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Introduction to Decision Analysis and Analytics

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

In God we trust. All others must bring data.
—W. Edwards Deming, statistician, professor, author, lecturer, and consultant

CHAPTER MENU

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. Having the right data and information at the right time with the right process enables decision-making. Our focus is on professional decisions, but the same principles apply to our personal decisions.

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

Companion Website: www.wiley.com/go/Decision_Analysis_2e

We begin by defining a decision. Howard defined 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 requires 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 decision-makers (DMs) vested with the authority and responsibility to make decisions for an organization or enterprise. Many decisions involve stakeholders (SHs) who are individuals and organizations that could be affected by the future consequences of the decision. Some decisions are easy because few SHs are involved, the values are clear, good alternatives are readily identified, and there are few uncertainties. However, some difficult decisions involve many SHs with potentially conflicting objectives, complex alternatives, large amounts of data, significant uncertainties, and large consequences. The discipline of decision analysis, the focus of this handbook, has been developed to help DMs with these complex decisions. This second edition builds on the first edition by incorporating data analytics information into decision analysis.

There are many definitions of decision analysis. Howard, who coined the term “decision analysis”, defined decision analysis as “a body of knowledge and professional practice for the logical illumination of decision problems” (Howard, 1966). In the first book on decision analysis, Raiffa 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). Keeney provided an intuitive and technical definition. Keeney’s intuitive definition was “a formalization of common sense for decision problems that are too complex for informal use of common sense” (Keeney, 1982). His technical definition was “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.” Phillips emphasized that decision analysis is a social-technical process to provide insights to DMs in organizations (Phillips, et al., 1990) and (Phillips, 2005). Clemen and Reilly stated 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 identify and create value for DMs and SHs facing difficult decisions involving multiple SHs, multiple (possibly conflicting) objectives, multiple data sources, 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.

Just like decision analysis has many definitions, people use various terms and definitions to describe analytics. Many of these connect analytics to metrics, summary statistics, data science, or decision-making. Rose (Rose, 2016) provides insight into the various definitions and states that analytics requires three separate definitions: (1) “a synonym for statistics or metrics,” (2) “synonym for data science,” and (3) “a very general way to represent a qualitative approach to organizational decision making.” We adopt the Analytics Body of Knowledge’s (ABoK) definition of analytics. ABoK defines analytics “as a process by which a team of people helps an organization make better decisions (the objective) through the analysis of data (the activity)” (Keenan, et al., 2022). This includes the use of descriptive (i.e., prepares and analyzes historical data), predictive (i.e., predicts future probabilities and trends), and prescriptive analytics (i.e., identifies and evaluates potentially new ways to operate). Using this definition, decision analysis is a prescriptive analytics technique.

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 better 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 useful in helping DMs make good decisions when faced with difficult and important choices. In addition, we hope to clarify the relationship between decision analysis and data analytics. Since many individuals and social organizations are involved in complex decisions, to be successful, decision analysis must use a social-technical process with as much data or information available to help individuals and organizations make decisions. Socially, the purpose of decision analysis is to provide credible, understandable, and timely insights to DMs and key SHs in organizations. Technically, decision analysis is an operations research/management science discipline that uses probability, value, and utility theory (see Chapter 3) and analytics to analyze complex alternatives under significant uncertainty to provide value for SHs 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. This chapter is organized as follows. Section 1.2 further describes decision analysis as a social-technical process. We introduce the decision analysis process that we use in the handbook, its connection to analytics, and 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 SHs. Section 1.3 emphasizes that decision analysis has many significant applications and compares three important application areas: oil & 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 Social-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 large data, DMs, SHs, and experts to perform a decision analysis. In this section, we describe the decision

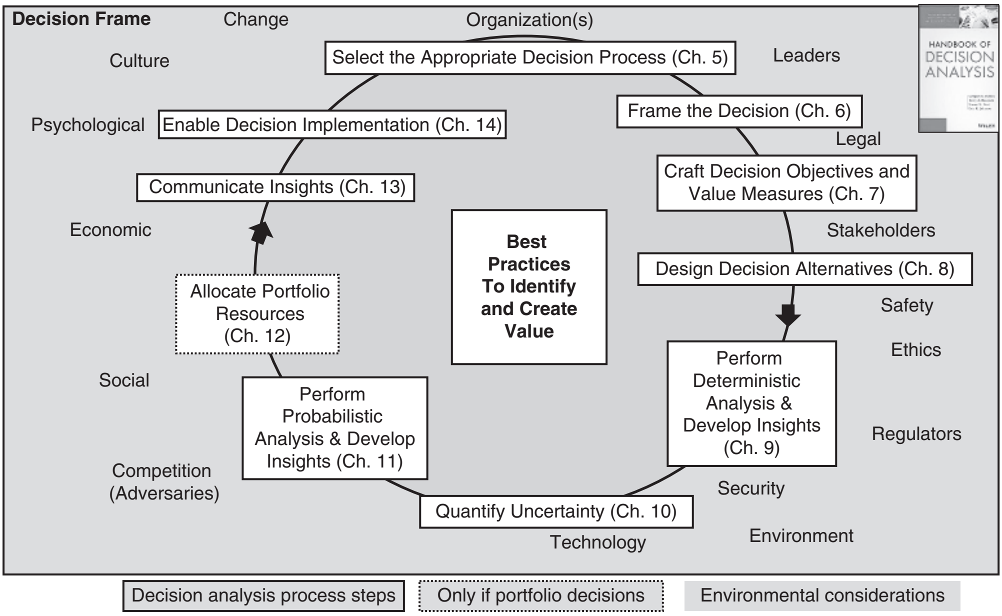

Figure 1.1 Decision Analysis Process.

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 DMs, SHs [1], subject matter experts (SMEs), and decision analysts to reach a good decision. Figure 1.1 shows the decision analysis process that we used to organize the first edition of 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 identify and create value for SHs. 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 allocate portfolio resources 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 steps may not be required in a particular application. In total, 16 environmental (12 in the first edition) factors are placed in the decision frame but outside the decision analysis process cycle to illustrate some of the important considerations that apply in a decision analysis process. The location of a factor is not necessarily an indication of alignment with a particular step in the process. The factors are meant to be illustrative and not all-inclusive.

This decision process overlaps with the generic analytics process, as shown in Figure 1.2 and discussed in the ABoK (Keenan, et al., 2022). In data analytics, you can either start with the decision or start with the data. The ABoK recommends that you combine the approaches by starting with the required decision and use data and data-driven techniques to inform the decision analysis. We agree with this approach.

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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.

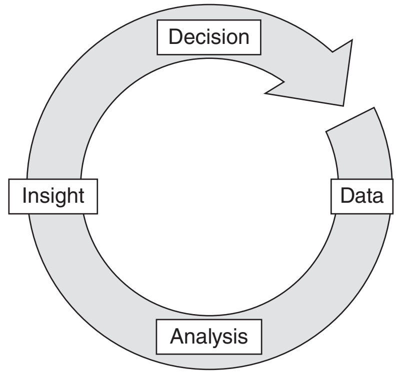

Figure 1.2 Generic Analytics Process Created from ABoK (Keenan, et al., 2022).

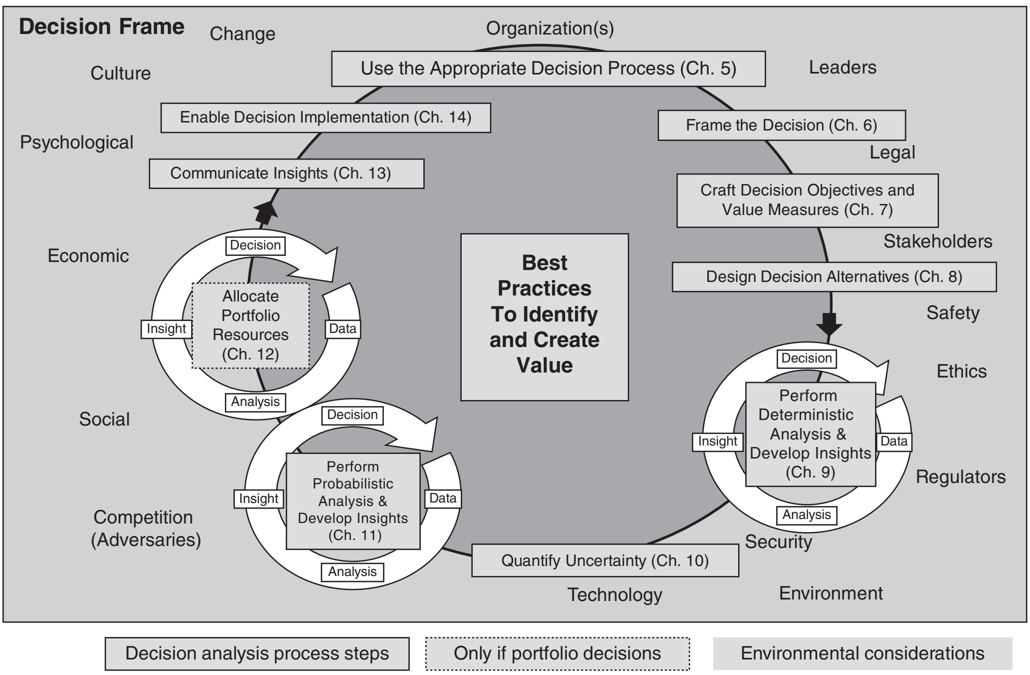

Figure 1.3 Combined Decision Analysis and Generic Analytics Processes.

Three of our decision analysis stages involve data analytics as illustrated in Figure 1.3. This is because you can view the entire generic analytics process as occurring at multiple decision analysis process stages. For example, in the perform deterministic analysis and develop insight stage, an analyst would focus on the decision. Then, they would develop a deterministic model based on the data and the key relationships between the data variables. The deterministic model is then used to perform the analysis to gain insights. This is used to inform the decision or problem statement to move to the next stage of quantifying uncertainty.

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

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	Think strategically Lead teams Manage teams
Fame the decision (Chapter 6)	DM, SH, SME	Vision statement Decision hierarchy Issue identification matrix Qualitative influence diagram Decision analysis schedule	Think strategically Lead teams Manage teams Research problem domain Interview DM & SH Facilitate group sessions Communicate insights
Craft decision objectives and value measures (Chapter 7)	DM, SH	Objectives hierarchy Functional value hierarchy	Think strategically 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 end network	Think strategically 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 Stacked bar chart 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 the 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	Think strategically Elicit risk preference Use individual and group creativity techniques to reduce risk and increase value
Allocate portfolio resources (Chapter 12)	DM, SH, SME	Portfolio constraints Portfolio model Efficient frontier Football chart	Think strategically Manage teams Interview DM, SH, SME to identify constraints Facilitate group session(s) to develop a 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 of risks and risk mitigation plan	Manage teams Interview DM, SH Facilitate group sessions to identify success measures and risks

Based on our experience and the above analysis, we selected the following nine soft skill categories.

- **Thinking strategically** about the client organization, the problem domain, the data sources, 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 includes developing team goals, motivating individuals to achieve team goals, and guiding the client organization to achieve the most value from the decision.
- **Managing** decision analysis projects, including developing analysis plans, identifying and scheduling activities, and managing the completion of tasks.

- **Researching** the problem domain, data sources, technologies for alternatives, and modeling approaches.
- **Interviewing** individuals (DMs, SHs, and SMEs) to frame the decision problem and obtain data, alternatives, and modeling information.
  - Interacting with senior leaders and SMEs (listening, learning, discovery)
  - Eliciting knowledge (data sources, preferences [value, time, and risk], probabilities, alternatives)
- **Surveying** SHs and expertise can be an efficient way to collect knowledge for a large number of geographically dispersed individuals.
- **Facilitating** groups of DMs, SHs, and SMEs to frame the decision problem and obtain data, alternative, and modeling information (also includes focus groups).
  - Frame the decision opportunity (initial and updated)
  - Elicit knowledge (preferences [value, time, and risk], probabilities, 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, SHs, and SMEs (see Chapter 13).
  - Communicate the story, analytic results, and 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. Decision analysis applications typically have four features in common: difficult decisions, multiple (possibly conflicting) objectives of SHs, 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 important application summaries are (Corner & Kirkwood, 1991) and (Keefer, et al., 2004). These two papers list several published applications in a wide variety of problem domains. Bier (Bier, 2024) reflected on the articles published in *Decision Analysis* during its first 20 years and found that the journal documents many applications of decision analysis. These application 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 the lack of incentives for publication.

Three important enduring areas of decision analysis applications have been oil & gas, pharmaceuticals, and military.[2] Table 1.2 (modified from (Burk & Parnell, 2011)) compares these three significant decision analysis applications using several factors: organizational objectives, key SHs, 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, intelligence, and homeland security) provide products and services that are not

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

Table 1.2 Comparison of Three Decision Analysis Application Areas.

Factor	Oil and Gas	Pharmaceuticals	Military & Intelligence
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 capabilities for 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 A 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 Intelligence Community Congress Federal budget organizations Defense contractors Military, civilian, and contractor employees International security groups Allies
Environmental uncertainties	Quantity of resources at particular locations Actions of competitors Actions of governments Actions of environmental 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	Prevalence of future diseases 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 Effectiveness of adversary systems Effectiveness of future weapons systems
Schedule uncertainties	Local, state, national, and international approvals and operational restrictions	Success of trials National and international regulatory approvals	Testing success Acquisition approvals Congressional funding authorizations
Cost uncertainties	Drilling resource availability, technology development problems, environmental protection requirements, and schedule slips	Size of clinical trials required Regulatory approval requirements	Changes by adversaries Immature technologies Schedule changes

(Continued)

Table 1.2 (Continued)

Factor	Oil and Gas	Pharmaceuticals	Military & Intelligence
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

easily measured in terms of dollars. The three examples illustrate the difficulty of decisions, the conflicting preferences of SHs, and the major uncertainties.

All three domains have a significant number of private and public SHs with complex and sometimes 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 30 years, Chevron has used decision analysis for its major decisions (Menke, et al., 2011). The Chevron Vice Chairman, George Kirkland, summarized the use of decision analysis to create value and manage risk on over 40 projects with investments of over $1B. According to Kirkland, Chevron "used 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. Chevron's Frank Koch noted the added confidence decision analysis gives decision makers 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.

> Chevron uses decision analysis because it works.

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) and (Menke, et al., 2011). SmithKline Beecham selected decision analysis because it was technically sound and organizationally credible. The results of this analysis were a dramatic increase in shareholder value. 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%."

1.3.3 Military and Intelligence Decision Analysis Success Stories

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

- **United States Army Installations.** In 2001, Congress enacted legislation that required a 2005 Base Realignment and Closure (BRAC) study to realign military units, remove excess facility capacity, and support defense transformation. This BRAC study was the fifth round of base closures. The United States Army used multiple objective decision analyses with 40 value measures to determine the military value of installations and an installation portfolio model to develop the starting point for the 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.[3] 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 five-year BRAC implementation, the Army estimated that the recommendations would create recurring savings of $1.5B annually. In addition, the Army leadership believes that the transformation realignments have made the Army more operationally effective.
- **Data Center Location.** Organizations with large computing needs have used data centers to help meet the demand for processing capabilities. At the time of this study, data centers cost around $0.5B percenter (without the computers and software costs!). There are typically many groups of SHs involved in the decision to select the best locations for these data centers, with highly diverse objectives. Multiple objective decision analyses have 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.[4] The success of these projects led us to develop the data center illustrative example used throughout this handbook.

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3 The overall acceptance rate for all defense agencies was 86%. The Army had the highest acceptance rate.
4 The first author facilitated the development of the first multiple objective value and life cycle cost model and mentored the analysts performing the studies.

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-analysis techniques to help decision-makers. 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 skills best practices to help senior leaders create value for their organizations. To be effective and credible to DMs and SHs, 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 B, Decision Conferencing). Other decision professionals acquire deep domain knowledge by working for extended periods in the field (e.g., energy, pharmaceuticals, or military).

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.

> 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 identify and create value for their organizations.

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. Some disciplines, such as systems engineering, use decision analysis as a recommended decision making method (Driscoll et al. 2022)

Many individuals become decision analysts after working in a particular application domain and by taking professional decision analysis training courses. All five 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."[5] The DAS is a subdivision of INFORMS, which is the world's largest organization of operations researchers and management scientists, with almost 12,000 members. The DAS is among the

5 Homepage of the Decision Analysis Society of INFORMS, http://www.informs.org/Community/DAS accessed April 11, 2024.

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*[6] which focuses on decision analysis theory and applications.

The Decision Analysis Affinity Group (DAAG) was 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 meetings usually ranged from 30 to 80 individuals. DAAG held 21 Meetings from 1995 to 2021. On September 15, 2021, the DAAG name was retired.

The Society of Decision Professionals (SDPs) is a newer organization devoted to helping "decision professionals become the trusted advisors of choice for decision makers facing important and complex decisions. Established in 2010, the society held its first meeting in the spring of 2011 at the annual Decision Analysis Affinity Group meeting. 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 decision makers."[7] The SDP wants to reach both DMs and decision professionals. From 2010 to 2021, the SDP annual meeting was the DAAG Annual Meeting. Since 2021, the annual meeting has been called the SDP Annual Meeting and Workshops.

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.

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.

The International Council on Systems Engineering is a not-for-profit membership organization and professional society in the field of systems engineering with about 17,000 members, including individual, corporate, and student members. A Decision Analysis Working Group[8] has been active since 2012 and has over 150 members.

1.4.4 Professional Service

Decision professionals perform professional service by taking leadership positions in professional societies and serving in national, regional, and local public service activities. Decision analysts

6 https://pubsonline.informs.org/journal/deca, accessed April 11, 2024.
7 Society of Decision Professionals, https://www.decisionprofessionals.com/,accessed April 11, 2024.
8 https://www.incose.org/communities/working-groups-initiatives/decision-analysis, accessed April 11, 2024.

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 Academies of Science, Engineering, and Medicine, where they use decision analysis expertise to help solve some 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).[9]

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. 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 the success of the decision analysis practitioner. Chapters 5–14 describe the decision analysis best practices in a sequential order. Chapter 15 provides a summary of these decision-analysis best practices.

Chapters 5 to 14 are aligned with the steps in our decision-analysis process (Figure 1.1–1.3). 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 processes of designing 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 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 illustrative examples. Third, we list and define the keywords 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 chapters of the text 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 problem is the New Product Launch example to illustrate a 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 an IT portfolio decision problem. We use these two examples to illustrate multiple objective decision analysis techniques. The fourth example is an oil and gas problem, Roughneck North American Strategy (RNAS), which uses net present value (NPV) and portfolio decision analysis.

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9 Decision Education Foundation homepage, http://www.decisioneducation.org/, accessed April 11, 2024.

Table 1.3 Location of Illustrative Examples.

Chapter	New Product Launch	Geneptin	Data Center	RNAS
Introduction (Chapter 1)	1.5.1	1.5.2	1.5.3	1.5.4
Decision-Making Challenges (Chapter 2)	2.8.1	2.8.2	2.8.3	Appendix D
Select the Appropriate Decision Process (Chapter 5)	5.4.1	5.4.2	5.4.3	Appendix D
Fame the Decision (Chapter 6)	6.6.1	6.6.2	6.6.3	Appendix D
Craft Decision Objectives and Value Measures (Chapter 7)	7.8.1	7.8.2	7.8.3	Appendix D
Design Decision Alternatives (Chapter 8)	8.7.1	8.7.2	8.7.3	Appendix D
Perform Deterministic Analysis and Develop Insights (Chapter 9)	9.5.1	9.5.2	9.7	Appendix D
Quantify Uncertainty (Chapter 10)	10.2 10.3	10.4.1	NA	10.4.3
Perform Probabilistic Analysis and Develop Insights (Chapter 11)	11.3	11.6.1	11.6.2	Appendix D
Allocate Portfolio Resources (Chapter 12)			12.4.3 Application to the Data Center Portfolio	12.4.2
Communicate Insights (Chapter 13)	13.5.1	13.5.2	13.5.3	Appendix D
Enable Decision Implementation (Chapter 14)	14.5.1	NA	14.5.2	Appendix D
Appendix D. RNAS				Appendix D

Since the 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 TechnoMagic New Product Launch

TechnoMagic is a hypothetical company that develops cloud-based software applications for complex operations management decisions in private corporations and public organizations. The company uses agile development to develop, deploy, improve, and maintain its applications. The more time they spend in agile development, the more capabilities can be developed, verified, implemented, and validated. For every application, TechnoMagic faces the decision of when to launch the new application in the market during their agile development. If they launch the application too early, early adopters may lose interest due to their limited capabilities. If they launch a more capable application on the market too late, they will lose business to competitors that get to market earlier. Based on their application development experience, the developers can estimate the percentage of desired capabilities they can successfully develop in each of the next three years. TechnoMagic's marketing department has performed a marketing study on the impact of application capabilities on international demand and the impact of application price on sales. The CEO wants to decide which year to begin sales of the app and what price to offer based on the NPV of the alternatives.

1.5.2 Geneptin Personalized Medicine for Breast Cancer

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 (Xu, et al., 2005) (Trusheim, et al., 2007), 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 (Xu, et al., 2012) (Laing, et al., 2011) (Frueh, et al., 2008) (FDA, n.d.).

One of the first successful personalized medicine products is Herceptin[10] (trastuzumab), which was marketed for cancer patients whose bodies make too much of the growth factor HER2, i.e., 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 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" the 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 HER2-negative patients?

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10 Herceptin, https://www.herceptin.com/, accessed April 11, 2024.

1.5.3 Data Center Location and IT Portfolio

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, technological advances have 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 a facility used to house computer systems and associated components, such as telecommunications and storage systems. It generally includes redundant or backup power supplies, redundant data communications connections, environmental controls (e.g., air conditioning, fire suppression) and security devices."[11] 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 operations 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 the Congress.

We also illustrate an IT portfolio decision (Chapter 12) as an example of portfolio decision analysis.

1.5.4 Roughneck North American Strategy (RNAS)

An example is an oil and gas problem that uses the net present value. The decision analysis is described in Appendix D. This appendix provides a more complex example, which explores additional useful approaches, but without step-by-step instructions to fully describe the analysis process.

1.6 Summary

This chapter provides an introduction to the discipline and practice of decision analysis. Decision analysis is a social-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 eight categories of soft skills (think strategically, leading teams, managing teams, researching, interviewing individuals, facilitating groups, and communicating) necessary to help organizations create value for their SHs. 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 describe some of their professional service activities. We conclude with an overview of the handbook and an introduction to the three substantive illustrative examples (New Product Launch, Geneptin, and Data Center/IT).

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11 http://en.wikipedia.org/wiki/Data_center accessed April 11, 2024.

Key Terms

Analytics A process by which a team of people helps an organization make better decisions (the objective) through the analysis of data (the activity) (Keenan, et al., 2022).
Decision An irrevocable allocation of resources.
Decision analysis Decision analysis is a philosophy and a social-technical process to identify and create value for DMs and SHs facing difficult decisions involving multiple SHs, 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.
Decision maker The leader is 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.
Subjective probability The use of probability distributions to describe an individual's belief about the potential likelihood of the outcomes of an event.
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 that is not known with certainty.
Value Relative worth, utility, or importance[12].

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