 1 emphasizes a modeling approach and the idea of a requisite model. If the notion of a requisite model seems a bit slippery, useful references are the articles by Phillips. (Specific references can be found in *Making Hard Decisions with DecisionTools.*) The concept is simple: A decision model is requisite if it incorporates all of the essential elements of the decision situation. The cyclical process of modeling, solution, sensitivity analysis, and then modeling again, provides the mechanism for identifying areas that require more elaboration in the model and portions where no more modeling is needed (or even where certain aspects can be ignored altogether). After going through the decision analysis cycle a few times, the model should provide a reasonable representation of the situation and should provide insight regarding the situation and available options. Note that the process, being a human one, is not guaranteed to converge in any technical sense. Convergence to a requisite model must arise from 1) technical modeling expertise on the part of the analyst, and 2) desire on the part of the decision maker to avoid the cognitive dissonance associated with an incomplete or inappropriate model.

Also important is that the modeling approach presented throughout the book emphasizes value-focused thinking (Keeney, 1992), especially the notion that values should be considered at the earliest phases of the decision-making process. This concept is initially introduced on pages 5-6.

To show that that decision analysis really is used very broadly, we have included the section "Where is Decision Analysis Used?" Two references are given. The *Harvard Business Review* article by Ulvila and Brown is particularly useful for students to read any time during the course to get a feel for real-world applications of decision analysis.

Finally, we have included the section "Where Does the Software Fit In?" to introduce the DecisionTools suite of programs.

**Topical cross-reference for problems**

| | |
|---|---|
| Constructionist view | 1.12,Du Pont and Chlorofluorocarbons |
| Creativity | 1.8 |
| Rice football | 1.7 |
| Requisite models | 1.2 |
| Subjective judgments | 1.3, 1.5 |

**Solutions**

**1.1.** Answers will be based on personal experience. It is important here to be sure the distinction is made between good decisions on one hand (or a good decision-making process) and lucky outcomes on the other.

**1.2.** We will have models to represent the decision structure as well as uncertainty and preferences. The whole point of using models is to create simplifications of the real world in such a way that analysis of the model yields insight regarding the real-world situation. A requisite model is one that includes all essential elements of the problem. Alternatively, a requisite model is one which, when subjected to sensitivity analysis, yields no new intuitions. Not only are all essential elements included, but also all extraneous elements are excluded.

**1.3.** Subjective judgments will play large roles in the modeling of uncertainty and preferences. Essentially we will build representations of personal beliefs (probabilities) and preferences (utilities). In a more subtle — and perhaps more important — way, subjective judgments also direct the modeling process. Subjective judgments are necessary for determining the appropriateness of a model's structure, what should be included in the model, and so on. Thus, subjective judgments play central roles in decision analysis. Good decision analysis cannot be done without subjective judgments.

**1.4.** An appropriate answer would be that decision analysis can improve your decisions — the way you make decisions — by providing a framework for dealing with difficult decisions in a systematic way. Along with the analytical framework, decision analysis provides a set of tools for constructing and analyzing decision models, the purpose of which is to obtain insight regarding difficult decision problems.

**1.5.** You require her subjective judgments on a number of matters. First is the problem of identifying important aspects of the problem. Her input also will be required for the development of models of her uncertainty and her preferences. Thus, her judgments will be critical to the analysis.

This question may also lead students to consider the implications of delegating decisions to agents. How can you ensure that the agent will see things the way you do? Will the same aspects of the problem be important? Does the agent agree with you regarding the uncertainty inherent in the situation (which outcomes are more or less likely)? Does the agent have the same feeling regarding trade-offs that must be made? In many cases it may be appropriate to obtain and use an expert's information. Can you identify some specific decision situations where you would be willing to accept an agent's recommendation? Does it matter who the agent is? Can you identify other situations in which some of the agent's input can be taken at face value (a forecast, say), but must be incorporated into a model based primarily on your own judgments?

**1.6.** Answers will be based on personal experience.

**1.7.** Some of the issues are 1) the monetary costs of staying in Division 1-A and of moving to Division III, 2) impact on both alumni and local businesses of moving to Division III, 3) political and social impact on campus of changing divisions.

Alternatives include 1) stay in Division 1-A, 2) move to Division III, 3) move to Division II, 4) delay the decision for a year or more to gather information, 5) investigate other sources of funding to cover the deficit, 6) drop out from the NCAA altogether ...

There is considerable uncertainty around the impact on the school of switching divisions. What will the fallout be from the faculty, students, alumni, and local businesses if Rice went to Division III? Will it impact recruiting? If so, how? What are the financial consequences? Is the deficit due to mismanagement or is it structural? What are the long-term consequences versus the immediate uproar? Sources of information could be surveys given to each constituency and/or interviews with leaders of the constituencies. Perhaps other schools have changed divisions, and information can be found from their experience.

The objectives that different groups want to work toward include 1) minimize short-term and long-term deficit, 2) minimize social upheaval, 3) maximize enjoyment of collegiate sports, 4) maximize student opportunity to participate in sports, 5) maximize quality of sports programs. Some students may identify still other objectives. Trading off these objectives may mean trying to balance the issues that are important to different constituent groups.

**1.8.** This is a creativity question. The Friends of Rice Athletics could fund raise, tuition and/or ticket prices could be increased, the stadium's name can be sold, the athletic staff could all take a pay cut, etc.

**1.9.** Answers will be based on personal experience.

**1.10.** Instead of thinking only about risk versus return, the socially responsible investor also must consider how to trade off risk and return for ethical integrity. It would not be unreasonable to suspect that to obtain a higher level of ethical integrity in the portfolio, the investor must accept a lower expected return, higher level of risk, or both.

**1.11.** For the most part, decision analysis is most appropriate for strategic, or one-time, decisions. These are situations that we have not thought about before and "don't know what to do." Hence, it is worthwhile to engage in some "decision making," or decision analysis, to figure out what would be an appropriate action.

This is not to say that decision analysis is inappropriate for repetitive decisions. In fact, if a decision is repeated many times, the savings that can be achieved over time by improving the decision-making process can be substantial. In fact, this is the basis of much of management science. However, the reliance on subjective judgments for the construction of tailored decision models in each decision situation may render decision analysis, as portrayed here, unsuitable for dealing with repetitive situations. The point, though, is that if one anticipates a long string of repetitive decisions in the future, and an optimal decision strategy has not been previously developed, then the situation is indeed one of "not knowing what to do." A decision-modeling approach would indeed be appropriate in that case.

**1.12.** Beliefs and values do appear to change and develop over time as we think about new issues. Decision analysis implicitly provides a framework for such changes through the identification and modeling of decision problems, beliefs regarding uncertainty, and preferences.

**Case Study: Commercial Space Travel**
A student's answer to being an early adopter or waiting until the industry matures is a personal choice and depends on many factors. Some of these are: track record of industry, affordability, health of student vis-à-vis demands of space travel, interest level, etc.

It certainly is true that new firms can come along and change an industry with leaner production or management systems. Often, these firms do not have to contend with the legacy of older systems in more established firms. In addition, the savings of a younger workforce and less established pension program can be quite significant. Thus, it is reasonable that the new furry animals can be competitive with a massive governmental organization.

On the other hand, the lack of experience of extreme situations might turn into a disaster for a newly established firm. The cost savings of the newer firms could come from more efficient operations or it could come from not having the equipment and policies in place to handle unusual situations. A space-flight disaster would make headlines across the world and probably doom the responsible for-profit company. To continue the survival-of-the-fittest analogy, it is not that every for-profit company will survive by avoiding life-threatening situations; it is that a subgroup will survive. Would you want to put your life or the life of a loved one on the line given the uncertainties surrounding early adopters in space travel?

**Case Study: Du Pont and Chlorofluorocarbons**
The major issues include shareholder welfare, social and environmental responsibility, and ethics. Of course, all of these might be thought of as means for ensuring the long-run profitability or survivability of the firm. The major sources of uncertainty involve research and development. Will substitute products work? Will they be accepted? The CEO might wonder whether the ozone problem really is a problem, or

whether the observed recent changes are part of a normal cycle. Finally, could Du Pont's efforts really have an effect, and how much?

It is undoubtedly the case that Du Pont's views of the situation have changed over time. Early on, the chlorofluorocarbon issue was essentially ignored; no one knew that a problem existed. In the 1970s and 1980s, it became apparent that a problem did exist, and as scientific evidence accumulated, the problem appeared to become more serious. Finally, we have arrived at a position where the ozone issue clearly matters. (In fact, it matters mostly because of consumers' views and preferences rather than because of the scientific evidence, which appears to be less than conclusive.) Du Pont appears to be asking "Can we do anything to help?" Many companies have developed a kind of "social awareness" in the past two decades as a way to maintain a high-integrity profile.

**Case Study: Choosing a Vice-Presidential Candidate**

A vice president tends not to have an important role in American politics except in gaining electoral votes during the election. A running mate is often chosen to balance the ticket geographically and ideologically. For example, choosing a conservative, women from Alaska helped McCain appeal to the conservative base of the Republican Party and to women. Alaska, however, has the minimum number of possible electoral votes at 3. While McCain could reasonably count on winning Alaska's 3 electoral votes, he could have chosen someone else from a more populous state for the electoral votes. McCain must have thought that Ms. Palin would provide a ticket with a wide appeal and that she could help pick up votes across the whole country.

It is hard to know how McCain's health affected his choice of Ms. Palin. Clearly, he knew how he felt, and given that he is still in office eight years later, it is reasonable to assume that his health was not a major concern when choosing Ms. Palin. A portion of the population, however, did find his age coupled with her inexperience troubling. If he personally was not concerned, he might at least have considered how the voters would perceive Ms. Palin being one heartbeat away from the presidency of the U.S.A.

The president is constantly gathering information, from the daily threat-assessment reports to meetings with his cabinet, congressional members, and world leaders. However, even with all of these intelligence reports, much uncertainty still remains, often requiring the president to make a judgment call. One of the more famous examples of this is President Obama's decision to send U.S. forces into Pakistan after Osama bin Laden. Although it was thought that bin Laden was hiding inside a residence, there was not definitive proof. Moreover, Obama also had to make judgment calls concerning the size of the force to send in and whether to alert Pakistani officials. Generally, the president's decisions are based (hopefully) on both facts and judgments. McCain's choice of Sarah Palin led many voters to question his judgment.

Choosing Sarah Palin might have turned out to be a very good choice for the United States, but it certainly had many political overtones. In all fairness, the choice of a vice-presidential running mate is a very political decision, one specially aimed at winning the election – a political event. On the other hand, appearances are of utmost importance in elections, and even an unsubstantiated rumor can completely derail a candidate. Thus, in choosing his running mate, McCain probably should have weighed the pros and cons of each candidate using his fundamental objectives, the fundamental objectives of his party, and, of course, the fundamental objectives of the United States as a whole.

# CHAPTER 2
# Elements of Decision Problems

**Notes**
This chapter is intended to start the reader thinking about decision problems in decision-analysis terms. Thus, we talk about decisions to make, uncertain events, and valuing consequences. To make sure that the richness of the terrain is understood, we introduce the concepts of dynamic decision making, a planning horizon, and trade-offs.

In our definition of terms, we refer to a decision maker's *objectives* where the term *values* is used to refer to the decision maker's set of objectives and their structure. The terms *decision* and *alternative* are adopted, and are used throughout the book rather than similar terms such as "choice" and "option." Likewise, we have adopted the term *uncertain event* (and sometimes *chance event*), which then has *outcomes*. Finally, and perhaps most significant, we have adopted Savage's term *consequence* to refer to what the decision maker experiences as a result of a combination of alternative(s) chosen and chance outcome(s). Another term that we use that comes from Keeney's value-focused thinking is the notion of *decision context*. This term is discussed in the text and still more thoroughly in Keeney's book. Briefly, it refers to the specific identification of the problem (from which we might suspect that when one solves the wrong problem, one has used the wrong decision context). It also can be used as a way to identify the class of alternatives that one is willing to consider; a broader context (safety in auto travel as compared to specific traffic laws, for example) leads a decision maker to consider a broader class of alternatives.

The time value of money appears in Chapter 2 and may seem out of place in some ways. It is here because it is a fundamental way that streams of cash flows are valued, and because it provides a nice example of a basic trade-off. Also, we have found that since most students have already been exposed to discounting, we have been able to incorporate NPV calculations into problems and case studies throughout the book. For the few students who have not encountered the topic, the early introduction to discounting in Chapter 2 provides enough information for them to proceed. Of course, the section on NPV may be skipped and used as a reference later for problems that require discounting or for the discussion of trade-offs in Chapter 15.

**Topical cross-reference for problems**

| | |
|---|---|
| Requisite models | 2.13 |
| "Secretary" problem | 2.6 |
| Sequential decisions | 2.2, 2.6, Early Bird, Inc. |
| Time value of money | 2.9-2.12, The Value of Patience |

**Solutions**
**2.1. a.** Some objectives might be to minimize cost, maximize safety, maximize comfort, maximize reliability, maximize cargo capacity (for shopping or vacationing), maximize maneuverability (in city traffic). Students will undoubtedly come up with others as well.

**b.** In this new context, appropriate objectives might be minimize travel time, maximize exercise, minimize total transportation cost, minimize use of fossil fuels, maximize ease (suitably defined) of visiting friends and shopping. New alternatives to consider include using a bicycle or public transportation, walking, rollerblading, skateboarding, motorcycle or scooter, renting a car, such as Zipcar. One might even consider moving in order to live in a more convenient location.

**2.2.** Future alternatives can affect the eventual value of the consequence. For example, a university faculty member, when accepting a position at a different institution, may not immediately resign his or her position at the first university. Instead, a leave of absence may be taken. The leave of absence provides the opportunity to decide in the future whether to stay at the new institution or return to the old one. A faculty member would most likely think about the two different situations — resigning the current position immediately versus taking a leave and postponing a permanent decision — in very different ways.

Another good example is purchasing a house. For many people in our mobile society, it is important to think about the potential for selling the house in the future. Many purchasers might buy an unusual house that suits them fine. However, if the house is too unusual, would-be purchasers might be afraid that, *if they decide to sell the house in the near future*, it may be difficult to find a buyer and the sales price might be lower than it would be for a more conventional house.

Finally, the current choice might eliminate a future valuable option. For example, our policy of powering cars with fossil fuels reduces our options for using oil for potentially more valuable and less destructive future activities.

**2.3.** In the first case, the planning horizon may be tied directly to the solution of the specific problem at hand. If the problem is an isolated one not expected to repeat, this is a reasonable horizon. If more similar problems are anticipated, the planning horizon might change to look forward in time far enough to anticipate future such situations. If the firm is considering hiring a permanent employee or training existing employees, then a planning horizon should be long enough to accommodate employee-related issues (training, reviews, career advancement, and so on). In this broader context, the firm must consider objectives related to hiring a new person (or training), which might include maximizing the welfare of current employees, minimizing long-term costs of dealing with the class of problems, satisfying affirmative-action requirements, or equity in treatment of employees.

**2.4.** In making any decision, it is important to 1) use all currently available information and 2) think carefully about future uncertainty. Thus it is necessary to keep track of exactly what information is available at each point in time. If information is lost or forgotten, then it will either be treated as an uncertainty or simply not used when deciding. Clearly, the farmer would want to keep up to date on the weather and incorporate any change to the forecast.

**2.5.** Some possibilities: insurance, hire another firm to manage the protection operation, press for regulatory decisions and evaluations (i.e., get public policy makers to do the necessary analysis), do nothing, develop a "cleanup cooperative" with other firms, or design and develop equipment that can serve a day-to-day purpose but be converted easily to cleanup equipment. Students may come up with a wide variety of ideas.

**2.6.** The employer should think about qualifications of the applicants. The qualifications that he seeks should be intimately related to what the employer wants to accomplish (objectives — e.g., increase market share) and hence to the way the successful applicant will be evaluated (attributes — e.g., sales). The planning horizon may be critical. Is the employer interested in long-term or short-term performance? The uncertainty that the employer faces, of course, is the uncertainty regarding the applicant's future performance on the specified attributes.

If the decision maker must decide whether to make a job offer at the end of each interview, then the problem becomes a dynamic one. That is, after each interview the decision maker must decide whether to make the offer (and end the search) or to continue the search for at least one more interview, at which time the same decision arises. In this version of the problem, the decision maker faces an added uncertainty: the qualifications of the applicants still to come. (This dynamic problem is sometimes known as the "Secretary Problem," and has been analyzed extensively and in many different forms in the operations-research literature. For example, see DeGroot (2004) *Optimal Statistical Decisions*, Hoboken, NJ: Wiley & Sons. P. 325.)

**2.7.** Decisions to make: How to invest current funds. Possible alternatives include do nothing, purchase specific properties, purchase options, etc. Other decisions might include how to finance the purchase, when to resell, how much rent to charge, and so on. Note that the situation is a dynamic one if we consider future investment opportunities that may be limited by current investments.

Uncertain events: Future market conditions (for resale or renting), occupancy rates, costs (management, maintenance, insurance), and rental income.

Possible outcomes: Most likely such an investor will be interested in future cash flows. Important trade-offs include time value of money and current versus future investment opportunities.

**2.8.** Answers depend on personal experience and will vary widely. Be sure to consider current and future decisions and uncertain events, the planning horizon, and important trade-offs.

**2.9.** NPV $= \frac{-2500}{1.13^0} + \frac{1500}{1.13^1} + \frac{1700}{1.13^2}$

$= -2500 + 1327.43 + 1331.35$

$= \$158.78.$

Or use Excel's function NPV:

=-2500+NPV(0.13,1500,1700) = $158.78

The Excel file, "Problem 2.9.xls" has the equation set-up as a reference to cells that contain the cash flows.

**2.10.** NPV $= \frac{-12000}{1.12} + \frac{5000}{1.12^2} + \frac{5000}{1.12^3} + \frac{-2000}{1.12^4} + \frac{6000}{1.12^5} + \frac{6000}{1.12^6}$

$= -10{,}714.29 + 3985.97 + 3558.90 - 1271.04 + 3404.56 + 3039.79$

$= \$2003.90$

Using Excel's NPV function:

=NPV(0.12,-12000,5000, 5000,-2000,6000,6000)
= $2,003.90

The internal rate of return (IRR) for this cash flow is approximately 19.2%.

The Excel file, "Problem 2.10.xls" has the equation set-up as a reference to cells that contain the cash flows.

**2.11.** If the annual rate = 10%, then the monthly (periodic) rate $r$ = 10% / 12 = 0.83%.

$$\text{NPV}(0.83\%) = -1000 + \frac{90}{1.0083} + \frac{90}{1.0083^2} + \ldots + \frac{90}{1.0083^{12}}$$

$= \$23.71.$

Or use Excel's NPV function, assume the 12 payments of $90 appear in cells B13:B24:

=-1000+NPV(0.1/12,B13:B24)= $23.71

(As shown in the Excel file "Problem 2.11.xls")

If the annual rate = 20%, then the monthly (periodic) rate $r$ = 20% / 12 = 1.67%.

$$\text{NPV}(1.67\%) = -1000 + \frac{90}{1.0167} + \frac{90}{1.0167^2} + \ldots + \frac{90}{1.0167^{12}} = \$\text{-}28.44.$$

Or use Excel's NPV function, assume the 12 payments of $90 appear in cells B13:B24:

=-1000+NPV(0.2/12,B13:B24)= $-28.44

(As shown in the Excel file "Problem 2.11.xls")

The annual interest rate (IRR) that gives NPV=0 is approximately 14.45%. You can verify this result by substituting 14.45% / 12 = 1.20% for *r* in the calculations above.

Or with Excel's IRR function, IRR(Values, Guess), assume the series of payments (the initial $1000 payment and the series of 12 payments of $90) are in cells B12:B24:
=IRR(B12:B24,0) = 1.20%

(As shown in the Excel file "Problem 2.11.xls")

**2.12. a.** If the annual rate = 10%, then the monthly rate *r* = 10%/12 = 0.83%. Always match the periodicity of the rate to that of the payments or cash flows.

$$\text{NPV(Terry)} = 600 + \frac{-55}{1.0083} + \frac{-55}{1.0083^2} + \ldots + \frac{-55}{1.0083^{12}}$$

$$= \$-25.60.$$

Be sure to get the orientation correct. For Terry, the loan is a positive cash flow, and the payments are negative cash flows (outflows). Thus, the NPV is negative. Because of the negative NPV, Terry should know that this deal is not in his favor and that the actual interest rate being charged is not 10% annually. If it were, then NPV should equal zero. The actual annual interest being charged must be greater than 10% as NPV is less than zero.

Or with Excel's NPV function, assume the series of 12 payments of $55 are in cells B12:B23.

=NPV(0.1/12,B12:B23)+600

= -$25.60

These calculations and those associated with the remaining parts of the question are shown in the Excel file "Problem 2.12.xls".

**b.** For the manager, the $600 loan is a negative cash flow, and the payments are positive cash flows. Hence,

$$\text{NPV(Mgr)} \quad = -600 + \frac{55}{1.0083} + \frac{55}{1.0083^2} + \ldots + \frac{55}{1.0083^{12}} \quad = \$25.60.$$

Or with Excel's NPV function, assume the series of 12 receipts of $55 are in cells B12:B23.

=NPV(0.1/12,B12:B23)-600

= $25.60

**c.** If the annual rate is 18%, then NPV is about $-0.08. In other words, the actual rate on this loan (the internal rate of return or IRR) is just under 18%.

Using Excel's IRR function, and assuming the cash flows are in cells B11:B23: