CHAPTER ONE

Introduction to Decision Analysis

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Nothing is more difficult, and therefore more precious, than to be able to decide.
—Napoleon, "Maxims," 1804

Handbook of Decision Analysis, First Edition. Gregory S. Parnell, Terry A. Bresnick, Steven N. Tani, and Eric R. Johnson.

1.1 Introduction

The consequences of our decisions directly affect our professional and personal lives. As Napoleon noted in our opening quote, decisions can be difficult, and making good decisions can be very valuable. Our focus is on professional decisions, but the same principles apply to our personal decisions.

We begin by defining a decision. Professor Ronald Howard of Stanford University defines a decision as an irrevocable allocation of resources (Howard, 1988). Consider the contracting process used by many companies and organizations. The company does not make a decision to buy a product or service when they begin thinking about the procurement. They make the decision when they sign a legally binding contract, which obligates them to provide resources (typically dollars) to the supplier of the product or service. Can they change their mind? Absolutely, but they may have to pay contract cancellation fees.

> A decision is an irrevocable allocation of resources.

Decisions are made by people vested with the authority and responsibility to make decisions for an organization or enterprise. Many decisions involve stakeholders who are individuals and organizations that could be affected by the future consequences of the decision. Some decisions are easy because few stakeholders are involved, the values are clear, good alternatives are readily identified, and there are few uncertainties. However, some difficult decisions involve many stakeholders with potentially conflicting objectives, complex alternatives, significant uncertainties, and large consequences. The discipline of decision analysis, the focus of this handbook, has been developed to help decision makers with these complex decisions.

There are many definitions of decision analysis. Howard, who coined the term "decision analysis" (Howard, 1966), defines decision analysis as "a body of knowledge and professional practice for the logical illumination of decision problems." In the first book on decision analysis, Howard Raiffa of Harvard University defined decision analysis as an approach that "prescribes how an individual faced with a problem of choice under uncertainty should go about

choosing a course of action that is consistent with personal basic judgments and preferences" (Raiffa, 1968). Ralph Keeney of Duke University (Keeney, 1982) provides an intuitive and a technical definition. Keeney's intuitive definition is "a formalization of common sense for decision problems that are too complex for informal use of common sense." His technical definition is "a philosophy, articulated by a set of logical axioms, and a methodology and collection of systematic procedures, based on those axioms, for responsibly analyzing the complexities inherent in decision problems." Professor Larry Phillips of the London School of Economics emphasizes that decision analysis is a socio-technical process to provide insights to decision makers in organizations (Phillips et al., 1990) and (Phillips, 2005). In a popular decision analysis textbook, Clemen and Reilly state that "decision analysis provides effective methods for organizing a problem into a structure that can be analyzed. In particular, elements of a decision's structure include the possible courses of action, the possible outcomes that could result, the likelihood of those outcomes, and eventual consequences (e.g., costs and benefits) to be derived from the different outcomes" (Clemen & Reilly, 2001). We will use the following definition of decision analysis:

> Decision analysis is a philosophy and a social-technical process to create value for decision makers and stakeholders facing difficult decisions involving multiple stakeholders, multiple (possibly conflicting) objectives, complex alternatives, important uncertainties, and significant consequences. Decision analysis is founded on an axiomatic decision theory and uses insights from the study of decision making.

In decision analysis, we distinguish between a good decision and a good outcome. A good decision is one that is logically consistent with our preferences for the potential outcomes, our alternatives, and our assessment of the uncertainties. A good outcome is the occurrence of a favorable event—one that we like. We believe that consistently making good decisions will lead to more good outcomes than otherwise. However, since there is uncertainty, even a good decision process may not always lead to a good outcome. Of course, a bad decision does not always result in a bad outcome—sometimes we can be lucky and obtain a good outcome. Unfortunately, we cannot count on being lucky.

The purpose of our handbook is to describe the best practices that decision analysts have found the most useful in helping decision makers make good decisions when faced with difficult and important choices. Since many individuals and social organizations are involved in complex decisions, to be successful, decision analysis must use a socio-technical process to help those individuals and organizations make decisions. Socially, the purpose of decision analysis is to provide credible, understandable, and timely insights to decision makers and key stakeholders in organizations. Technically, decision analysis is an operations research/management science discipline that uses probability, value, and utility

theory (see Chapter 3) to analyze complex alternatives, under significant uncertainty, to provide value for stakeholders with multiple (and possibly conflicting) objectives. Since it relies on the reasonable axioms of choice (Chapter 3), decision analysis identifies decisions that are logically consistent with our preferences, our alternatives, and our assessment of the uncertainties.

This chapter introduces the field of decision analysis and defines some of the key terms that we use in the handbook. The chapter is organized as follows. Section 1.2 further describes decision analysis as a socio-technical process. We introduce the decision analysis process that we use in the handbook and use the process to list the key technical concepts and techniques and the soft skills necessary to help organizations create potential value for themselves and their stakeholders. Section 1.3 emphasizes that decision analysis has many significant applications and compares three important application areas: oil and gas, pharmaceuticals, and defense. We also briefly describe four decision analysis success stories. Section 1.4 defines the decision professional, discusses the education and training of decision professionals, identifies some of their major professional societies, and describes some of their professional service activities. Section 1.5 provides an overview of the handbook and introduces the three substantive illustrative examples used in the handbook. Section 1.6 provides a summary of the key ideas in the chapter.

1.2 Decision Analysis Is a Socio-Technical Process

An effective decision analyst must understand the challenges of decision making in organizations, the mathematical foundations of decision analysis, and the soft skills required to work with decision makers, stakeholders, and experts to perform a decision analysis. In this section, we describe the decision analysis process used in the handbook and use that process (and our experience) to identify the critical soft skills that are essential for the successful use of decision analysis.

There are several decision processes (see Chapter 6) that have been used by decision analysts to integrate the contributions of decision makers (DMs), stakeholders[1] (SH), subject matter experts (SMEs), and decision analysts to reach a good decision. Figure 1.1 shows the decision analysis process that we use to organize the handbook. The decision frame is how we view the decision opportunity. At the center of the figure is a reminder that our purpose is to use best practices to create value for DMs and SH. The steps in the process are shown as 10 boxes around the center. Although sequential arrows are used in the figure, the process is iterative. The order of the steps should be tailored to the application and some steps may not apply. For example, if the decision is a choice of the best alternative, the portfolio resource allocation chapter would not apply. Also, some steps can be combined. For example, the decision framing and crafting of the decision objectives may be done at the same time. In addition, some

[1]For the purpose of this chapter, "stakeholders" refers to all interested and affected individuals besides the DM(s) and SMEs. We will use SH instead of SHs for simplicity.

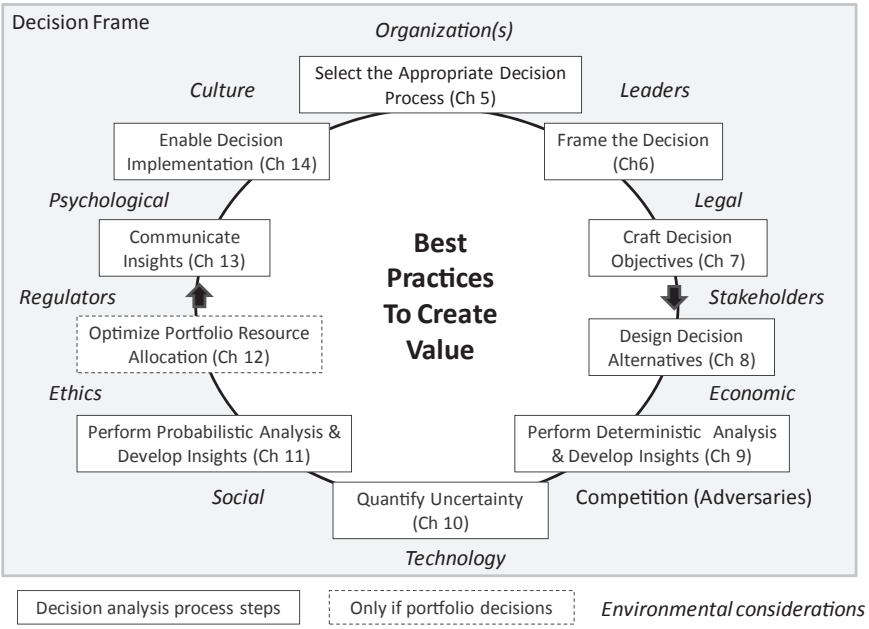

FIGURE 1.1 **Decision analysis process.**

steps may not be required in a particular application. Twelve environmental factors are placed in the decision frame of Figure 1.1, but outside the decision analysis process cycle to highlight the important considerations that apply in many of the steps of the decision analysis process. The location of a factor is not necessarily an indication of alignment with a particular step in the process. The 12 factors are meant to be illustrative and not all inclusive.

Next, we use this decision analysis process to identify the decision analysis technical products and soft skills that are essential for the decision professional. We identify these skills in Table 1.1 with steps in the process. Soft skills include personal and interpersonal skills.

Based on our experience and the above analysis, we aggregate the soft skills into the following nine categories.

- **Thinking strategically** about the client organization, the problem domain, and the role of the decision analysis in achieving the current strategy or, when appropriate, developing a new strategy, and new decision opportunities
- **Leading teams**, including developing team goals, motivating individuals to achieve team goals, and guiding the client organization to achieve the most value from the study
- **Managing decision analysis projects**, including developing analysis plans; identifying and scheduling activities; and managing the completion of tasks

TABLE 1.1 List of Technical Products and Soft Skills

Steps	Engagements	Technical Products	Soft Skills
Select the appropriate decision process (Chapter 5)	DM, SH	Decision process diagram	Strategic thinking Lead teams Manage teams
Fame the decision (Chapter 6)	DM, SH, SME	Vision statement Decision hierarchy Issue identification matrix Qualitative influence diagram Study schedule	Strategic thinking Lead teams Manage teams Research problem domain Interview DM & SH Facilitate group sessions Communicate insights
Craft decision objectives (Chapter 7)	DM, SH	Objectives hierarchy Functional value hierarchy	Strategic thinking Interview DM, SH Survey SH, SMEs Facilitate group sessions Communicate insights Aggregating expertise
Design decision alternatives (Chapter 8)	SME, SH, DM	Strategy generation table Strategic alternatives Real options Means ends network	Strategic thinking Use individual and group creativity techniques Research problem domain
Perform deterministic analysis and develop insights (Chapter 9)	SME, SH, DM	Deterministic influence diagram Quantitative deterministic value models (NPV and multiple objective models) Swing weight matrix Value components Value over time Value by business unit Waterfall chart Direct and delta tornado diagrams Sensitivity analysis Cost vs. value chart	Research data Interview SME to develop model structure Aggregating expertise Facilitate group sessions to develop model structure Elicit value curves Elicit swing weights Assess alternative scores Communicate insights
Quantify uncertainty (Chapter 10)	SME, SH, DM	Influence diagram Probability assessments of uncertain variables	Elicit probabilistic relationships Aggregating expertise Elicit probability distributions

TABLE 1.1 (*Continued*)

Steps	Engagements	Technical Products	Soft Skills
Perform probabilistic analysis and develop insights (Chapter 11)	SME, SH, DM	Decision tree Monte Carlo simulation Net present value distribution Dominance analysis Value component chart Direct and delta tornado chart Perform sensitivity analysis Value over time Value by business unit Risk preference Utility	Strategic thinking Elicit risk preference Use individual and group creativity techniques to reduce risk and increase value
Portfolio resource allocation (Chapter 12)	DM, SH, SME	Portfolio constraints Portfolio model Efficient frontier Football chart	Strategic thinking Manage teams Interview DM, SH, SME to identify constraints Facilitate group session(s) to develop value model and evaluate alternatives Communicate insights
Communicate insights (Chapter 13)	SH, DM	Communication objectives Analysis story Key insights Executive summary Presentation(s) Technical report(s)	Develop the story and key insights Present analytical results Communicate to DM, SH
Enable decision implementation (Chapter 14)	SH, DM, SME	Implementation schedule Implementation success measures Implementation risks and risk mitigation plan	Manage teams Interview DM, SH Facilitate group sessions to identify success measures and risks

- **Researching the problem domain, modeling approaches, and data sources**
- **Interviewing individuals** (DMs, SH, and SMEs) to frame the decision problem and obtain modeling information
  - Interact with senior leaders and SMEs (listening, learning, and discovery)
  - Elicit knowledge (preferences [value, time, and risk], probabilities, and alternatives)
- **Surveying stakeholders and experts** can be a efficient way to collect knowledge for geographically dispersed individuals
- **Facilitating groups** of DMs, SH, and SMEs to frame the decision problem and obtain modeling information (also includes focus groups)
  - Frame decision opportunity (initial and updated)
  - Elicit knowledge (preferences [value, time, and risk], probabilities, and alternative)
  - Use individual and group creativity techniques (values, sources of risk, strategy design, strategy improvement) to generate better alternatives
- **Aggregating expertise** is needed to combine different views of SHs and SMEs
- **Communicating with DMs, SH, and SMEs** (see Chapter 13).
  - Communicate the story, analytic results, and the key insights in ways that are understandable to the audience.

In the subsequent chapters, we present in more detail both the technical skills and the soft skills that are essential to decision analysis.

1.3 Decision Analysis Applications

Decision analysis has been used in many important corporate and public applications. These decision analysis applications typically have four features in common: difficult decisions, multiple (possibly conflicting) objectives of SH, significant uncertainties, and important consequences. One of the first compendiums of decision analysis applications was published in 1983 (Howard & Matheson, 1983). In addition to applications, this two-volume set also includes some important early foundational technical articles on decision analysis. Two more recent applications summaries are Corner and Kirkwood (1991) and Keefer et al. (2004). These two papers list several published applications in a wide variety of problem domains. These applications summaries greatly underestimate the number of applications since practitioners generally do not publish their work due to the confidentiality of the results, the lack of time for writing publications, and lack of incentives for publication.

Three important enduring areas of decision analysis applications have been oil and gas, pharmaceuticals, and military.[2] Table 1.2 (modified from Burk & Parnell [2011]) compares these three significant decision analysis application areas using several factors: organizational objectives, key SH, major environmental uncertainties, technological development uncertainties, schedule uncertainties, cost uncertainties, operating environment, strategic partnerships, intraorganizational resource competition, and decision reviews. The primary organizational objective of private firms (e.g., oil and gas and pharmaceuticals) is to increase shareholder value, while public organizations (e.g., military) provide products and services that are not easily measured in terms of dollars. The three examples illustrate the difficulty of decisions, the conflicting preferences of SH, and the major uncertainties.

All three domains have a significant number of private and public SH with complex and, many times, conflicting objectives. Clearly, each application area has a significant number of environmental, technical, schedule, and cost uncertainties. The operating environments and adversaries are different. Finally, the resource competition and decision review processes are significantly different for public and private problem domains.

There are many decision analysis success stories. Next, we describe decision analysis success stories in each of the three major application areas.

1.3.1 OIL AND GAS DECISION ANALYSIS SUCCESS STORY: CHEVRON

Over the past 20 years, Chevron has used decision analysis for its major decisions (Menke et al., 2011). The Chevron Vice Chairman, George Kirkland, summarizes the use of decision analysis to create value and manage risk on over 40 projects with investments of over $1B.[3] According to Mr. Kirkland, Chevron "uses decision analysis because it works." Chevron's Larry Neal estimated the benefit of decision analysis as $100B over 10 years, and highlighted the additional benefits of decision framing (see Chapter 6) and improvements in thinking.[4] Chevron's Frank Koch noted the added confidence decision analysis gives DMs to pursue projects and accept risk (see Chapters 11 and 12). In addition, Koch stated that the marginal cost of doing decision analysis is small and the cost of training and learning software is significantly outweighed by the benefits.[5]

> Chevron uses decision analysis because it works.

[2]Perhaps not surprisingly, the authors have worked in these application areas.

[3]http://www.youtube.com/chevron#p/u/12/JRCxZA6ay3M, recorded December 1, 2010.

[4]http://www.blip.tv/file/4567268

[5]Op. cit.

TABLE 1.2 Comparison of Three Decision Analysis Application Areas

Factor	Oil and Gas	Pharmaceuticals	Military
Illustrative organizational objectives	Increase shareholder value Provide energy for the nation and energy consumers Protect the environment	Increase shareholder value Improve health and quality of life of patients Minimize potential side effects	Provide defense capabilities for the national command authority to achieve national objectives Minimize causalities if a conflict occurs Reduce collateral damage during a conflict Be cost-effective
Key stakeholders	Board of directors Shareholders Government regulators Environmental groups Nation where resources are located Energy distributors and retailers Consumers Employees	Board of directors Shareholders Current and future patients Health care providers Government regulators Employees	Citizens Department of Defense Congress Federal budget organizations Defense contractors Military, civilian, and contractor employees International security groups Allies
Environmental uncertainties	Existence and quantity of resources at particular locations Actions of competitors Actions of governments Actions of environment groups	Causes of diseases Efficacy of competitor and company's drugs Prevalence of future diseases	Future national, regional, and terrorist threats to national interests Economic resources devoted to defense Political constraints on military actions
Technology development uncertainties	Effectiveness and efficiency of location, extraction, and processing technologies Impact of operations and products on the environment	Efficacy of drugs Unwanted side effects of new drugs	Technology readiness to develop and produce future systems R&D test failures in potential operational environments Battlefield conditions impact on weapons systems
Schedule uncertainties	Local, state, national, and international approvals to extract and operational restrictions	Success of trials National and international regulatory approvals	Testing success Acquisition approvals Congressional funding authorizations

TABLE 1.2 (*Continued*)

Factor	Oil and Gas	Pharmaceuticals	Military
Cost uncertainties	Drilling rig availability, technology development problems, environmental protection requirements, and schedule slips	Size of clinical trials required	Changes by adversaries, immature technologies, and schedule changes
Operating Environment	Natural environment Competition	Pharmaceutical laboratories Human body Competition	Hostile natural and adversarial environment
Strategic partnerships	Mergers and acquisitions	Mergers and acquisitions	Foreign military sales to offset costs and support international security objectives Joint deterrence activities
Intra-organizational resource competition	Divisions Other corporate programs	Divisions Other corporate programs	Services and defense agencies Other government programs
Decision reviews	Corporate Board of directors	Corporate Board of directors	Military hierarchy, defense agency, Department of Defense, Office of Management of Budget, Congress

1.3.2 PHARMACEUTICAL DECISION ANALYSIS SUCCESS STORY: SMITHKLINE BEECHAM

Research and development decisions are the lifeblood of any pharmaceutical company. SmithKline Beecham (now GlaxoSmithKline) used decision analysis to make better resource allocation decisions (Sharpe & Keelin, 1998; Menke et al., 2011). SmithKline Beecham selected decision analysis because it was technically sound and organizationally credible. In their article, Sharpe and Keelin describe the benefits of decision analysis as follows:

> The new process not only reduced the controversy in the resource allocation process, it also led the company to change its investment strategy. Although top management had set out to cut back on the company's development budget, they now saw their investment decision in a new light; they believed the new portfolio to be 30% more valuable ($2.6B) than the old one without any additional investment. Furthermore, the marginal return on additional investment had tripled from 5:1 to

15:1. To exploit this opportunity, the company ultimately decided to increase development spending by more than 50%.

The results of this analysis were a dramatic increase in shareholder value.

1.3.3 MILITARY DECISION ANALYSIS SUCCESS STORIES

Public organizations use multiple objective decision analysis to evaluate the stakeholder value of alternatives and make defensible decisions.

1.3.3.1 U.S. Army Installations. In 2001, Congress enacted legislation that required a 2005 Base Realignment and Closure (BRAC) round to realign military units, remove excess facility capacity, and support defense transformation. This BRAC round was the fifth round of base closures. The U. S. Army used multiple objective decision analysis with 40 value measures to determine the military value of installations and an installation portfolio model to develop the starting point for identification of potential unit realignments and base closures and provide the basis for evaluating all recommendations (Ewing et al., 2006). The BRAC 2005 Commission accepted 95% of the Army's recommendations.[6] According to Army estimates, the approved recommendations will create a 20-year gross savings of $20.4B for a one-time cost of $12.8B and generate 20-year net savings of $7.6B, which are 1.2 times the net Army savings of the first four BRAC rounds combined. After completion of the 5-year BRAC implementation, the Army estimated that the recommendations would create a recurring savings of $1.5B annually. In addition, the Army leadership believes that the transformation realignments have made the Army more effective.

1.3.3.2 Data Center Location. Organizations with large computing needs have used data centers to help meet the demand for processing capabilities. The data centers can cost around $0.5B per center (without the computers and software costs!). There are typically many groups of SH involved in the decision to select the best locations for these data centers, with highly diverse objectives. Multiple objective decision analysis has been successfully used four times in the intelligence community to select the best location that provides the highest value data center at an affordable life cycle cost.[7] The success of these projects led us to develop the IT illustrative example used throughout this handbook.

1.4 Decision Analysis Practitioners and Professionals

This handbook is intended for decision analysis practitioners. Some decision analysis practitioners may only occasionally use one or more of the decision

[6]The overall acceptance rate for all defense agencies was 86%. The Army had the highest acceptance rate.

[7]The first author facilitated the development of the first multiple objective value and life cycle cost model and mentored the analysts performing the studies.

analysis techniques to help DMs. Other decision practitioners, whom we call decision professionals, are individuals who, for a significant portion of their professional careers, seek to learn and apply proven decision analysis technical and soft skill best practices to help senior leaders create value for their organizations. To be effective and credible to DMs and SH, the decision professional must have knowledge about decision making and decision analysis techniques. Some decision professionals use their decision analysis techniques and soft skills to help groups solve problems in domains where they do not have significant knowledge or expertise (See Appendix C, Decision Conferencing). Other decision professionals acquire deep domain knowledge by working for extended periods in the field (e.g., oil and gas, pharmaceuticals, or military).

> A decision professional is an individual who seeks to learn and apply proven decision analysis technical and soft skill best practices to help senior leaders create potential value for their organizations.

To support their continual learning, many decision professionals belong to two types of professional societies. The first are societies that focus on decision analysis methods, education, and professional development. The second are professional societies that focus on particular problem domains.

1.4.1 EDUCATION AND TRAINING

Some decision professionals learn decision analysis in undergraduate or graduate degree programs. A listing of the graduate decision programs can be found on the Decision Analysis Society website (see the next section). Many decision professionals begin their education with a degree in engineering, science, or business. Some even begin with a liberal arts degree. Many individuals become decision analysts after working in a particular application domain by taking professional decision analysis training courses. All four of the authors took graduate courses in decision analysis and later taught undergraduate, graduate, and/or professional training courses. All of us have supplemented our formal education with reading to better understand our application domains and human and organizational decision making.

1.4.2 DECISION ANALYSIS PROFESSIONAL ORGANIZATIONS

The oldest decision analysis professional organization (founded in 1980) is the Decision Analysis Society (DAS) of the Institute for Operations Research and Management Science (INFORMS). DAS "promotes the development and use of logical methods for improving decision-making in public and private enterprise . . . members include practitioners, educators, and researchers with

backgrounds in engineering, business, economics, statistics, psychology, and other social and applied sciences."[8] The DAS is a subdivision of INFORMS, which is world's largest organization of operations researchers and management scientists, with over 10,000 members. The DAS is among the largest of INFORMS' subdivisions, with more than 1000 members. Historically, a large percentage of the members have been consultants and students. DAS conducts its annual meeting and sponsors one or more tracks at the annual INFORMS meeting in the fall of each year. DAS has also organized decision analysis tracks in other INFORM sponsored meetings, including international meetings.

INFORMS and international operations research societies publish decision analysis articles in their technical journals. In addition, INFORMS and DAS publish *Decision Analysis*, which focuses on decision analysis theory and applications.

The Decision Analysis Affinity Group (DAAG) is a group of corporate and consulting decision analysis leaders who meet once a year for 2 or 3 days to share decision analysis insights, challenges and successes. It is more "practitioner" oriented than INFORMS DAS, which has a heavier "academic" and theoretic focus. The attendance at these meeting usually ranges from 30 to 80 individuals.

The Society of Decision Professionals (SDP) is a newer organization devoted to helping "decision professionals become the trusted advisors of choice for DMs facing important and complex decisions. The Society fosters collaboration, continual learning, and networking amongst its members and other professional societies and organizations so that as a growing community, we can bring clarity and insight to DMs."[9] The SDP wants to reach both DMs and decision professionals. Established in 2010, the society held its first meeting in the spring of 2011 at the annual Decision Analysis Affinity Group meeting.

1.4.3 PROBLEM DOMAIN PROFESSIONAL SOCIETIES

Many problem domains have professional societies that include decision analysis applications in their meetings and publications. As an example, the Military Operations Research Society (MORS) is a professional society devoted to furthering the development and use of operations research techniques for national security problems. Since the late 1980s, MORS has had a decision analysis working group at their annual meeting. In addition, INFORMS also has a Military Applications Society that has many military decision analysts, including the authors of this chapter.

The Society for Petroleum Engineering publishes many journals about oil and gas exploration and production, including some that address the decision analysis involved in the effort.

[8]Homepage of the Decision Analysis Society of INFORMS, http://www.informs.org/Community/DAS accessed July 29, 2011.

[9]Society of Decision Professionals, http://www.decisionprofessionals.com/, accessed July 29, 2011.

The Society for Medical Decision Making holds annual meetings and publishes a journal that has decision analysis approaches to guide the choice of medical treatment, at both the individual and societal level.

1.4.4 PROFESSIONAL SERVICE

Decision professionals perform professional service by taking leadership positions in professional societies and serving on national, regional, and local public service activities. Decision analysts have been president of many professional societies, including INFORMS, MORS, Society for Risk Analysis, and, of course, DAS and SDP. Many decision analysts have served on committees of the National Research Council where they use decision analysis expertise to help solve some of our nation's most significant challenges. As another example, decision professionals volunteer their time and talents to teach decision analysis concepts to youth through programs such as the Decision Education Foundation (DEF).[10]

1.5 Handbook Overview and Illustrative Examples

The handbook is organized as follows. Chapters 2–4 provide essential information that all decision analysis practitioners should know. Chapters 5–14 describe the decision analysis best practices in a sequential order. Chapter 15 provides a summary of these decision analysis best practices.

Chapter 2 describes the decision-making challenges in organizations and the cognitive and motivational biases from the behavioral decision analysis literature. Chapter 3 provides the theoretical foundations of decision analysis. Chapter 4 describes the soft skills that are the key to success of the decision analysis practitioner.

Chapters 5–14 are aligned with the steps in our decision analysis process (Fig. 1.1). Chapter 5 addresses the important issue of tailoring the decision process for the organization. Chapter 6 describes the use of soft skills to develop the decision frame. Chapter 7 describes techniques to craft the decision objectives. Chapter 8 introduces the creative process of designing the decision strategies. Chapter 9 focuses on the technical skills of model building and the soft skills of getting credible data for the models. We introduce single- (e.g., net present value) and multiple-objective value models. Chapter 10 focuses on the techniques for assessing uncertainty. Chapter 11 describes probabilistic modeling and analysis techniques to improve value and better manage risk. Chapter 12 introduces and describes the important techniques of portfolio decision analysis. Chapter 13 focuses on communicating the analysis results and insights to DMs to help them select the best alternatives. Chapter 14 addresses the implementation of the decision to achieve the potential value identified at the time of the

[10]Decision Education Foundation homepage, http://www.decisioneducation.org/, accessed July 31, 2011.

decision. Chapter 15 provides a summary of the decision analysis best practices that have been described in the book.

Each chapter has several standard features. First, we begin the chapter with a quotation to capture an important theme of the chapter. Second, we present the chapter material and illustrate the material with the three illustrative examples. Third, we list and define the key words introduced in the chapter. Fourth, we provide a list of the references we have used in the chapter.

One of the key features of this handbook is the integration of illustrative examples in almost all chapters of the book to illustrate the key concepts and techniques, to show the diversity of applications, and to demonstrate how the techniques are tailored to different problems. The first example is an oil and gas problem that we use to illustrate a single objective decision analysis using net present value. The second problem is the development and commercialization decision of a personalized medicine for breast cancer that also illustrates the use of net present value. The third example involves a government agency's decision about data center location and, in Chapter 12, an IT portfolio decision problem. We use this example to illustrate multiple objective decision analysis techniques.

Since the three illustrative examples are used throughout the book, we provide Table 1.3 as a reference to where to find the material for each of the examples. The table is also referenced in subsequent chapters.

1.5.1 ROUGHNECK NORTH AMERICAN STRATEGY (RNAS) (by Eric R. Johnson)

The title of the first illustrative example is the Roughneck North American Strategy (RNAS). The example is based on a specific decision analysis consulting engagement, but content is changed to preserve client confidentiality. Roughneck is the fictitious name of an international oil and gas operator, with headquarters and sizeable holdings in North America. Typical revenues were $1.5B a year. Market cap was roughly $5B. In the years preceding the strategic decision-making process described here, Roughneck had viewed North America as a mature market that was largely played out, and had focused its plans for growth on international assets. This was found to be less promising than initially hoped, due to ever-rising prices for development assets being paid by other international bidders, particularly developing countries with large populations and high aspirations for economic growth. Accordingly, Roughneck wanted to take another look at the growth potential of its North American properties.

1.5.2 GENEPTIN PERSONALIZED MEDICINE FOR BREAST CANCER (by Sean Xinghua Hu)

Our second illustrative example is a decision in the field of personalized medicine. Most medicines today are intended for a broad patient population, and many are effective in only 30–50% of patients. Personalized medicine, sometimes referred to as stratified medicine (Hu et al., 2005) (Trusheim et al., 2007),

TABLE 1.3 Section Locations of Illustrative Examples in Each Chapter

Chapter	Roughneck North American Strategy	Geneptin	Data Center
Introduction (Chapter 1)	1.5.1	1.5.2	1.5.3
Decision-making challenges (Chapter 2)	2.8.1	2.8.2	2.8.3
Select the appropriate decision process (Chapter 5)	5.4.1	5.4.2	5.4.3
Fame the decision (Chapter 6)	6.5.1	6.5.2	6.5.3
Craft decision objectives (Chapter 7)	7.8.1	7.8.2	7.8.3
Design decision alternatives (Chapter 8)	8.7.1	8.7.2	8.7.3
Perform deterministic analysis and develop insights (Chapter 9)	9.6 Spreadsheet Model 9.8 Analysis	9.11.1	9.11.2
Quantify uncertainty (Chapter 10)	10.2 Influence Diagram 10.3 Elicit and Document Assessments	10.4.1	NA
Perform probabilistic analysis and develop insights (Chapter 11)	11.3 Value Dialogue	11.5.1	11.5.2
Optimize portfolio resource allocation (Chapter 12)	12.3.3 RNAS Portfolio and 12.3.5 Tradeoffs	NA	12.4.3 Application to the Data Center Portfolio
Communicate insights (Chapter 13)	13.5.1	13.5.2	13.5.3
Enable decision implementation (Chapter 14)	14.5.1	NA	14.5.2

uses a diagnostic test (often referred to as "companion diagnostic tests") based on a molecular biomarker to "preselect" (or "stratify") the patients for whom the drug is most suitable. There have been only a few dozen personalized medicine drugs developed to date (Frueh et al., 2008; Laing et al., 2011) (Hu et al., 2012; FDA, n.d.).

One of the first successful personalized medicine products is Herceptin[11] (trastuzumab), which was marketed for cancer patients whose bodies make too much of the growth factor HER2, that is, they "overexpress" it. It is approved for treating HER2-overexpressing breast cancer patients, both for metastatic stage, and as an adjuvant therapy for early-stage patients. It is also approved for

[11]Herceptin, http://www.herceptin.com/breast/herceptin/, accessed May 25, 2012.

HER2-overexpressing metastatic gastric cancer. Herceptin was the first targeted medicine whose regulatory approval relied upon the use of a "companion diagnostic" to identify patients with a biomarker (in this case, HER2 overexpression). Herceptin was developed and marketed by Genentech (now owned by Roche).

Our "Geneptin" case is based on the development of Herceptin, but modified, simplified, and fictionalized to demonstrate some general considerations of personalized medicine development decision making.

Our Geneptin case is set in 1994, when the hypothetical Geneptin manufacturer, DNA Biologics, was designing the large, expensive "Phase III" clinical trial aimed at demonstrating safety and efficacy in metastatic breast cancer to secure FDA approval. DNA Biologics needed to decide whether to use a traditional all-comers approach, or to restrict the trial to patients who overexpress HER2. Previous Phase II studies had given some indication that HER2-overexpressing patients would likely respond better to Geneptin, though the evidence from these small trials was far from definitive.

The VP of Clinical Development at DNA Biologics believed that stratification could result in an enhanced benefit/risk ratio to patients and, therefore, a higher probability of technical and regulatory success (PTRS) of the drug development effort. However, it was not clear how to implement the stratification, because HER2 expression was measured on a continuous scale. The key question was where to draw the line defining HER2 overexpression?

Meanwhile, the VP of Commercialization believed that patient stratification would mean a smaller addressable patient population; based on the internal opinion on where to draw the line defining HER2 overexpression, HER2 overexpression-positive patients likely comprise only 25–35% of metastatic breast cancer patients. Would the reduction of addressable patient population still allow Geneptin to be a commercially viable product? Or, should the company proceed with an all-comers approach to maximize the number of patients Geneptin could serve, and avoid the risk of unnecessarily denying access to a somewhat arbitrarily defined population of HER2-negative patients?

1.5.3 DATA CENTER LOCATION AND IT PORTFOLIO (by Gregory S. Parnell and Terry A. Bresnick)

Our third decision example focuses on information technology (IT) for a large government organization. IT is critical to the ability of many organizations' ability to perform their missions. This government agency collects and processes large amounts of data. Due to the expanding variety and rapidly increasing volume of data, the agency required significant increases in data analytics. In addition, technology advances had resulted in supercomputers and servers becoming smaller, consuming more power, and requiring more cooling. The agency uses large data centers to process the collected and stored data. "A **data center** is the department in an enterprise that houses and maintains back-end information technology (IT) systems and data stores—its mainframes, servers and databases. In the days of large, centralized IT operations, this department and all the systems resided in one physical place, hence the name

data center."[12] At the time of the case, all of the agency's data centers were located in one metropolitan area. Senior leaders viewed the need for a new data center as an opportunity to make data center operation more secure by selecting a new location outside of the metropolitan area. There would be multiple approval levels to obtain the funds and approve the location decision within and outside of the agency. The agency needed to select the best data center location and justify the decision to budget approvers in the executive branch and Congress.

We also illustrate an IT portfolio decision (Chapter 12) for the same agency as an example of portfolio decision analysis. Again, the agency needed to justify the IT portfolio decisions to budget approvers in the executive branch and the Congress.

1.6 Summary

This chapter provides an introduction to the discipline of decision analysis. Decision analysis is a socio-technical process that must have sound quantitative theoretical underpinnings, but also must be done in the context of organizational and environmental considerations. We introduce the iterative decision analysis process that we use in the handbook and use this process to list the key technical products and the nine categories of soft skills (strategic thinking, leading teams, managing teams, researching, interviewing individuals, surveying individuals, facilitating groups, aggregating expertise, and communicating) necessary to help organizations create value for their SH. We compare three important application areas (oil and gas, pharmaceuticals, and military) and summarize several decision analysis success stories (Chevron, SmithKline Beecham, Army base realignments and closures, and government data centers). Next, we define a decision professional, discuss the education and training of decision professionals, identify some of their major professional societies, and described some of their professional service activities. We conclude with an overview of the handbook and an introduction to the three substantive illustrative examples (RNAS, Geneptin, and Data Center/IT).

KEY TERMS

Decision An irrevocable allocation of resources.
Decision analysis Decision analysis is a philosophy and a social-technical process to create value for DMs and SH facing difficult decisions involving multiple SH, multiple (possibly conflicting) objectives, complex alternatives, important uncertainties, and significant consequences.
Decision analyst An individual who uses the technical and soft skills of decision analysis.

[12]http://www.gartner.com/it-glossary/data-center/, accessed November 24, 2012.

Decision maker The leader vested with the responsibility and the authority to make organizational decisions.
Decision professional An individual who wants to learn and apply the decision analysis technical and soft skills that have been proven to help senior leaders create value for their organizations.
Probability A mathematical theory of uncertainty based on three axioms. See Appendix A.
Stakeholder An individual or an organization with a significant interest in a decision under consideration.
Risk Risk is the probability and consequence of a bad outcome.
Uncertainty The potential outcome of an event or events, which is not known with certainty.
Value A fair return or equivalent in goods, services, or money for something exchanged.[13]

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