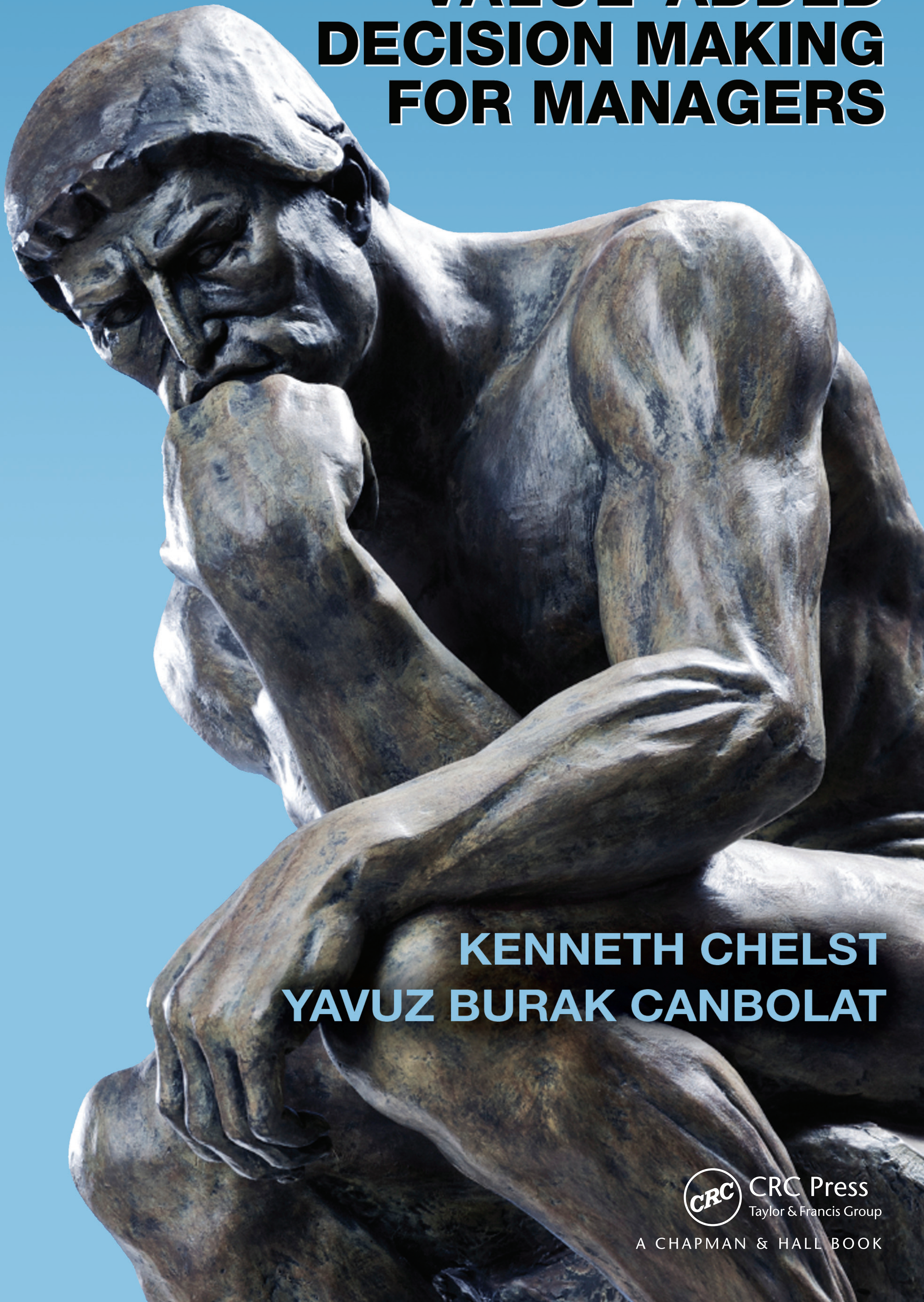
VALUE-ADDED DECISION MAKING FOR MANAGERS



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CRC Press
Taylor & Francis Group
A CHAPMAN & HALL BOOK

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CRC Press
Taylor & Francis Group
Boca Raton London New York

CRC Press is an imprint of the
Taylor & Francis Group, an **informa** business
A CHAPMAN & HALL BOOK

CRC Press
Taylor & Francis Group
6000 Broken Sound Parkway NW, Suite 300
Boca Raton, FL 33487-2742

Version Date: 2011913

International Standard Book Number-13: 978-1-4398-9755-3 (eBook - PDF)

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http://www.crcpress.com

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Preface

This book was developed from a course on decision and risk analysis that we have taught to hundreds of experienced technical managers over the last 18 years. Our primary thesis is that there is more to decision making than just picking the best alternative. A structured approach clarifies the strengths and weaknesses of the best alternatives and enables the decision maker to develop a plan for improving on the best by adding value and reducing risk. Throughout the book, we explore the important interaction between decisions and management action and clarify the barriers to rational decision making. Specifically, this book

- Provides a wide range of realistic decision contexts—routine, semi-routine, and strategic—for both industry and personal life
- Develops and illustrates the concept of value-added decision making
- Gives equal weight to modeling both multi-objective decisions and decisions in the presence of uncertainty, and comes packaged with Logical Decisions software for multi-objective decisions and Decision Suites software for probabilistic decisions
- Provides a comprehensive review of diverse challenges to "rational" decision making, including chapters on forecasting bias and decision bias
- Includes chapters on negotiated decisions, strategic decisions, and ethical decisions, covering alternate approaches and perspectives

The core of the book addresses decisions that involve selecting the best alternative from a distinct list of a handful or more of alternatives. The decisions include buying a car, picking a supplier or house contractor, selecting a technology, picking a location for a manufacturing plant or sports stadium, hiring an employee or selecting among job offers, deciding on the size of a sales force, making a late design change, and sourcing to emerging markets. More complex decisions that involve multiple dimensions simultaneously are covered in the later chapters on negotiations, strategy, and ethics.

There are numerous activities placed throughout the book. These activities are intended to encourage the reader to stop, think, and assimilate the ideas by finding similar examples in his or her work environment or personal life. These same activities appear in the exercise section.

Book Website

The book comes with two software packages, but we chose to not include discussion of the software commands in the book. We were concerned that any software changes would make those sections obsolete. Software downloads are described in the appendices at the end of the book. We will maintain on the website for the book some basic up-to-date tutorials developed around examples in the book. The website address is http://ise.wayne.edu/research/decision.php. In addition, we chose not to include basic probability in the book or appendices. If necessary, the basic probability concepts used in the book can be covered in a couple of lectures drawn from any introductory book. The website will also contain a password-secure section for instructors. This section will have PowerPoint presentations for each chapter and solutions to all of the numeric examples. To gain instructor access send a request to the author at kchelst@wayne.edu.

The book is divided into 5 parts and 17 chapters.

Part I: Structuring Hard Decisions

Chapter 1. The Case for a Structured Analytic Decision Process
The chapter begins with a discussion of common complaints about organizational decisions. It then explores the factors that complicate decision making and why gut feeling and instinct often produce bad decisions. Common symptoms of a poor decision-making process on both an organizational and personal level are detailed, concluding with a discussion of what constitutes a quality and efficient decision-making process.

Chapter 2. Influence Diagrams: Framing Multi-Objective and Uncertain Decisions
A wide range of decisions involves multiple objectives and/or uncertainty. This chapter introduces the reader to influence diagrams used in the early stages of decision making to obtain agreement on the critical values and uncertainties surrounding the decision. The chapter develops and explores this tool through a series of examples: investing in automation, planning a theater party, buying a used car, launching a new product that is late to market, and adding transmission power lines.

Chapter 3. Common Decision Templates
A primary concern with any structured decision process is that it is too complex and takes too much time. Chapter 3 presents decision templates that can serve as a foundation for efficiently beginning the decision-structuring process.

Part II: Decisions with Multiple Objectives

Chapter 4. Structure Decisions with Multiple Objectives
Multi-objective analysis begins by framing the decision with a hierarchy of objectives and subobjectives in the form of a tree. The tree culminates with a list of measures used to characterize the objectives. The book discusses different types of measures. These include natural measures such as cost or miles per gallon as well as categorical measures. Categorical measures require the analyst to creatively define, quantify, and group the range of possible values for items that are often easier to describe qualitatively than quantitatively. The concepts are developed and illustrated with a series of examples involving lightbulbs, salesclerks, used cars, kitchen remodelers, and global facilities. The chapter concludes with a set of real-world case studies.

Chapter 5. Structured Trade-Offs for Multiple Objective Decisions: Multi-Attribute Utility Theory
This chapter presents a process for assigning weights that reflects the relative importance of each measure and objective. Weights are the primary mechanism for making trade-offs between objectives. The next step involves converting raw data on each measure into a scale between 0 and 1. Several methodologies for the conversion are presented. These two steps are combined

in multi-attribute utility theory (MAUT) to calculate and compare the overall score for each alternative. The chapter uses Logical Decisions software to facilitate the process.

Chapter 6. Value and Risk Management for Multi-Objective Decisions
This chapter demonstrates the process of adding value by a thorough analysis of the strengths and weaknesses of the best alternatives. Ideally, this leads to creating an enhanced or hybrid solution that is even better than any of the original alternatives, by creatively improving the top alternatives, addressing areas of weakness within highly valued objectives, and reducing any significant risks. The chapter leverages the capabilities of Logical Decisions to identify and clarify strengths and weaknesses.

Chapter 7. Multiple Objective Decisions with Limited Data: Analytical Hierarchy Process
In this chapter, we introduce the analytical hierarchy process (AHP), a second analytical methodology for multi-objective decisions. AHP is less data intensive and structured than MAUT with regard to measures and scaling. It is less rigid in its data requirement and is built on a natural decision process of pairwise comparisons. The examples given include choosing a snowblower, selecting among job offers, and purchasing project management software. Classic decision analysis questions the validity of this methodology because of issues of rank-order reversals however. The chapter closes with a discussion of the relative merits of MAUT and AHP.

Part III: Decisions and Management under Uncertainty

Chapter 8. Value-Added Risk Management Framework and Strategies
This chapter begins with an exploration of the role that uncertainty plays in both day-to-day management and decision making. It presents a multistep risk management process that begins with risk identification and concludes with strategies to avoid, mitigate, or manage risks. The chapter includes a limited discussion of standard tools for identifying and prioritizing risks: fishbone diagrams, failure mode effect analysis (FMEA), and likelihood-impact maps.

Chapter 9. Spreadsheet Simulation for Decisions with Uncertainty
This chapter is a basic introduction to stochastic simulation used to model a collection of uncertainties. It is a descriptive tool that produces a risk profile, but unlike decision trees it does not identify the optimal decision. The software used is @Risk, an Excel add-on. Investment in project acceleration, forecasts of drug development profits, and sourcing to emerging markets are the examples used here.

Chapter 10. Decisions with Uncertainty: Decision Trees
This chapter presents decision trees as an analytic tool for making decisions involving uncertainty. It is a normative decision-making tool that identifies the optimal decision based on expected value or expected utility. The software package Precision Tree, an Excel add-on, is used to carry out the decision tree analysis and perform sensitivity analysis. The examples in this chapter include capacity planning, design change, automation investment, make or buy, and choice of technology.

Chapter 11. Structured Risk Management and the Value of Information and Delay
This chapter presents a structured approach to risk management that is developed around decision trees. It begins with the demonstration of two graphical tools, a tornado diagram and a spider plot, used to highlight critical variables. The chapter develops the concepts of expected value of perfect

control, expected value of perfect information, and imperfect information. It illustrates the role that contingent contracts and real options can play in risk management.

Chapter 12. Risk Attitude and Utility Theory
This chapter introduces the concept of translating an individual's attitude toward risk into a risk utility function. This function is then used in decision trees with the objective of maximizing the expected value of the utility function. The value of utility theory is demonstrated with examples involving insurance and risk-sharing partnerships. The chapter explores a number of paradoxes that challenge key assumptions of utility theory.

Part IV: Challenges to "Rational" Decisions

Chapter 13. Forecast Bias and Expert Interviews
This chapter addresses a core issue in decision trees, the accurate specification of subjective probabilities. All decisions require data, estimates, and forecasts, and the chapter explores a range of biases that undermine forecasting accuracy. The biases discussed include motivational bias, overconfidence, availability bias, representative bias, confirmation bias, and errors in probabilistic reasoning. The chapter also describes an expert interview process designed to reduce these biases.

Chapter 14. Decision Bias
The goal of this chapter is to develop an understanding of how to overcome cognitive decision biases that are antithetical to good decision making. These biases produce tendencies to select non-optimal alternatives and to reject good ideas. Discussed here are biases of sunk cost, escalation and de-escalation of commitment, framing, status quo and omissions, regret, and groupthink. The chapter also discusses how mood affects decision making.

Part V: Decisions with Multiple Perspectives

Chapter 15. Value-Added Negotiations
This chapter develops the knowledge and analytic skills for making negotiated decisions that culminate in value-added agreements, providing a systematic framework for improving negotiation outcomes. One of the key recommendations is that negotiators focus on the interests of opposing parties and not on opposing parties' positions. The chapter describes a negotiation process intended to create value that the parties can then divide according to their needs. Cross-border negotiations affected by different cultural behaviors are also discussed.

Chapter 16. Ethical Decisions
This chapter is designed to raise awareness regarding a wide range of ethical issues that routinely arise when making decisions. It focuses on day-to-day situations that often involve conflicting ethical issues, presents a list of common ethical values, and identifies those that are most often in conflict. The chapter discusses a number of biases, barriers, and pressures that often affect our ability to see all the ethical issues involved in decisions we make. It concludes with a series of small cases that include some of the more common ethical conflicts.

Chapter 17. Strategic Direction, Planning, and Decision Making
This chapter develops a broad perspective as to how companies and individuals should plan, develop, and refine their strategies. It starts by describing a strategic planning process and the critical decision elements of a strategy. The chapter presents an overview of the concept of SWOT analysis

(strengths, weaknesses, opportunities, and threats) and also introduces two basic tools, a decision hierarchy and a strategy table. Strategic planning often requires the development of alternative scenarios in order to assess the robustness of various strategies. The chapter concludes with a description of the dialogue decision process used in large organizations to keep key stakeholders engaged and aligned with the developing strategy.

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Acknowledgments

In 1992, the Department of Industrial and Systems Engineering (ISE) of Wayne State University launched the Engineering Management Master's Program (EMMP) at Ford Motor Company. Faculty from the Leaders for Manufacturing Program at MIT mentored the department in designing a graduate program that integrated engineering and business principles for Ford engineers. Ford has continued to support this program with fresh nominations of high-potential engineers each year since, even through the darkest days of the U.S. automotive industry from 2007 to 2009.

Ford management originally requested that a course in decision and risk analysis be included in the curriculum, but it offered little guidance on specific content. I was asked to develop and teach the course, having taken standard courses in decision analysis as a graduate student at NYU and MIT. Those courses emphasized technical modeling aspects, and I was unsure of how to make the topics relevant to experienced engineers. The decision tree examples seemed either simplistic or relevant only to the oil industry, while the multi-objective concepts seemed most relevant to major public policy decisions.

At the time, there was no widely used up-to-date text book that integrated relevant software packages. Reading the collection of articles in *The Principles and Applications of Decision Analysis*, edited by Ronald A. Howard and James E. Matheson, was a turning point in broadening my understanding of the way decision analysis might be applicable to engineers on the path to technical leadership. That book was complemented by *Decision with Multiple Objectives: Preferences and Tradeoffs,* by Ralph L. Keeney and Howard Raiffa. Together, these volumes led me to a fateful decision: the course would give equal time to multiple objective decisions and uncertain decisions. In addition, a significant portion of the course would be allocated to softer issues such as bias. Logical Decisions was an integral part of the course from the very beginning and was complemented by a variety of decision tree packages that have changed over the years before settling on Precision Tree. The Ford engineers would be required to complete and present team projects in the course. The breadth of the real-world decisions they tackled in a short span clearly demonstrated the relevance of the material to their day jobs.

For more than a decade, the primary book for the course was *Making Hard Decisions* by Robert Clemen; a new edition co-authored with Terence Reilly includes the Decision Suites software. This was supplemented by a large collection of outside articles. As time went on, however, I found I was replacing many of the examples in the book with problems more relevant to the Ford engineers. More important, MAUT was the lead modeling tool in the course and was supported by Logical Decisions software, whereas the Clemen and Reilly book places far more emphasis on decisions with uncertainty than on multiple objective decisions. In addition, since it does not use multi-objective software, the analysis it presents is limited. As a result, I began the process of converting my lecture notes and examples into a book, and along the way decided to broaden the scope to include chapters on negotiations, ethics, and strategy. Because I have few skills in negotiations, I asked Professor Hal Stack, the former director of the Center for Labor Relations at Wayne State University, to write that chapter. Dean Pichette, a retired Ford engineering manager and lecturer at Wayne State, accepted the challenge to develop the ethics chapter, which focuses on day-to-day ethical dilemmas.

Dr. Yavuz Burak Canbolat is co-author of this book. He completed his PhD at Wayne State under my direction. During his years of study, he was the teaching assistant for the course as well as a technical consultant for a number of major projects at Ford. Upon receiving his doctorate, he entered the pharmaceutical industry as an internal decision analysis consultant. Currently, he is a manager at Abbott Laboratories in the decision analysis group. His practical experiences over the last several years have further enriched the material covered in this book.

I would like to acknowledge a number of individuals who have contributed to and encouraged this work. David Strimling mentored me as I began to develop this course. As a senior manager at General Dynamics, he had both used and taught the tools of decision analysis. A number of my current and former doctoral students contributed examples and ideas along the way. These include Mustafa Sefik, Ali Yassine, Gang Wang, and Saman Alaniazar. Other friends and colleagues who have helped and offered encouragement along the way are Sam Bodily, Robert Bordley, Jay Johnson, Azriel Chelst, Kenneth Riopelle, and Philip Lanzisera. A special debt of gratitude is owed to the main editors of the book, Eric Schramm and Pessie Novick. Bob Stern of Taylor & Francis was enthusiastic about the book from the moment I approached him and stuck with us even though the writing took much longer than anticipated. Tom Edwards has worked with me to develop a series of examples that can even be taught to high school students. Without Gary Smith, the developer of Logical Decisions, the MAUT and AHP sections would have been limited to small, unrealistic examples. I owe a special debt of gratitude to the legions of engineers at Ford, Visteon, and ACH who challenged me every step of the way to ensure that the concepts taught were relevant. Their outstanding projects were proof of the relevance of decision analysis to working engineers. Without the continued support for EMMP from the technical leadership of Ford, especially Derrick Kuzak, I would never have developed the practical knowledge needed to write this book. Last, I owe an unrepayable debt to Tamy, my wife of more than 40 years, for supporting me through the excruciatingly long challenge of bringing this work to conclusion.

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I would like to acknowledge my colleagues at Merck and Abbott who helped me work on a broad range of decision analysis problems. I owe a special debt of gratitude to Kerime, my wife, for her support while working to complete this book.

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Dr. Chelst's research interests include engineering management, emergency service management, global engineering, and the use of operations research to enhance K–12 mathematics education. He was an Edelman Prize Finalist for a team project he headed for Ford. He is also the author of *Does This Line Ever Move: Everyday Applications of Operations Research* as well as *Exodus and Emancipation: Biblical and African-American Slavery.*

Yavuz Burak Canbolat received his BS from Yildiz Technical University, his MS from Sakarya University, and his PhD in industrial engineering from Wayne State University under the supervision of Dr. Kenneth Chelst. He is currently a senior manager in the Decision Support Group at Abbott Laboratories. Prior to Abbott Laboratories, Dr. Canbolat worked as an associate manager in decision analysis for Merck & Co., Inc., and as an instructor in the Industrial Engineering Department of Qafqaz University.

Dr. Canbolat has applied decision analysis and operations research techniques to R&D portfolio evaluation and management, strategic planning, financial and economic analysis, global operations and logistics, risk analysis, and capacity planning. He has developed sales and financial models to predict commercial opportunities for R&D projects. He has received numerous performance awards from Abbott Laboratories and Merck & Co., Inc., and research and teaching awards from Wayne State University and Qafqaz University.

Dean W. Pichette received his BSEE and MBA from Michigan State University and his MS in electronics and computer control systems from Wayne State University. He is currently a senior lecturer in the Industrial and Systems Engineering Department at Wayne State University. Previous positions include various engineering and management assignments at Ford Motor Company, with much of them focused on the development and implementation of electrical and electronic architectures and systems.

His teaching and research interests include systems engineering, project and program management, and engineering economics. He also co-leads capstone and leadership projects, which provide students with the opportunity to apply classroom learning to solve real-world business issues or to improve methods and processes using a project management methodology.

Hal Stack received his BA from the University of Notre Dame and his MA from the University of Wisconsin. He recently retired as director of the Master of Arts in Industrial Relations (MAIR) program and the Labor Studies Center, a comprehensive labor education and research center at Wayne State University. The MAIR program prepares students for careers in labor and employment relations. The Labor Studies Center provides training and technical assistance to unions on labor relations and workplace issues, and assists unions and employers in the design and implementation of joint initiatives to enhance labor–management relations, employee involvement, and organizational effectiveness.

Hal Stack's teaching and research interests focus on negotiation, interventions to increase union effectiveness, the design and implementation of joint labor-management programs, and the impact of organizational restructuring on labor relations and work organization. In addition to his labor relations work, he has worked with cities, nonprofits, community-based organizations, and government agencies as a facilitator of strategic planning, community visioning, consensus building, and participative organizational redesign.

Part I

Structuring Hard Decisions

Chapter 1

The Case for a Structured Analytic Decision Process

1.1 Goal and Overview

The primary goal of this chapter is to motivate the need for a structured analytic decision process by discussing the limits and flaws of an intuitive unstructured process.

The chapter begins by describing common concerns with decision making as practiced in many organizations. It explores three major dimensions that limit an intuitive process. First, there are common cognitive biases that contribute to flawed intuition. Second, decision making is difficult because of problem complexity and organizational and personal pressures. Last, intuition is limited in its ability to consider multiple objectives and uncertainty. Some of the symptoms of a poor decision process include arbitrarily revisited decisions and personality driven decisions with few alternatives honestly evaluated. This chapter explores the elements of good decision making: the process should be high quality, efficient, easily updated, disciplined, transparent, and committed to implementation. The process proposed here incorporates both hard data and expert opinion and can work both for the individual decision maker and for a group in a complex organizational setting involving multiple stakeholders.

1.2 The Challenge

The best laid schemes o' mice an' men, Gang aft a-gley

Robert Burns

> We never have enough time to make the right decision the first time but we always seem to have enough time to review the decision over and over again *after* beginning implementation!
>
> Engineering, marketing, manufacturing, and finance never seem to reach a consensus. They all leave the meeting more frustrated than when they came, and then complain that they weren't heard!
>
> We spend more time justifying the decision we made than analyzing what the best decision should be!
>
> Every time a new manager is appointed, we have to review the decision and start over from scratch!
>
> Finance keeps raising the bar for 'return on investment' and the corporate technologists keep exaggerating the potential value of new technology. And the game goes on!
>
> We don't have enough data to nail the decision, yet, we have more data than we could possibly process in time to make a timely decision.

These laments are often heard as corporate decision makers tackle tough problems. These individuals face high levels of complexity as they attempt to integrate technical and marketing expertise to design, develop, launch, manufacture, deliver, and continuously improve new products and services. Difficult issues arise whether the context is an automobile, a washing machine, a critical subsystem, an integrated chip, a software product, or a power plant. The decision-making environment includes not only the uncertainty of the marketplace but also the uncertainty of new technology and the accuracy of projected product performance. These challenges abound in a service economy as well, whether you are a provider or consumer who is considering anything from the design of a new health insurance policy to a cell phone plan. Decision makers at all levels must weigh their priorities while also making trade-offs for the sake of what can be delivered at a specific price.

Uncertainty, trade-offs, and cross-organizational teams abound, whether your organization provides a physical product or delivers a service. Health care providers must constantly assess the need to upgrade and integrate new technologies. Hotel managers and airline industry executives struggle to find the right mix of service, facility and equipment upgrade, and price in the presence of brutal competition. The trade-offs are no less complex when similar decisions are made by state and local government officials under pressure to hold the line on taxes while meeting citizen expectations of service.

The same issues extend to personal decisions. Trade-offs among objectives arise when buying a home, a cell phone, a digital camera, an automobile, health insurance, or financial services. Deciding which contractor to hire for a kitchen remodeling project is as complicated as picking a supplier to maintain the corporate IT infrastructure, but the home decision is more emotionally laden. When evaluating a possible job or even career change, an individual will need to balance short- and long-term goals involving significant career path uncertainty. A company might face a dilemma when deciding whether to replace an existing technology with a state-of-the-art alternative that is said to have unlimited potential but is as yet unproven.

1.2.1 Decision-Making Environments

The decisions explored in this text are primarily one-time decisions. They range from classes of decisions that are semi-routine such as choosing a supplier to those that are once in a lifetime, such as when to stop extreme efforts to prolong life. These decisions arise in corporate organizations and governmental bodies as well as in our private lives. Multiple objectives, uncertainty, and concerns regarding decision dynamics are critical in each of these environments; yet, there are important distinctions between them.

Corporations often have access to large amounts of data and multiple technical experts. These experts may be drawn from marketing, finance, operations, product development, manufacturing, and a variety of support services. The long-term objectives will consist of some set of financial measures such as profit and return on investment (ROI). Nevertheless, it will be impossible to link every decision directly to the ultimate fiscal viability of the firm. Hard decisions will cut across multiple departments of an organization. Often, they will involve multiple levels of higher management reviews. Additionally, the corporate world is experiencing unprecedented global pressures on profitability. Consequently, there is an overall tendency to place too much emphasis on short-term instead of long-term goals. Last, there is an information explosion that is rapidly changing how we do business, and there is a premium on speed to market.

Governmental bodies routinely make decisions that impact lives. They have responsibility for and are responsible to multiple constituencies. As a result, they must constantly balance efficiency and equity. Members of elected bodies must deal with powerful public sector worker organizations that can influence elections and ultimately their jobs. Public sector managers may be more closely aligned with their workers than with the top-elected officials, who, in theory, set budgets and policies and oversee the managers' performance. These managers and workers are often shielded from accountability by rules, regulations, and practices that were originally designed to protect the integrity of the work environment, preventing cronyism and nepotism. The decisions of such governmental bodies as city councils and legislatures often involve public discussion and almost always public votes. These votes can require more than simple majorities to pass, as in California, which requires a two-thirds majority for budgetary votes. In addition, preliminary discussions and the information gathered can be subject to freedom of information rules. There are also checks and balances between the legislature, executive, and the judiciary built into the decision-making system. Today almost all such organizations are facing extreme budget constraints that necessitate compromises across different agencies and different levels of service cuts. These must be carefully balanced in order to maintain a productive working relationship among the various departments of a particular organization.

Personal decisions impact one's own life as well as those of family members, and, to a lesser extent, friends and co-workers. There will always be multiple objectives. Individuals generally have limited time to gather all of the information that could help in the decision; nor do they necessarily have access to it all. At other times, they face information overload; they do not have the ability or time to process all of the information that is obtainable. Thus, people tend to face significant uncertainty as they make decisions. There is a constant tension between short-term goals and needs and longer-term interests. Personal values and biases implicitly affect how one approaches decisions as do the people who most influence the decision maker. Finally, most people face substantive budget constraints when making decisions involving significant investments.

1.3 Decision Analysis Effectiveness

We offer here no quick fixes for professional and personal decision challenges, nor do we have access to a prophet or visionary who can resolve all uncertainty. Instead, we offer a structured, well-established, and well-researched process that begins with decision framing and proceeds through formal quantitative analysis while reducing biases and attempting to avoid common decision-making pitfalls. This methodology explicitly and formally incorporates two factors that complicate many decisions: multiple objectives and uncertainty. It is also designed to support group decisions involving multiple perspectives and concerns. We present two methods to address multi-criterion decisions: Multi-Attribute Utility Theory (MAUT) and the Analytic Hierarchy Process (AHP). For uncertain decisions, the primary modeling technique is decision and risk analysis with decision trees.

Throughout the text, we emphasize that decision making is a process and not just an event (Quinn and Rohrbaugh 1981); our goal is to facilitate the development of an inquiry-based collaborative decision process instead of an advocacy conflict-ridden contest of wills (Garvin and Roberto 2001). The process is facilitated by software packages that structure the decision, compare alternatives, and provide sensitivity analysis in graphic form. We claim that the approach is proven QED: quality driven, efficient, and disciplined. Equally important, this inquiry-based process adds value to the resulting decision, as we explain and demonstrate.

An obvious but difficult question is "Do these analytic techniques measurably improve decisions when compared to alternative, less analytic and structured processes?" Matheson and Matheson (2001) performed ground-breaking macroanalysis of corporate performance and the use of best practices. They identified nine aspects of best practices of corporate management and created an IQ test to measure a company's use of these practices. High IQ companies were almost five times more likely to be high-performing companies when compared to low IQ companies. Four of the nine aspects directly relate to decision processes presented here: embracing uncertainty, employing disciplined decision making, a culture that emphasizes value creation, and alignment and empowerment. Other research into decision aid effectiveness presented three levels of effectiveness: process, output, and outcome effectiveness (Schilling et al. 2007).

Process effectiveness is described as the quality of the decision and is the most often studied variable. Rohrbaugh (2005) describes key elements of a quality decision process. These include adequate information, clear and rational thinking, flexibility, and creative and sufficient participation.

Matheson and Matheson (1998) add clear value trade-offs and commitment to action. Timmermans and Vlek (1994) and Davison (1997) focus on the quality of communication between the team members making the decision.

Schilling et al. (2007) used a series of six complex cases in a controlled environment to assess the perceived effectiveness of multi-criterion decision analysis (MCDA) when compared to existing decision processes. MCDA was consistently perceived as being better on a multiplicity of measures. It increased strategic insights, creativity, and the quality and quantity of information exchange.

Output effectiveness is described as the ability of the decision process to achieve the organizational objectives (Dean and Sharfman 1996). Phillips and Costa (2007) demonstrated how MCDA improves decision output effectiveness. In both public and private organizations, this process increases communication that leads to a shared understanding and a sense of shared purpose that helps organizations achieve their objectives. In addition, the clear articulation of multiple objectives increases transparency that facilitates communication of the decision to stakeholders and provides a mechanism for auditing how decisions are made. This transparency has increasing relevance for public sector decisions that too often seem to be dominated by special interests.

Outcome effectiveness is hard to measure, especially in an uncertain environment when the best decision might still produce a bad outcome. A detailed study of the role of decision analysis at Kodak estimated that decision analysis added $1 billion in value across 178 project decisions evaluated over a period of 10 years (Clemen and Kwit 2001). The fact that many highly successful pharmaceutical and energy firms routinely use decision and risk analysis is further confirmation of their overall effectiveness.

1.3.1 Quality

The decision processes of this text incorporate the needs and values of both the primary decision maker(s) and various stakeholders and facilitate communication. They factor in both hard data and subjective judgment in a transparent process that is intended to reduce the impact of cognitive biases that undermine rationality. The methodologies are designed to produce robust decisions in the presence of uncertainty and to be less subject to the variability of personality inherent in intuitive decision making. They yield insights into the strengths and weaknesses of the various alternatives, resulting in greater decision defensibility and better buy-in for implementation and tracking.

1.3.2 Efficient

When time is not just money but also a competitive advantage, no decision-making process can afford to be burdensome or subject to long delays and over analysis. We cannot claim that the methods in this book are faster than intuition, gut feeling, or seat-of-the-pants decision making, only that they can be streamlined as time and context demand (Timmerman and Vlek 1994). It is for this reason that we provide numerous decision templates to enable decision makers to more rapidly frame decisions by analogy. Where data do not exist or are too time-consuming to gather, subjective expert opinion can fill the gap. However, true efficiency comes from the need in many contexts to explain and modify the decision, often more than once. There may be higher and higher level management reviews or reviews and modifications when management changes. Decisions should also be reviewed and updated when new information becomes available, the environment changes, or new options arise.

1.3.3 Disciplined

Corporate executives often establish, oversee, and strive for discipline in product development, manufacturing, or service delivery, but they fail to expect discipline when it comes to decision making. They embrace Six Sigma as a quality management tool that can bring discipline and reduce variability in processes but often do not see the parallel need when it comes to the process of decision making. The decision-making processes presented here offer a discipline that is replicable throughout a corporation across a broad array of decision contexts. They support decision making at all levels of the organization and across departments. The ability to replicate the processes also means that they can be continuously improved and organizational structures can be put in place to deliver and maintain critical data inputs as well as to streamline and update decisions. The discipline can also bring transparency to the process, thereby enhancing buy-in and speeding implementation.

1.3.4 Value-Added Decisions

The types of decisions we address involve a limited number of distinct alternatives. If our only goal is simply to find the best choice, it would be difficult to demonstrate that the proposed process is much better than a gut feeling. However, the approach of this text is geared toward clarifying the strengths and weaknesses of the strongest alternatives, not merely in finding the best one. This clarification enables a decision maker to develop more robust strategies and cost-effective contingency plans as uncertainty evolves. In addition, the analysis provides insights that enable creative individuals and decision teams to enhance an alternative or to develop a hybrid that is better than all the original options. Thus, the outcome of a particular decision may be enhanced in any or all of the following ways:

- Considering a more complete list of alternatives will result in outcomes that have higher values and entail fewer risks.
- Clarity of explanation will lead to a greater chance of implementation.
- Clarification of the strengths and weaknesses of a particular plan will enable more effective updating as the situation changes.

1.4 Do Not Trust Your Gut

"Two of every three (executive) decisions use failure-prone practices" (Nutt 2002). The goal of this chapter is to force you to take a hard look at how you and others around you in your organization, whether it is a company, government agency, or educational institution, make important decisions. The primary alternative to a structured decision-making process (leaving aside astrology, crystal balls, and prophecy) is intuition developed from experience. We develop the case *against* intuition from three vantage points: (a) representative debacles and patterns of bad decisions, (b) experimentally demonstrated biases, and (c) evidence of decision complexity.

It is common to find articles and even entire books in praise of intuition. *Harvard Business Review* published "When to trust your gut" (Hayashi 2001), but later followed up with "Don't trust your gut" (Bonabeau 2003). The primary case for experienced intuition has often been made by senior executives who, almost by definition, have had successful decision-making careers—sometimes relying heavily on gut feelings. One survey has reported that 45% of executives use intuition more than analysis to run their businesses (Bonabeau 2003). And yet, as Ralph S. Larsen, the former CEO of Johnson and Johnson, noted (Hayashi 2001) what works during the early phases of a career may not succeed when one climbs up the corporate ladder: "Very often, people will do a brilliant job up through the middle management levels, where it's very heavily quantitative in terms of decision making. But then they reach senior management, where the problems get more complex and ambiguous, and we discover that their judgment or intuition is not what it should be. And when that happens, it's a problem; it's a *big* problem." Larsen's point reaffirms the main thesis of this book; indeed, our primary audience is not the CEO, but the lower-level manager working his way through the ranks of middle management. It is he, or she, who must learn from the very start to integrate a proper balance between intuition—a specious quality at best—and quantitative analysis—a far more reliable, scientific approach to assessment of plans.

Larsen himself stresses the utility of intuition with regard to mergers and acquisitions: "When someone presents an acquisition proposal to me, the numbers always look terrific: the hurdle rates have been met; the return on investment is wonderful; the growth rate is terrific. And I get all of the reasons why this would be a good acquisition. But it's at that point—when I have a tremendous amount of quantitative information that's already been analyzed by very smart people—that I earn what I get paid. Because I will look at that information and I will know, intuitively, whether it's a good deal or bad deal." Part of the justification for the unprecedented growth in salaries for senior corporate executives in the United States is reflected in Larsen's self-assessment of his value. A board of directors must pay a premium for the experienced-based intuition retained in the memory bank of the unique and irreplaceable CEO—or so goes conventional thinking.

We cannot speak to Larsen's personal track record on mergers, but the literature is clear: mergers and acquisitions do *not* usually deliver the forecasted added value to the acquiring corporation, and, in fact, they often reduce its value (Cartwright and Schoenberg 2006). In one study of 53 high tech mergers, only 11 were considered successes (Chaudhuri and Tabrizi 1999). In a study of 131 mergers greater than $500 million, 60% reported negative returns at the end of 12 months (Eccles et al. 1999).* Strangely enough, Hayashi included in his list of star decision makers Bob Pittman of America Online. Pittman is quoted as saying that "probably more than half of [his] decisions are wrong" but that he does not worry because he routinely reviews his decisions, learns quickly from his mistakes and makes adjustments as needed. This self-proclaimed flexibility notwithstanding, the AOL Time Warner merger failed to live up to expectations, and Pittman was forced to resign in 2001. In 2009, AOL was spun off and became an independent company once again.

Let's take a closer look at mergers and acquisitions, since decisions in these areas are both highly visible and prone to intuitive decisions (for better or worse). The acquiring corporate management team always pays a premium on the value of the acquired corporation, on average 36% (Nutt 2002) under the belief that the combined organization can deliver synergies in the form of increased market potential and dramatic cost savings. This optimistic executive belief in their own abilities to create greater value and minimize the challenges of combining two distinct corporate cultures is representative of a variety of decision-making biases described by Lovallo and Kahneman (2003) in the aptly titled HBR article, "Delusions of Success, How Optimism Undermines Executive Decisions." To cite an extreme example consider the Daimler-Benz and Chrysler merger/acquisition of 1998. This merger involved two companies of similar size with very distinct national and corporate cultures. The stock value of Chrysler at the time was an estimated $38 billion; in 2007, when the merger was reversed and Chrysler was sold, its value was less than $10 billion.

When considering claims of the value of intuition from successful executives, imagine the findings from a study of successful lottery winners. What would you learn from asking a 100 lottery millionaires, "What strategy did you use to pick the winning number?" If you believe their answers would be of value, you probably should stop reading this book now and either ask for a refund or sell it. Use the cash to buy a lottery ticket. While it is an exaggeration to say that CEOs reach their exalted positions simply by luck, randomness will cause individuals with winning streaks of so-called good decisions to stand out.

* The high tech mergers study reported eleven successes, nine failures and 33 with zero or slightly positive returns. The study of large acquisitions noted that 59% of the time the stock market value of the acquiring company went down with the announcement. Clearly, the markets did not believe the majority of these mergers created value for the acquirer.

1. **Activity**: Coin flip: You are about to flip a coin eight times. Please choose which of the following outcomes you expect.
    1. An equal number of heads and tails
    2. The number of heads and tails differs by exactly two
    3. The number of heads and tails differs by three or more

Now flip a coin eight times.

Record the number of heads ______ and tails ______ and the net difference ______.

Did the outcome match your choice? ______ If the choice and outcome agree, does that mean that you made the best decision? ______

In a class of 30 students, the number of students whose choice matches the outcome could be as low as 4 or as high as 16. Did all of those students whose decision and results match make the "best" choice, even though their choices for the identical experiment were different?* Do you believe that they were better at controlling their destiny in achieving their predicted result?

Now consider a hypothetical scenario. Your organization has 500 workers, each making decisions with only a one-in-two chance of success. A manager who decided "correctly" seven times in a row would seem to have a much better understanding than the average manager. The likelihood of picking correctly seven times in a row on a 50–50 bet is only one in 128 ($1/2^7$). A decider this good is in the top 1% of the class. However, purely by randomness, an average of 4 managers out of every 500 should hit it right seven times in a row. Those who decide correctly at least six times out of seven will be in the top 7% of their peer group. Nevertheless, they need not have any special insights—just better luck. Bazerman (2006) offers a similar analogy with regard to placing your money with an investment agent. Every year just by randomness a percentage of brokers will outperform a stock portfolio indexed to the S&P 500, but the percentage keeps dropping dramatically as you take a longer and longer multiyear look at the data. Bottom line: it is wiser to go with an index with low fees than trying to pick a fund that seems to be an above-average performer.

2. **Activity**: Can you point to a situation in which you believe your organization made an extremely risky decision to save a buck, such as using an unproven technology or inexperienced supplier, that you did not think was justified but the results turned out satisfactorily? Were decision makers rewarded because of the outcome? Explain.

    ____

3. **Activity**: Can you point to a personal situation in which you or someone you know made an extremely risky decision that in retrospect was not really justified but the results turned out satisfactorily? Explain.

    ____

Conversely, it is not necessarily correct to focus on examples of bad or unsuccessful outcomes in order to uncover bad decision processes. Research and Development (R&D) projects are notable examples of low probabilities of success. A failed R&D project, one that did not result in a profitable product, does not necessarily mean that it was a bad decision to pursue the project initially. However, a company that has an 8% success rate of converting projects into marketable products or services

* This experiment follows the Binomial Distribution Probabilities discussed in Appendix A.
(1) Equal number (70/256 = .273)
(2) Differ by exactly 2 (112/256 = .438)
(3) Differ by 3 or more (74/256 = .289)
Individuals who made the best choice, "differ by exactly 2," will still experience a bad outcome more than half the time. However, individuals who selected 1 or 3 will experience a bad outcome almost 3 out of 4 times.

year after year as compared to only 3% for a company in a similar industry likely has a better process for evaluating projects and managing the transformation from laboratory idea to commercial product.

4. **Activity**: Can you point to situation in which you believe your organization made a reasonable choice in an uncertain world but the results turned out unsatisfactorily? Were decision makers punished because of the outcome? Explain.

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5. **Activity**: Can you point to a personal situation in which you or someone you know took a realistically evaluated risk but the results turned out to be unsatisfactory? (e.g., you spent a good deal of time gathering available information about a new job offer, but the company went bankrupt a year later due to corporate executive misinformation.) Explain.

Individual examples of debacles do not make the case *against* intuition in the corporate executive suite any more than successful executive careers built on intuition make the case *for* intuition. It is valuable to recall Robert Burns's classic lines,

But, Mousie, thou art no thy lane,
In proving foresight may be vain:
The best laid schemes o' mice an' men
Gang aft-agley…

The mouse expended significant energy in designing its little home only to have it plowed under by the oblivious farmer.

The focus on infamous debacles can also misdirect research. It has been argued (Fuller and Aldag 1998) that too much of group decision research has been distorted by the groundbreaking study of the Kennedy Administration's Bay of Pigs fiasco that led to the popularization of the term Groupthink (Janis 1972). However, Paul C. Nutt, in *Why Decisions Fail*, uses a more rigorous approach to determine good and bad decision-making processes and to highlight "blunders and traps that lead to debacles." We present the results of this and related research in Chapters 13 and 14.

At the microlevel, Klein (1999) builds a case for intuition based upon examples involving chess masters, fire fighters, officers on the field of battle, or emergency room physicians, who successfully employ split second intuition to make decisions that are, for the most part, successful. Even retrospectively, they are unable to provide a structure for their decision-making process. We do not debate Klein's underlying thesis, but we reject the idea that these experiences can be usefully extrapolated to the vast majority of professional or personal decisions. Unlike the chess master, few of us play and replay in our minds thousands upon thousands of variations of chess board patterns, learning to recognize good strategies without exhaustively thinking and weighing the alternatives. Nor are we like the firefighters or soldiers who spend hundreds and sometimes thousands of hours training for a range of emergencies and studying other people's mistakes so that they can make the best split second decision possible. Nor are we like the emergency room physician with a decade of education supplemented by thousands of hours of direct mentoring along with constant review and debate regarding actions and decisions including things that went wrong.

Even within the medical field, the Society for Medical Decision Making has, since 1979, pushed for more structure for medical decisions so as to integrate physician experience and hard data. Of particular concern is the reality that physicians often function under extreme time pressure leaving inadequate time to assess fully the available data. The journal *Medical Decision Making* features articles that offer structure to both individual treatment decisions as well as public policy questions. We will draw on their examples to demonstrate the main methodologies of this text.

There are three primary difficulties in developing intuition for tackling complex problems. First, we seldom have the opportunity to learn directly from our experience, since we rarely face the same decision context over and over again. How many times in your life are you going to choose which college to go to, what subject to major in, or which first job to accept at the start of your career? This problem is compounded in the American corporate culture wherein managers expect to change jobs frequently as they rise up the corporate ladder. This situation precludes their developing the deep technical intuition that is common in, for example, the managers of German and Japanese, automotive companies.

Second, as Yogi Berra said, "When you come to a fork in the road, take it." After selecting a college, we can look back on the experience we had, but we cannot know how our lives and careers would have developed if we had picked the alternative. The same is true when we pick a supplier for our IT infrastructure or our home remodeling. We will know how well the choice worked out and experience the problems that arose, but we will never know what would have happened had we gone in another direction. As Robert Frost said, "I could not travel both and remain one traveler." (Frost, "The Road Not Taken").

Finally, the feedback loop leading to success or failure, especially when involving major corporate decisions, could take years to close. There will be numerous intervening factors, some controllable and some uncontrollable, that will affect the final success or failure of, for example, the launch of a major new product or service. Moreover, the individual who made the decision is likely to have long since moved on to another part of the organization. All of the aforementioned issues contribute to why decision-making experience does not readily translate into expertise (Bazerman and Neale 1992).

Meteorology is one context in which decisions are repeated daily; some feedback loops are closed in a day and others in 10 days. Weather forecasters do not use intuition, but rather sophisticated models that are continually being refined. Over time, they have been able to deliver better and better probabilistic forecasts over longer and longer periods of time. Theirs, however, is not a typical situation.

Nevertheless, despite education and extensive research, executives continue to cling—with no small amount of pride—to the unique value of their intuition. Each can personally recall one or more instances in which, he claims, following his intuition produced exciting results. The intermittent reinforcement of high profile success makes it extremely difficult to overcome what is still a dysfunctional behavior. Perhaps, it is time for executives and their organizations to stop relying on intuition and begin adopting and refining approaches outlined here so as to develop more consistent and higher quality decisions.

While criticizing the overuse of intuition, we do not want to minimize the value of in-depth *knowledge* in specialty areas such as engineering design or new product marketing. In 2007, Ford Motor Company significantly reduced its vehicle launch problems, thereby reducing dramatically their warranty costs, when they brought together a team of experienced assembly line workers and engineers to spend months reviewing the final design of a new model. They were able to identify numerous potential problems and suggest appropriate means through which to prevent them from occurring (*Detroit Free Press*, August 28, 2007). This was possible because sitting at the table was literally more than a thousand person-years of work experience, involving some of the company's best workers from both engineering and manufacturing.

1.5 Maximize versus Satisfice

The decision-making processes developed in this text include the following basic tasks:

- Identify as wide a range of alternatives as practically feasible
- Collect comparable data for each of the alternatives
- Select the best alternative based on some measurement scale

These processes are aligned with the approach first articulated by von Neumann and Morgenstern (1953) that includes axioms that characterize rational economic decision making (see also Simon 1955, 1956, 1957). However, extensive research in psychology and behavioral economics has documented a wide range of common behaviors that violate the assumptions of consistent rational economic man. These issues are explored in two later chapters, on forecasting bias and decision-making bias. In these chapters, we define the biases and suggest ways of overcoming them with the goal of being more consistently rational economically. However, there is one decision-making approach, called satisficing, that is at almost total variance with a strategy of utility maximization.

A satisficer seeks an alternative that is good enough. He has defined for himself an acceptable threshold and picks the first alternative that surpasses this threshold. His search is far more limited than the maximizer's because he is unconcerned with finding and picking the best. Simon (1956) argued that this type of behavior is still economically rational if the cost of additional search and analysis is less than the expected gain from considering more alternatives. However, it is well documented that the primary reasons for choosing to satisfice rather than maximize are psychological and not the result of an analysis of the benefit of additional search.

A satisficer scans what is playing in the local movie theaters and picks a movie he thinks he will enjoy. A maximizer identifies multiple movies that he is interested in seeing and then decides which movie he would prefer that day. A satisficer looking for a home to buy will stop his search when he finds the first house he likes that has generally what he wants and is in his price range. A maximizer will continue searching until he has seen a number of houses he is willing to buy and only then compare and contrast them to determine which is best.

Schwartz et al. (2002) developed a scale to determine whether an individual is primarily a satisfier or maximizer. Some of the self-descriptions used to characterize an individual as a maximizer are as follows:

1. Whenever I make a choice, I'm curious about what would have happened if I had chosen differently.
2. When I am in the car listening to the radio, I often check other stations to see if something better is playing, even if I'm relatively satisfied with what I'm listening to.
3. I'm a big fan of lists that attempt to rank things (the best movies, the best singers, the best athletes, the best novels, etc.).
4. I never settle for second best.

The second dimension of this research assessed the overall psychological status of the two groups of undergraduates in the study. In comparison, maximizers reported significantly less life satisfaction, less happiness, less optimism, and lower self-esteem. They tended to more frequently make social comparisons between themselves and others in a variety of contexts. Schwartz et al. (2002) hypothesized that the very nature of maximization involves not only considering a wider range of alternatives but also always wondering whether there is another alternative that is even better. When a final choice is made, there is a greater opportunity for regret since the maximizer has taken more responsibility and ownership for the choice he has made and for the choices he did not make. Parker et al. (2007) documented the greater tendency for regret among maximizers and also found that maximizers more frequently reported avoiding or postponing decisions.

Last, Iyengar et al. (2006) carried out an interesting study that involved tracking more than 500 soon-to-graduate students at 11 diverse universities as they pursued their post-university jobs. These students were surveyed as they began their search, once again in the middle of the search, and also at the end of the process when they accepted a job. Maximizers reported an average 20% higher salary and yet reported that, on average, they were less satisfied with the final job offer when compared to satisficers. In addition, they experienced more negative emotions during the job search process when compared to satisficers.

All of the earlier research was done with college students and involved personal decisions. What is not clear is how much of this phenomenon exists in organizational decision-making settings. Do business managers often utilize a satisfice approach to making business decisions? Do personal behavioral decision traits carry over into the work world?

1.6 Established Biases

There is extensive literature based on classroom experiments and observations of decision makers that demonstrate common, unconscious biases that arise when making forecasts and decisions. Bazerman (2006) provides an excellent summary of the psychological literature, while Keeney et al. (1998) provide a focused managerial perspective. We cover these issues in Chapters 13 and 14 but for now we will illustrate the following three biases.

1.6.1 Sunk Cost

Have you ever gone to an expensive show or movie and after 15 or 20 minutes found you disliked the show or movie, yet you stayed to the very end? Did you find yourself thinking, "Well, maybe it will get better" as you sat there longer and longer trying to remain focused? This scenario illustrates the concept of sunk cost. Having invested money and time in an enterprise, you are reluctant to admit that your investment was wasted. You may even be embarrassed if you brought a friend along. This is likely to cause you to proceed to invest even more time, thereby escalating your commitment further.

A clear-headed rational decision maker would focus solely on future value and not money and time already wasted—cost that has already sunk. The decision whether or not to stay should simply depend on your estimate of the future. However, the concept of sunk cost can cloud your judgment. Experience tells you that movies or plays rarely get better after a poor beginning; they are not like football games. Yet you hope, irrationally, for the best in order to redeem your initial decision to attend the movie. The same bias comes into play with life and death consequences in wars. Even when a clear consensus agrees that a war cannot be won, it is extremely difficult to start planning a strategic withdrawal. How often have we heard that we cannot leave a particular confrontation because to do so would suggest the lives sacrificed thus far were wasted? And yet, it is unspeakably wasteful to risk additional lives because of a stubborn unwillingness to focus on the future and recognize the sunk cost of the past.

1.6.2 Framing

Scenario A: Imagine you drive up to the gas station and see the price per gallon is $3.10. The sign says this is the price if you pay cash. However, if you want to pay with a credit card, you will have to pay a 10 cent premium per gallon.

Scenario B: The price on the pump is $3.20 if you use a credit card. However, if you choose to pay cash you will receive a 10 cent discount per gallon.

Drivers in scenario B are more likely to use the credit card than in scenario A. The framing of the credit card as a base value instead of a premium affects people's willingness to pay the $3.20 credit card rate.*

* This example also includes an anchoring bias. Anchoring occurs when an individual fixes on the first number he sees and assesses everything as a deviation from this base. Negotiators may start negotiations by using an initial value that is extremely in their favor. They might price a product at double its value recognizing that counteroffers are likely to be 10% or 20% less, not 50%.

Such a framing bias had serious consequences for Coca Cola in 1985 and contributed to the decision to change its recipe and launch New Coke. Management was concerned about recent declines in market share (Whyte 1991). As a result, they made a risky decision to change their formula even though this meant jeopardizing their very large base of still loyal customers. It is well documented that when decisions are framed as a potential loss, decision makers become more risk-prone. For example, people will take the risk of holding on to stocks that have lost value longer than they should as compared to holding on to stocks whose value has increased. In both instances, the only factor, aside from tax issues, that should govern the decision is future projections and not the original price paid (Shefrin and Statman 1985; Odean 1998).

1.6.3 Motivational

One of the toughest biases to overcome is when self-interest leads to overly optimistic predictions. Many companies require proposals for a new product or service to include an estimate of the ROI. To be approved, the new concept must have an ROI that surpasses some established hurdle value. Not surprisingly, the team that has generated and worked diligently on the new concept may consciously or subconsciously overestimate market potential while underestimating the time and money it takes to bring the concept to market. Light rail and other mass transportation projects, for example, often generate motivationally biased forecasts. In one study of 10 light rail projects, the projected ridership was 15%–75% above the actual. Construction cost overruns averaged 150% and operating costs averaged 200% above forecasts (Nutt 2002).

1.7 What Makes a Decision Difficult?

Decision making is difficult for reasons we have grouped into three categories: impact, problem complexity, and context. Decisions with a major impact may keep you awake at night worrying. If the problem is complex, it will be difficult to sort out the factors, account for all of the issues, and assess the likely impact of your decision. Last, many decisions are not made in a vacuum: they are complicated by the need for others to be involved in the decision and by a process compressed due to time pressures.

1.7.1 Major Impact

Decisions become tougher as more hangs in the balance. On a personal level, we all periodically face life-changing decisions. Where to go to college? Whether or not to get married, and if so, to whom? Whether or not to have children, and if so, how many? Which community to live in and which house to buy? No less difficult are the decisions we make at the end of our lives. When faced with a serious illness, for example, we often must decide—for ourselves or for those we love—on a treatment option that involves a trade-off between quality of life and projected length of life.

Many of our high-impact personal decisions are job related. A career choice sets the educational foundation for a wide range of future decisions, as may one's first job choice. However, as societies change and people switch jobs and even careers more frequently than in previous generations, the consequences of each decision decline in significance. Although money often seems to dominate the decision-making process, other factors related to job environment are, in fact, more important when it comes to job satisfaction. And toward the end of an individual's career, one of the more difficult life-changing decisions—one that seems to be occurring more frequently, especially in the biggest corporations—is whether or not to accept the offer of a buyout or early retirement.

At the corporate level, mergers, acquisitions, and bankruptcy impact the very essence of a corporation as well as its tens of thousands of workers. Major internal organizational restructuring options should be, but are not always, treated as tough decisions. The process is further complicated by the inability of management to quantify the short-term as well as the long-term effects of their decisions. In some instances, these decisions force a paradigm shift upon the organization as it attempts to redefine itself. But aside from obviously significant restructuring decisions, there are other seemingly smaller decisions that may ultimately have equally great impacts on an organization. Outsourcing one segment, such as IT, is an especially tough call, one that is usually extremely difficult to reverse. This only adds to the pressure to get it right the first time.

1.7.2 Problem Complexity

Among the factors that increase decision complexity are multiple objectives and uncertainty. The challenge of balancing and trading off multiple, often-conflicting objectives adds complexity to every service and product development project. There will always be financial objectives to consider alongside of performance objectives. In addition, minimizing time to launch is often an implicit objective, especially in today's highly competitive market.

Decisions related to the selection of plant equipment involve balancing objectives such as operational issues, space requirements, training requirements, and cost. Decisions related to selecting a supplier involve both multiple objectives and elements of uncertainty if the company has not worked with the supplier before. There are issues of cost, quality of work, timeliness, and responsiveness to concern. Uncertainty complicates the comparison of alternatives, especially when the level of uncertainty is not equal across the alternatives, such as when choosing between a proven and unproven technology. The unproven technology is surrounded by uncertainty regarding the time it will take to complete myriad engineering design tasks as well as the cost and resources required to implement and maintain it. Other concerns relate to whether or not the new technology can be implemented in the time allotted and whether or not the launch of a product or manufacturing start-up might need to be delayed.

Every new product or service faces uncertainty regarding market demand. This uncertainty creates ambiguity regarding predictions of revenue and profitability. Unknowns surrounding competitive actions compound the randomness. Every policy regarding the handling of customer complaints and whether or not to provide financial compensation faces uncertainty regarding a disgruntled or satisfied customer's future behavior and how that behavior might influence others in his social group.

The analytic techniques of this book are designed to assist in selecting the single best option among distinct alternatives when faced with multiple objectives and/or uncertainty. However, there are many other decision contexts and various other factors that affect decision complexity, and the recommended modeling approaches for these are beyond the scope of this book. We list some other modeling techniques in the appendix at the end of the chapter.

1.7.3 Personal and Organizational Context

The context in which a decision is made can also increase its difficulty. If you are a wealthy orphan deciding on which college to attend, the decision is yours alone. In contrast, if your parents are alive and well and are paying for your college education, the decision dynamic becomes more interesting. The level of involvement will also vary as a result of whether or not your parents are also college graduates. At the minimum, you will have to provide a valid justification and explanation of your decision.

The same concept applies in hierarchical organizations in which critical decisions must be reviewed and approved by multiple layers of management and possibly across organizational divides

TABLE 1.1: Context complicates decisions.

Management turnover	Multiple organizational perspectives
Time pressure	Global cultures
Competitive pressures	Negotiated decision
Strong personalities	Poor quality and availability of data
Dynamic environment	Competing interests: equity versus efficiency
Long lead times to implement	

such as finance, marketing, and engineering. If the decision is a technical one, there may be an added challenge that can vary across national cultures. In an American company, the technical expert may find he has to explain the decision to higher levels of management who are not technically sophisticated and know significantly less about the technical issues and challenges. However, much of the time spent defending the decision will focus on estimates of time and resources required while management may downplay the project's complexity, since it neither comprehends nor appreciates this aspect of the endeavor. If there is frequent management turnover, the requirement to justify a decision can become a nightmare. In contrast, in a German or Japanese company, the individual will often have to spend more time justifying the technical elements of a decision, as the higher-level officials are likely to have more expertise than he.

Time pressure is perhaps the single most common factor that increases the difficulty in making high-quality decisions (Svenson and Mauke 1993). It forces managers to take shortcuts such that there may be only enough time to evaluate one or two alternatives. Time pressure precludes taking a step back to look at the big picture, including multiple objectives. Complex decisions are simplified to absurdity. When time runs short in a group decision, the influence of personality becomes even greater. Strong personalities may push through decisions that are inadequately evaluated and negate other alternatives without allowing a full hearing. Table 1.1 lists contextual factors that complicate decision making.

Decisions that cut across organizational boundaries will be more complicated, particularly when it comes to reaching a consensus. In today's global economy, products and supply chains are likewise global, and meetings and decision teams are likely to involve experts and managers from diverse national cultures. These experts bring different values to discussions, the dynamics of which are often culturally sensitive.

Public sector decisions involving power plants, resource allocation, public transportation, or governmental regulations face a special trade-off decision. They must juggle both what is best for the public and what is equitable for the various special interest groups affected by the decision.

Negotiated decisions represent a unique class. Two sides are approaching the same issue, each from its own perspective. Usually, each side's objective is to get the best deal for itself that the other side will accept. Analytic tools can help any one side evaluate a contract offer; however, other skills are required in order to obtain the best results, especially if the two sides expect to maintain a mutually beneficial long-term relationship.

1.7.4 Fuel Tank Example

Let's illustrate the decision context challenge with what may seem a relatively narrow automotive concern: the design and location of a fuel tank. It would be nice if one human being had all the knowledge and information required to make this technical decision, but that is extremely unlikely. The decision team must have knowledge of material science as it relates to the fuel tank itself, the sensing devices within the tank, and the impact of diverse gasoline additives that vary across gasoline retailers. The team must understand manufacturability, packaging, and survivability under various crash conditions, not all of which can be tested in the laboratory. They must also be up to date on all the latest environmental regulations, current and proposed. In all likelihood, they will also need the blessing of finance officials to certify that their investment and variable cost estimates are accurate and in line with those that have been authorized for the targeted vehicle program. Finally, they might need a marketing analyst to assess the importance of the capacity of the fuel tank. Smaller size might ease issues of packaging but may place the intended vehicle at a competitive disadvantage. The challenge to the team is to draw upon and integrate the narrowly focused expertise of individuals from broadly different backgrounds—engineering, marketing, and finance.

Now imagine the fuel tank is to be used on a vehicle to be marketed around the globe. Fuel mixtures vary from country to country. Vehicle operating conditions, which might stress the fuel system, also vary in terms of ambient temperature and road conditions.

If all these factors have not created enough pressure for the decision team, someone brings up the infamous Ford Pinto gas tank that could not withstand certain rear-end crashes and resulted in the loss of millions of dollars in lawsuit judgments. Then, someone else jumps in with the story of CBS reporters and producers staging a side impact crash on a GM truck and then artificially creating a fireball explosion. In the end, the decision maker must decide while facing multiple levels of management scrutiny and recognizing the fact that there is no one viable gas tank that can withstand every possible crash scenario.

1.8 Symptoms of a Poor Decision-Making Process

Reliance on intuition as the primary decision arbiter is but one symptom of a poor decision-making process. Other common symptoms include a tendency to consider just one alternative, failing to look at the big picture, frequently revisiting one's decisions, allowing strong personalities to drive decisions, ignoring uncertainty, overusing inexpert opinion, and establishing a weak link between decisions and implementation.

1.8.1 Narrow Focus: One Alternative and One Objective

One of the most common symptoms of poor decision making is a tendency to frame decisions around a single alternative.

Should we set up low-cost manufacturing in China?
Should we buy a new software technology to streamline product development?
There is a new high-tech gizmo that can be added to a car; should we design it into the next product?

These sorts of question should not be considered in a vacuum; too many factors hang in abeyance. And yet, strangely enough, four out of five decisions consider only one idea (Nutt 2002).

Alternatively, do you find yourself bombarded with these types of questions from upper management in your organization while you are trying to get your work done? Does every new idea, repackaged idea, technology, material, or business opportunity that a manager learns about generate a study as to what the company should do? Does every new product or service your competitor launches lead to the question of whether your company should offer this product or service as well? Worse yet, are these requests framed with a sense of urgency?

While rushing to set up low-cost manufacturing in an emerging market, a certain company went through a series of wasted initiatives. This company chose a candidate product and identified a suitable manufacturer only to find out months later that one of this product's components could not be manufactured at the quality level necessary for inclusion in a mainstream product in the United States. The mistake was repeated as the company considered product after product for manufacture in the emerging market. Sadly, but not atypically, this dynamic was triggered in part by a senior executive announcement that within 12 months the company would be importing hundreds of millions of components from this low-cost country. The powers that be did not take the time to frame the issue as a set of related decisions or to broaden the discussion.

The discussion should have included the following questions:

- Which of our company's products should be manufactured in China, Mexico, Eastern Europe, or somewhere else?
- What are the risks, and what strategies can be employed to mitigate those risks?
- How can the company streamline product development and how does global manufacturing play a role in this process?
- Can manufacturing in a low-cost country also add value to our products or only cut costs?
- Can low-cost manufacturing open up new market segments for our products?

On a personal level, do you tend to frame your decisions as "Should I buy this car that is on sale?" instead of "Which car should I buy?" Much of price-reduction marketing is designed to get the consumer to focus on the one alternative, here and now, rather than consider the big picture that includes a range of alternatives. Similarly, do you live in a city in which local officials suddenly decide that there is a need for a new city hall, a new high school, and a new library or fire station, without delineating the process through which this important decision came about? If you are lucky, you get to vote yes or no on a bond issue, but you are unlikely to be made aware of any serious debate with regard to the range of options, leasing versus buying, or facility size.

One factor that contributes to limiting the range of alternatives and narrowing the focus is time pressure (Svenson and Mauke 1993). If you often hear around the office statements such as "We do not have time to consider other alternatives" or "We need to make the decision now!" then the decision-making process is flawed.

6. **Activity:** Describe the last time a senior executive or boss came up with one specific new alternative and asked you to evaluate it. Was there time pressure? Alternatively, describe a yes or no facility decision of your local government. Would it have made sense to look at a broader range of alternatives?

Has your organization blindly pursued one overriding objective to the detriment of other factors that would make an organization healthy and successful in the long run? Senior executives of American corporations have been on a short-term stock price binge for almost a decade. How many groups have faced serious cost-cutting drives while paying lip service to quality and customer service? What about market share as the focus and "to hell with profitability?" "Thou shalt cut inventory to the bone" is another mantra that ignores the need for safety stock to handle fluctuations in demand or in the supply chain

7. **Activity**: Describe a specific decision that was heavily influenced by your company's pursuit of one objective to the detriment of an entire range of other measures.

1.8.2 Decision Arbitrarily Revisited

Have you ever watched as turnover in management resulted in a comprehensive review of issues that you thought had long ago been resolved? American organizations move their managers from job to job more frequently than their counterparts in Europe and Japan. The reason is to increase the breadth of these managers' experience as they move up the corporate ladder. The individual may stay less than 2 years before moving to a whole new area. He is unlikely to develop in-depth knowledge within his sphere of responsibility. However, rather than simply accepting the opinions of those with technical expertise and abiding by earlier decisions, a new manager may be driven to make an impact quickly. Thus, many prior decisions are up for review even though the circumstances surrounding the original decision have not changed significantly.

The staff regathers the data, updates the presentation, and begins the debate all over again. Unfortunately, the lack of a structured decision-making process means that the earlier so-called final decision had an irreproducible dose of gut feel. It was also influenced by the dynamics of the decision meeting that may have involved a different mix of experts.

1.8.3 Personality-Driven Decisions

Another challenge arises when decisions are heavily influenced by strong personalities in leadership roles. If an executive states his support for one position and the result is that few if any negatives are allowed to be presented, then your organization has a dysfunctional decision-making process. If much of your time is spent trying to find out what one executive is likely to think about an option, your decision-making process is misdirected. If meetings are dominated by individuals with the highest rank, your organizational structure is dysfunctional. If much of the time of your support staff is spent proving that a preconceived solution is the best rather than assessing the potential of the alternatives, you have a problem of misplaced analysis.

Worse yet, an organization might have a "multiple-personality disorder." Strong personalities and their supporters in various parts of the organization may strongly advocate their specific agendas. Instead of open discussion and debate on merits and weaknesses of different alternatives, each side only presents the positives for its preferred choice, hiding the negatives so as not to undermine its cause. In the end, one side "wins" and the other "loses," which inspires the latter group to work, either passively or actively, to undermine decision implementation (Garvin and Roberto 2001).

8. **Activity**: Describe an instance in which a strong leader did not allow for adequate analysis and discussion of strengths and weaknesses.

1.8.4 Ignoring Uncertainty

Market demand is unknown, technologies are unproven, product development timelines contain many uncertainties, and competitors are unpredictable. Yet, too many organizations still use only single-point estimates to guide their decision making. As an admission of their planning or forecasting fallibility, they add modest buffers to budgets, timelines, or manufacturing capacity. Yet, they shy away from explicitly acknowledging and analyzing the depth and breadth of the uncertainty surrounding a decision or initiative.

One of the major themes of this book is that uncertainty should be articulated, communicated, analyzed, and anticipated. Forecasting uncertainty requires greater knowledge and experience than coming up with a single-point estimate. Uncertainty is neither an admission of ignorance nor evidence of weak, unfocused leadership (Shephard and Kirkwood 1994). It is recognition of an uncertain reality. Einstein may or may not have been right when he said, "God does not play dice with the universe." However, in the absence of prophets who might have an inside track into perceiving God's will, we live in an uncertain dynamic world, especially with regard to technology.

9. **Activity**: Describe an instance in which a decision was made while ignoring a broad range of obvious uncertainties that would affect the outcome of the decision.

1.8.5 Inexpert Opinion

Many decisions involve data collection and extensive analysis. In a technical environment, this could also include complex testing. And yet, in the final analysis, a significant amount of subjective judgment is used to complement the data collection. Few decisions are exactly the same as the one before; the data are not complete and cannot cover all situations. There are always new facets and challenges to consider when new ideas are integrated. Moreover, the egalitarian nature of many U.S.-style decision meetings and conferences allows everyone present to offer an opinion on every issue brought up. This can be counterproductive; not all people at a meeting are equally qualified to offer their opinion. With apologies to George Orwell, some are "more equal than others," namely those who have expertise in particular areas. This problem is compounded by the American philosophy of management, which posits that even the managers of technical groups do not need to be experts in their respective fields in order to be good managers.

This prevailing sense of egalitarianism dictates that experts with decades of experience in their specialty must cope with representatives from other specialties chiming in at meetings. Worse yet is when, for example, the finance staff asks, "Why can't you get by with less time, money, and personnel?" or "Why can't this object be made of a lighter, less costly material?" Conversely, engineers do not hesitate to offer their opinion on market trends and whether or not the product fits the customer niche, even if there is little overlap between the engineer's experience or expertise and the concerns of the targeted customers. One senior automotive executive declared his objection to a vehicle's sound system because he had just bought a $10,000 sound system for his home and claimed that this qualified him to know what a good car sound system should sound like. He was oblivious to the fact that the vehicle was targeted at the low end of the price spectrum, and he was 30 years older than the average purchaser and had different values.

10. **Activity**: Describe an egregious example of an individual offering an opinion on a technical issue outside his area of competence.

1.8.6 Decisions Poorly Linked to Later Management Actions and Little Accountability

Has your organization decided to make a particular process paperless, change suppliers, change a material of a critical component, add a major new facet to a new product, or redesign a manufacturing process? All these decisions require extensive follow-up, throughout and beyond the process of implementation. Rarely are complex decisions simple to implement, especially with limited resources and an environment in which staff are already stretched to their limits.

A decision that goes unimplemented is not much of a decision. Yet, ease of implementation is not necessarily factored in when evaluating alternatives. All too often, key stakeholders with primary responsibility for making things happen may feel that their experience was not adequately considered in the decision-making process and have therefore not bought into the decision. They hope that the decision will just go away so that they can get on with their regular jobs without the added hassle of one more poorly thought out top–down decision.

Complex decisions cut across multiple organizational functions. The interdisciplinary team that was involved in the decision may not have sorted out areas of responsibility for the implementation and issues of coordination. The high-level decision makers may not even have direct responsibility for the groups that will bear the major burden for implementation.

Oftentimes, implementation carries added costs that were not budgeted for at the decision-making stage. State and federal government agencies and decision makers are notorious for forcing significant change without considering how these changes will be paid for. The No Child Left Behind Act, for example, mandated significant testing, monitoring, and process improvement requirements in local school districts without providing resources to sustain this initiative.

11. **Activity**: Describe a context in which a decision did not adequately account for difficulty of implementation. Explain what was lacking. Were there any significant unbudgeted costs associated with implementation?

1.8.7 No Feedback Loop on Decision Quality

Most amazingly, once a decision has been made, organizations often do not have processes in place to provide feedback on the quality of the decision. Decision makers are thus not held accountable for the impact of their decisions, especially in the long term. Even though ROI is a major factor in a wide variety of organizations and decision contexts, few companies actually track the ROIs for each decision. In such cases, there is no way of knowing whether forecasts of ROI were reasonable to begin with, based on realistic forecasts, or whether they were artificially inflated to justify decisions. Nor could they possibly know what, if any, systematic biases were built into the ROI estimates. In one set of interviews of the top 10 leaders of a corporate division, each admitted that he used personal adjustment factors when hearing presentations involving forecasts. These adjustments depended on their personal experiences with the presenter or organization in question and were rarely discussed openly.

In an uncertain world, the need for decision and implementation tracking goes beyond assessing the final outcome. As implementation proceeds, new information is gathered, and the underlying uncertainty is resolved. If in the original decision, uncertainty was clearly explicated, a flexible risk management plan could have been concurrently developed and rolled out as needed. Unfortunately, if the original decision ignored uncertainty, there was no justification for investing time and energy in developing a risk management strategy. As events unfold, not necessarily according to the single scenario planned for, management can only tweak the decision implementation in order to reduce the negative impact of unplanned for contingencies in an uncertain world.

Many of these symptoms of a poor decision process, such as a failure to consider uncertainty, apply equally to personal decisions. The following activities below ask you to score your organization and your personal decision processes.

12. **Activity**: *Organization*—Score each of the symptom categories listed in Table 1.2 (0 = not a problem; 1 = occasional problem; 2 = recurring problem; 3 = major problem) as they arise in your organization. A total score of 9 or less is excellent, 10–12 is good, 13–15 is problematic, and 16 or more is poor.
13. **Activity**: *Personal*—Score each of the symptom categories listed in Table 1.3 (0 = not a problem; 1 = occasional problem; 2 = recurring problem; 3 = major problem) as they arise in your life. A total score of 6 or less is excellent, 7 or 8 is good, 9–12 is problematic, and 13 or more is poor.

TABLE 1.2: Symptoms of an organization's poor decision process.

Symptoms	Score
(1) Too few alternatives (often only one)	
(2) Multiple objectives often not considered	
(3) Uncertainty ignored	
(4) Decisions arbitrarily revisited	
(5) Strong personalities dominate	
(6) Inexpert opinion affects decisions	
(7) Decisions poorly linked to implementation	
(8) Lack of long-term accountability for decisions	
(9) Other—specify	
Total score	

TABLE 1.3: Symptoms of a person's poor decision process.

Symptoms	Score
(1) Too few alternatives (often only one)	
(2) Multiple objectives often not considered	
(3) Uncertainty ignored	
(4) Decisions arbitrarily revisited	
(5) Family and friends overly influence your decisions	
(6) Delay making decisions as long as possible	
Total score	

1.9 Transparent and Efficient Decision Making

A primary factor of quality decision-making is transparency, clarifying the rational basis for a decision so as to facilitate effective implementation. Participants and stakeholders should understand the basis for a decision even if they do not necessarily agree with the final viewpoint. The starting point for this process is developing the appropriate frame for the decision using a structured method. The tool we propose for representing the decision frame is an influence diagram. The decision frame defines the scope of the decision or decisions, the timeframe to be covered, the underlying assumptions, the key objectives, and the main uncertainties. As discussed in Chapter 2, this descriptive tool can be directly linked to analytic modeling techniques involving multiple objectives and decision trees.

The modeling framework also explicitly incorporates uncertainty. Experts are interviewed individually or in small teams to obtain reliable estimates of the range of values. The structured interviews are designed to reduce, as much as possible, the standard types of biases that arise in making forecasts. Each area of expertise is explicated separately to avoid having individuals offer opinions in areas outside their expertise. Conversely, this method enables all parts of the organization to contribute to the decision-making process by offering their views within their areas of expertise.

The openness and clarity of the process facilitates communication and consensus from multiple organizational perspectives. This should lead to a broader commitment to action. Even more important, the clarity of decision making leads to significantly greater efficiency, notwithstanding that the first time this structured process is employed, it will likely take longer than past decision making. Moreover, critical decisions often undergo repeated reviews. As new information becomes available or uncertainties resolve, the decisions will need to be updated. This structured process, built around a mathematical model, is easily updated as model parameters change. Finally, as executives come and go, changes can be captured in the weights assigned to various objectives. This is also easily accommodated without revisiting the entire decision-making process.

The analytic modeling tools that are integral to the decision-making process are computer based. The software is designed not only to identify the best alternative but also to facilitate an assessment of its strengths and weaknesses. The software enables the decision maker to assess the robustness of the best alternative to changes in key parameters. The explicit modeling of uncertainty and objectives also facilitates the development of a risk management strategy and the creation of hybrid alternatives that are better than any of the original set of alternatives. The computer-implemented structured model is simple to update as new information becomes available. It also generates a consistent review process.

Are you motivated to consider an alternative to your current decision-making dynamic? Or are you just confused? There is an alternative to the modeling tools and approach we are proposing here, and it has certainly withstood the test of time. This method involves using a consultant with expertise in stargazing or astrology. More widely used alternatives today are based on two parts of the human anatomy: gut-feel and seat-of-the-pants. Then, there is always the classic American strategy of aggressive debating until truth wins out. The process presented here is not designed to discourage healthy debate but rather to structure and focus this debate around specific strengths and weaknesses that underlie assumptions as well as the quality of data and expert opinion (Garvin and Roberto 2001). Finally, you can simply list the pros and cons of the various alternative methods and see which list is longer.

You may feel comfortable continuing with gut feeling/seat-of-the-pants decision-making process or heated personality-driven debates, if that is what your organization relies on. But if, instead, you are motivated to consider an alternative to your current method, or are simply confused by what passes for process in your organization and would like to change it, then consider the approach and modeling tools described in the succeeding chapters.

Appendix 1. A: Other Modeling Tools

In this text, we present modeling techniques that are applicable to a wide range of difficult decisions but by no means all situations. Our primary decision focus involves *discrete choice decisions* involving a *limited number of comprehensive alternatives*, generally no more than 10, that face significant uncertainty and/or require trade-offs among multiple objectives. The goal of the analysis is to identify the single best alternative and to understand the strengths and weaknesses of the best and near best alternatives. In studying this methodology, there is a danger that the reader will try to fit every decision challenge into the paradigms presented here. One may mistakenly believe that we have provided the manager with a hammer and that, from now on, every decision can be reduced to trying to hit the nail on the head. In fact, however, a particular problem context might not require a hammer at all, but rather a screwdriver or saw. In Chapter 3, we provide decision templates that should help the reader understand the decision contexts that can be appropriately addressed with the modeling tools of this text. However, the reader interested in learning about a broader array

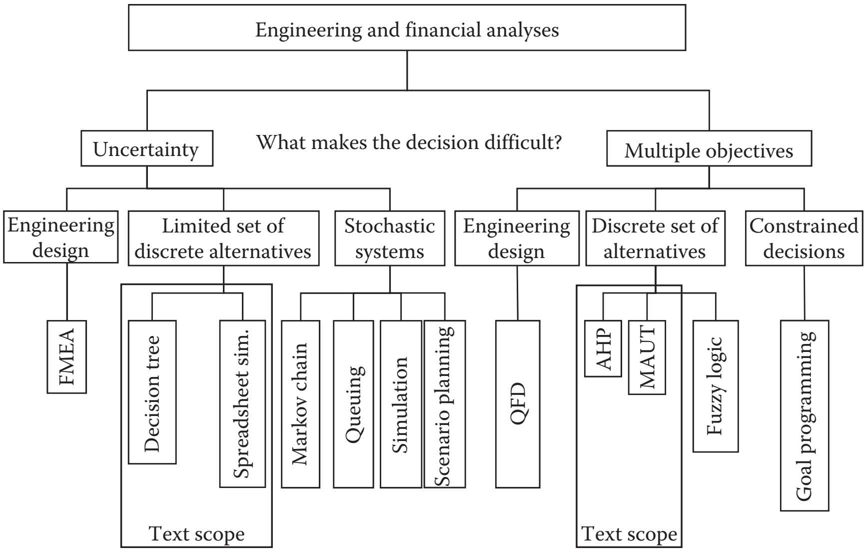

FIGURE 1.1: Systems and decision modeling techniques.

of decision modeling tools may turn to any one of a large number of survey texts in the field of operations research and management science. The modeling techniques presented in Figure 1.1 broadly fall into two categories: probabilistic and deterministic.

1.A.1 Probabilistic Models

Randomness and uncertainty arise in a wide variety of decision and management contexts. One key element of many decision support systems involves forecasting models used to continually predict critical variables such as demand. Inventory management is a fertile area for the use of probabilistic models to cope with the projected and actual random demand. Probabilistic models are also essential to the field of financial engineering.

Designing and developing a new product always involves initial uncertainty as to how well the design will perform. Modeling techniques that are used to support the design, testing, and refinement of a new product include reliability, design of experiments (DOE), analysis of variance (ANOVA), and Taguchi methods. If the focus is to identify and quantify possible sources of component or system failures, failure modes effects analysis (FMEA) is an effective tool.

Decision trees incorporate a collection of random events, which are generally independent of one another or at most linked through conditional probability. However, randomness and uncertainty can pervade an entire complex system such as a production line or airport. Modeling tools for analyzing these interconnected *stochastic systems* include simulation, queueing theory, Markov chains, and hierarchical inventory models. For example, manufacturing plants and airport runways are often modeled through simulation. Queueing theory is used to model the performance of telecommunications systems, toll booths on a highway, or tellers in a bank. Markov chains are the basis for a number of inventory models and customer loyalty analysis.

1.A.2 Deterministic Models

Product mix planning and the associated production often involve thousands if not tens of thousands of decision variables in the presence of large numbers of constraints. These decision challenges are often addressed using mathematical programming models that maximize profit or minimize cost in the presence of thousands of constraints. Similar deterministic models are used to develop schedules for airline crews or process and blend petroleum products. This class of models can be used to address a number of logistics and supply chain operational decisions.

There is another whole group of deterministic models that have been developed around a graph-network structure involving arcs and nodes. These include routing vehicles or shipping product through a network or selecting an optimal subset of nodes for a network of facilities such as new car dealerships.

Multiple objectives are also a factor in every engineering design. Quality function deployment (QFD) is a technique that helps designers identify customers' most critical desires and then converts their concerns into design performance metrics while striving to maximize the quality assurance of the final product. Goal programming is a more structured but less widely used tool. This tool is an extension of mathematical programming in which the objective function is a weighted sum of deviations from each of a series of goals or objectives. The weighting reflects the relative importance of the goals to the decision maker.

Exercises

Complete Chapter Activities

1.1 Coin flip: You are about to flip a coin eight times. Please choose which of the following outcomes you expect.

a. An equal number of heads and tails

b. The number of heads and tails differs by exactly two

c. The number of heads and tails differs by three or more

Now flip a coin eight times.

Record the number of heads ______ and tails ______ and the net difference ______.

Did the outcome match your choice? _______ If the choice and outcome agree, does that mean that you made the best decision? _______

1.2 Can you point to a situation in which you believe your organization made an extremely risky decision to save a buck, such as using an unproven technology or inexperienced supplier, that you did not think was justified but the results turned out satisfactorily? Were decision makers rewarded because of the outcome? Explain.

1.3 Can you point to a personal situation in which you or someone you know made an extremely risky decision that in retrospect was not really justified but the results turned out satisfactorily? Explain.

1.4 Can you point to situation in which you believe your organization made a reasonable choice in an uncertain world but the results turned out unsatisfactorily? Were decision makers punished because of the outcome? Explain.

1.5 Can you point to a personal situation in which you or someone you know took a realistically evaluated risk but the results turned out to be unsatisfactory? (e.g., you spent a good deal of time gathering available information about a new job offer but the company went bankrupt a year later due to corporate executive misinformation.) Explain.

1.6 Describe the last time a senior executive or boss came up with one specific new alternative and asked you to evaluate it. Was there time pressure? Alternatively, describe a yes or no facility decision of your local government. Would it have made sense to look at a broader range of alternatives?

1.7 Describe a specific decision that was heavily influenced by your company's pursuit of one objective to the detriment of an entire range of other measures.

1.8 Describe an instance in which a strong leader did not allow for adequate analysis and discussion of strengths and weaknesses.

1.9 Describe an instance in which a decision was made while ignoring a broad range of obvious uncertainties that would affect the outcome of the decision.

1.10 Describe an egregious example of an individual offering an opinion on a technical issue outside his area of competence.

1.11 Describe a context in which a decision did not adequately account for difficulty of implementation. Explain what was lacking. Were there any significant unbudgeted costs associated with implementation?

1.12 Use Table 1.2 to assess your *Organization's* decision-making process—score each of the symptom categories listed in the following (0 = not a problem; 1 = occasional problem; 2 = recurring problem; 3 = major problem) as they arise in your organization. A total score of 9 or less is excellent, 10–12 is good, 13–15 are problematic and 16 or more is poor.

1.13 Use Table 1.3 to assess your *Personal* decision-making process—score each of the symptom categories listed in the following (0 = not a problem; 1 = occasional problem; 2 = recurring problem; 3 = major problem) as they arise in your life. A total score of 6 or less is excellent, 7 or 8 is good, 9–12 are problematic and 14 or more is poor.

Discuss the Factors That Made the Following Decisions Difficult

1.14 President Obama's decisions to send additional troops to Afghanistan. Clarify the components of the decision.

1.15 The decision whether or not to include a public option in the health care legislation of 2010.

1.16 The decision to fire Fritz Henderson as CEO of General Motors less than a year after he successfully led GM into and out of bankruptcy.

1.17 Identify a difficult decision at your organization that was made within the past 2 years by you, your manager, or a higher-level manager you interact with.

1.18 Identify a difficult decision at the local or state government level that was made within the past 2 years that could impact you.

1.19 Identify a difficult personal decision that you or a family member made within the past few years.

For questions 1.17, 1.18, or 1.19 discuss in 600 to 800 words all of the following:

a. The decision context and the specific decision that was made.
b. Major subsequent decisions, if any, influenced by this decision.
c. The primary objective and any secondary objectives that drove the decision.
d. Describe the factors that made it a hard decision. The factors should be grouped under the categories "major impact," "problem complexity," "personal or organizational context" as discussed in the text. The discussion of these factors and their categorization is the major focus of the write-up. Do not spend too much time describing the technical details that made the decision hard.
e. The dollar magnitude of the decision.

f. The risks associated with the decision.
g. Time pressures if any.
h. If the decision was revisited, explain the circumstances.
i. Constraints surrounding the selection of viable alternatives.
j. Globalization's potential impact or role in the decision, if any.
k. What concerns would you have with the quality of the process used to make the decision? (This is an important issue.)

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Chapter 2

Influence Diagrams: Framing Multi-Objective and Uncertain Decisions

2.1 Goal and Overview

The primary goal of this chapter is to develop skills in using an influence diagram to frame decisions involving uncertainty and multiple objectives in preparation for quantitative analysis.

The first challenge in tackling any decision is to create an appropriate frame around it. A decision frame defines the scope of the decision in terms of the factors to be considered, the time horizon, the organizational breadth, and a range of alternatives. In a group decision, it is especially critical to have the team reach consensus as to the appropriate frame before data collection and analysis begins. There is nothing more disconcerting than to proceed through a detailed analysis of several alternatives for sequencing next year's new product or new service launch and then have someone chime in halfway through the process that "we really need to plan the next five years all at once."

There are a number of brainstorming techniques and associated graphic representations that can be used to facilitate achieving a framing consensus. In this chapter, we explore the role of influence diagrams in framing decisions involving uncertainty and multiple objectives. The power of an influence diagram is its direct link to two analytic tools, decision trees and multiattributed utility theory, that move the decision maker from a descriptive statement of the decision problem to a prescriptive analysis. In Chapter 17, which focuses on strategic decision making, we introduce two additional framing tools: the strategy table and hierarchical decision pyramid.

Influence diagrams were first introduced in 1973 at the Stanford Research Institute as a tool to solve decision problems being studied by the Defense Intelligence Agency (Howard and Matheson 2005a, Howard et al. 2006). The decision analyst community soon recognized the value of influence diagrams as an excellent communication tool for solving complex problems. The initial applications were in the petroleum industry, where oil company executives needed to make a decision on whether or not to drill for oil in a particular location. Influence diagrams helped to form the basis for intelligently discussing the major factors that impact a decision and for representing these factors in the form of a diagram for easy understanding and evaluation. Researchers found that the executives would enumerate important variables and their relationships, after which the analysts would ask the executives to define important outcomes and values regarding the decision. Over the years, applications have spread from the oil industry to the pharmaceutical industry. Influence diagrams have also been utilized for medical issues, evaluation of military systems, and virtually the whole spectrum of decision-making problems. The journal *Decision Analysis* dedicated a special issue in 2005 to influence diagrams. Two of the articles focused on influence diagrams' impact on the fields of medical decision making (Pauker and Wong 2005) and artificial intelligence (Boutilier 2005).

A typical complex business decision involves representatives from different parts of an organization who bring differing perspectives to the problem. The major goal of a high-quality decision-making process is to communicate the issues, clarify the problems, and reach an action-oriented decision. An influence diagram is a simple but powerful descriptive tool that facilitates a common vision among decision makers surrounding the decision alternatives and context, whether this

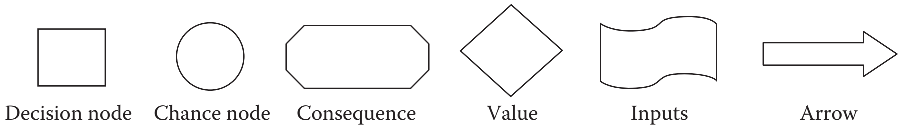

FIGURE 2.1: Influence diagram shapes.

involves a new automotive product at GM (Kusnic and Owen 1992), a medical decision (Nease and Owens 1997), a global product and manufacturing strategy at DuPont (Krumm and Rolle 1992), or a decision related to power company transmission lines (Borison 1995). Howard (1988) considers the influence diagram the best tool for transforming an opaque idea into a clear and crisp decision as well as the greatest advance he has seen in communication, elicitation, and detailed representations of human knowledge.*

In this chapter, we describe the building blocks of an influence diagram and the iterative process used in its construction. The visual modeling tool supports our major underlying premise for decision making: the need to include uncertainty and multiple objectives as integral elements. It also encourages the decision-making group to think about the essence of the decision in question. Is this really one decision or should it be viewed as a sequence of decisions?

2.2 Components of an Influence Diagram

An influence diagram provides a graphic map of the decision problem through six components, as illustrated in Figure 2.1: decision nodes, chance nodes, consequences and objectives, ultimate value, inputs, and arrows.

These elements are represented in an influence diagram by different shapes. Rectangles are used to represent decisions. Circles and ellipses represent the chance nodes that capture the uncertainties that the decision maker believes will influence the desired outcome of the decision. The rounded rectangles represent the consequences or subobjectives that may be of interest to the decision maker. There will be one-rounded rectangle for each of the subobjectives associated with the decision. Each of the objectives should be associated with either the term "minimize" or "maximize." The wavy box describes the deterministic inputs that are needed to support the decision. Finally, a single diamond restates in succinct terms the single ultimate value or goal of the decision. The consequences or multiple objectives lead toward the "overall objective."

The wavy box (inputs) is not a standard part of the literature of influence diagrams. However, we have found that it is important for the group to discuss the data needed to support the decision analysis and to assign responsibility for bringing data to the table. Unlike random events, these data may encompass little or no uncertainty.

These different shapes, referred to as nodes, are linked together by the last major component, arrows. An arrow connecting one node to another (see following text) describes the relationship between the two connecting nodes. By analogy, the nodes of an influence diagram are its vocabulary, with the arrows serving as its syntax—by connecting the nodes.

The influence diagram in Figure 2.2 describes a decision about developing a new late-to-market product scheduled to be launched several months after a competitive product is released. There is, first, the basic decision as to whether or not to develop this product. Two other related decision nodes involve what features to include in the product and the launch price. The major uncertainties are

* Glenn Koller (2005, p. 109) argues for a simpler style diagram when focusing on risk assessment. He calls his approach a contributing factors diagram. It includes only elements that contribute to uncertainty.

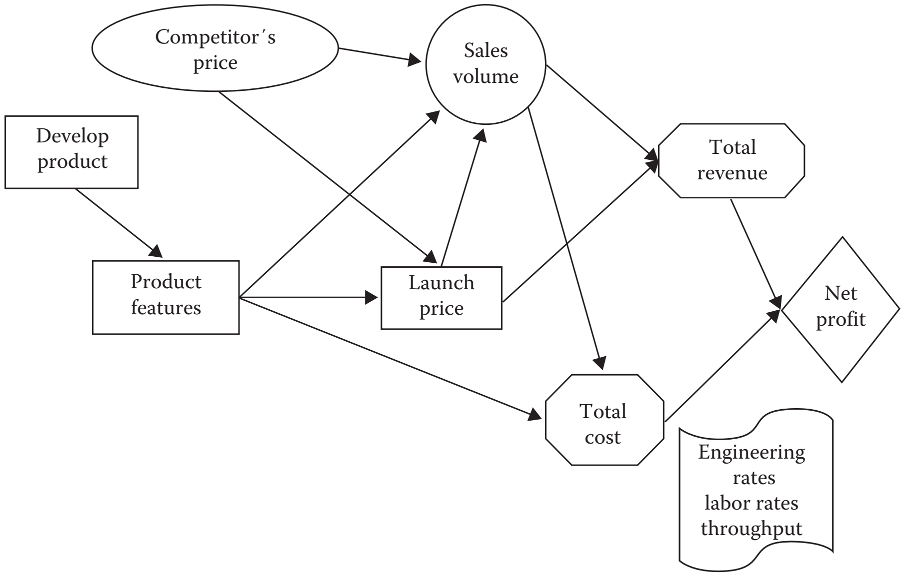

FIGURE 2.2: New late-to-market product development.

the competitor's price and the sales volume. The primary objectives are to minimize total cost and maximize total revenue, thus leading to the ultimate objective, to maximize net profit. The total cost is determined by gathering critical estimates of engineering rates, labor rates, and factory throughput. Later, in this chapter, we discuss this example in greater detail.

The construction of the influence diagram is an iterative process. Initially, it is more important to get the main issues down on the board in the form of nodes and only later worry about the relationships (arrows), the decomposition of the decisions, and the overall sequence of decisions and events. The process can be grouped into six steps:

1. Articulate decision(s)
2. Define objectives
3. Identify uncertainties
4. Step back and look at the bigger picture (considering time horizon, organizational breadth, and additional decision details)
5. Link nodes with appropriate arrows
6. Identify critical data needs

Step 1: Articulate decision(s)

The diagram construction process begins by articulating the basic decision, such as choosing a supplier, bidding on a house, selecting a material, selecting a medical treatment, specifying the number of service people, selecting a manufacturing technology, choosing a product design, or determining plant capacity. It is not critical at this stage to work out the details of the decision or whether this decision should be subdivided into multiple decisions. For example, the decision on plant capacity may be a multiyear expansion plan, with each year's expansion a separate decision. If the decision involves choosing a supplier, it is important to clarify whether this is to be a local supplier or a global supplier or possibly a pair of suppliers. If the decision is to define a buyout package for employees, will it be just one package or an array of packages?

TABLE 2.1: Broad categories of common objectives.

Costs (variable and investment)	Time to complete
Profit—NPV, TARR, ROI	Risk of not meeting targets
Human resources required	Management issues
Long-term value	Operational issues
Performance	Sales and/or market share
	Training requirements

Step 2: Define objectives and ultimate value

The decision maker begins to articulate the objectives that are of importance and the final value such as picking the best supplier. When it comes to selecting a supplier, these objectives could include minimizing cost, maximizing quality, and maximizing engineering design capability. In the case of material selection, the objectives could be minimizing cost, maximizing manufacturability, and maximizing durability. When choosing a medical procedure, the objectives are likely to include life expectancy, quality of life, and cost. When buying a home to live in, the primary objectives might include cost, location, size, and amenities. When selecting a manufacturing technology, the major objectives could include minimizing total cost, minimizing space requirements, minimizing training requirements, and maximizing throughput. Table 2.1 summarizes broad categories of common objectives.

At this stage when constructing an influence diagram, it is not critical to think about how these objectives will be quantified or where data will come from. In Chapter 4, we present the concept of an objectives hierarchy, which provides a detailed expansion of these objectives and involves meticulous definitions of measures. To facilitate and stimulate discussion of objectives for a specific decision, we offer a list of categories that cover a broad array of decisions. In addition, in Chapter 3, we present influence diagram templates that can be used as starting points for various classes of decisions.

Step 3: Identify uncertainties

At this step, the team is challenged to define what factors cannot be known with certainty before the first decision is made. Are the projected costs accurate estimates, or can the actual costs vary by 5% or 10%, enough to possibly change the decision? The projections for demand are always uncertain variables, despite the salesmanship of the executive pushing for the development of a new product or service. When it comes to medical decisions, survival and side effects are common unknowns. When merging two companies, the synergies that will actually develop cannot be predicted with certainty. When investing in an emerging economy, political developments are a major uncertainty. Even within the personal domain, such as buying a home or a used car, there can be significant uncertainty regarding future repair costs.

Likewise, the element of time is a variable that must be considered in every decision and every action plan. However, except in the case of routine processes with long track records, time is a key uncertainty. In fact, time uncertainty could appear as a separate node for each activity if the decision maker wonders how long each task takes to complete. Alternatively, this uncertainty may be succinctly captured by a single node corresponding to "Will the project deadline be met?" This single-node form might be used when making or missing a deadline is one of the critical elements of the decision. If the medical decision involves a surgical procedure, the recuperation time the patient needs before returning to work or other daily activities is an uncertainty. On the other hand, a college student developing a semester schedule may wish to specify a separate node to represent the amount of time required by each subject.

Uncertainty with regard to cost is similar to uncertainty of time. The more experience a company has had with similar projects, the less the uncertainty is. Thus, there would be little uncertainty

TABLE 2.2: Common uncertainties.

Time needed to complete task or reach goal	Performance to specifications
Resources required	Warranty claims and quality control
Cost	Competitive actions
Market demand	Is task doable?
Revenue	Will some specific event occur, such as who will be elected president or will a pandemic occur?
Throughput–productivity	

surrounding the costs of a new warehouse or even the construction of a well-defined chip factory. In contrast, estimates of the variable cost of production for a totally new product can involve significant uncertainty, especially in the early design phase. In chemical processes and chip manufacturing, cost uncertainty starts with process yield variability. This uncertainty would be compounded if the technology of the production processes were unproven. In addition, cost estimates often fail to accurately factor in the impact of a learning curve (Wells 1993).

When selecting a college to attend, the starting tuition is known, but annual increases are a significant unknown factor. When selecting a health plan, the basic cost structure is known, but total costs for a year after accounting for deductibles will be a function of unforeseen medical problems.

As a design team is given a complex new design challenge, they are unsure as to whether they can deliver a design that will meet specifications within the given time and budget constraints. Additionally, the actual performance of the design upon release at a specified date in the future can be modeled as another uncertainty. This uncertainty arises for equipment, software, or pharmaceutical products. In software products, there will be uncertainty with regard to the number of undetected bugs at the time of release. For a car, the ultimate NVH (noise, vibration, and harshness) or ride and handling will be uncertain until physical prototypes are on the test track. And even after the first tests, there still will be uncertainty as to how much improvement can be achieved within the time allowed. For a drug, there may be years of uncertainty with regard to its effectiveness and possible toxicity.

Table 2.2 is a list of uncertain events, discussion of which can facilitate diagram construction. The terms are generally self-explanatory with one exception. The item, "Will some specific event occur?" refers to a wide range of uncertainties that involve whether or not something happens. For example, a company involved with significant environmental issues is directly impacted by the random event, the outcome of a presidential election. Bars and restaurants near Yankee Stadium see their revenues impacted by whether or not the New York Yankees play in the World Series. Other discrete events that may or may not occur: laid off from a job, Congress passes specific legislation, or a company declares bankruptcy.

While developing an influence diagram, confusion can arise when laying out the uncertainties and the objectives, since there can be overlap between the two entities. A cost can be both an uncertain variable and an objective in terms of the need to minimize. One option is to define total cost as the objective to be minimized and to specify as uncertain one or more highly volatile cost components such as energy cost. We will try to clarify this issue later in the chapter by citing examples. However, it is important to note that there is no single correct design for an influence diagram since the same decision frame can often be represented in multiple ways.

Step 4: Step back and review the big picture (and nodes)

The team should now pause and think in terms of the big picture. How broad a frame should be used for the decision? Can they isolate and decide on manufacturing capacity for a single plant for the coming year? Or must they look at multiple years and multiple plants at the same time? For example, if a company is considering opening an office in the near future in China, can it focus on just this decision or must the decision be integrated into a global strategy that covers all branch decisions in a variety of countries over the next 5 years? Can the company decide on one specific product or service or should the decision-making team look at the entire product strategy? Are they selecting an IT supplier for North America or a supplier who is to be a global partner? Do they need to select one piece of equipment for one plant or consider a common strategy for multiple plants, even if only one piece of equipment is to be bought this year?

There are three key questions with regard to framing or scoping the decision.

1. How many years are to be covered by the decision analysis?
2. How broad a geography must be included so as to capture the interaction between a local decision and a more global decision?
3. How broad a product line is to be considered?

The goal is not simply to define the "right" time frame or scope but for key stakeholders to openly discuss the decision and reach a consensus. It is always easy to suggest that a broad frame be used. However, the broader the frame of reference, the more data is required and the more complicated the analysis will be. Thus, more time will be needed to reach a decision and implement it. There will always be a trade-off between decision-making efficiency and breadth of analysis.

A direct corollary to the three questions is whether a single decision or a series of decisions is to be made. When deciding whether or not to launch a new product or service, is there much to discuss and decide with regard to the price of the service, or is price a given based on the competitive marketplace? In deciding whether or not to open an office in a particular country, will the decision be affected by the choice of city or is the basic decision independent of the exact final location?

After reviewing the decision nodes, the team should focus on the objectives to see if the list is complete. Is profit the primary objective, or is market share more important? Should the team include hard-to-quantify objectives such as the decision's impact on the company's image or reputation? If this is a public sector decision, such as where to locate a library or park, do concerns over the fairness to different population groups arise?

Finally, the list of key uncertainties should be debated. In global decisions, does the team need to worry about uncertain political events in the countries under consideration? Are currency fluctuations a significant factor? Is variability with regard to inflation a concern in the time horizon of the study? Are the costs of implementation well understood, or is there significant uncertainty? What will be the timeline for completion?

Step 5: Link nodes with arrows

Arrows are used to bring the picture together, as well as to define how uncertain nodes and decisions are related or sequenced. Interspersing decisions and random events with judicious use of arrows identifies which events are unknown today as well as which will be known in time for a later decision. For example, in planning a multistage capacity expansion, the decision maker will not know the demand for the coming year, but he may obtain more market information before having to make the final decision in year two for expansion or contraction. Similarly, a plan to launch a family of new products over a staggered timeframe will rely on new data that is unknown when the first product is launched, but becomes clear once the process has begun and before the latter part of the product strategy is rolled out.

The placement of arrows is the single biggest source of confusion in building an influence diagram. The difficulty lies in the fact that an influence diagram is not a flow chart. There are specific rules of arrow placement that, like rules of grammar, may seem counterintuitive. These rules are best discussed and explored through the use of examples in the next section.

Step 6: Data input

In every decision context, much data are required that can be ascertained accurately. Often, these data must be gathered from multiple sources with different parts of the organization responsible for certifying data accuracy. This last set of nodes is intended to clarify data needs and responsibility for collection. In planning for a new product, the demand is an unknown, but the size of the market segment may be known. It will be marketing's responsibility to bring that data to the decision analysis. Although yields and throughput may be random variables, the manufacturing staff will know with some certainty the cost of equipment and related facility costs.

2.3 Learn by Simple Example: Automation Investment

Consider the decision case at Boss Controls (BC). BC is gearing up to manufacture an option that would be made available over the next several years to a total of 1 million purchasers of new cars worldwide. Initial projections posit that the take-rate, the percentage of people who purchase the option, could be low or high. The plan calls for BC to deliver the option to the Original Equipment Makers (OEMs) at a price of $60 each. Timothy O'Leary, VP for imaginative products, is considering two alternatives that differ significantly in the level of investment in automation and the related variable cost of production. The decision is over which automation investment to choose.

The next step in framing the problem is to understand the values of the decision maker. In this simple case, Tim wants to maximize corporate profits by meeting demand for the product. Thus, the overall objective is to maximize the profits, and there is no need of intermediate objectives or consequence nodes. (The word maximize was omitted so as not to squeeze the wording in the figure.) The influence diagram for this case is given in Figure 2.3.

The arrow from the decision node to the value node shows that the automation investment decision influences profits. Similarly, the outcome of the uncertain take-rate also influences profits. The input data box makes reference to the need for data on the volume of the market segment, the variable cost, and the investment cost.

Note that there is no arrow connecting the chance node and the decision node. Absence of an arrow between the chance node and the decision node does *not* mean that the uncertainty in take-rate does not influence the decision. It only means that the probability that the take-rate is low or high is independent of the decision Tim makes with regard to automation. Everything in the diagram affects the optimal decision. We will discuss more about the properties of arrows as we proceed.

In the initial representation, it was assumed that the OEM's forecast of 1 million cars to be sold was on target. This would be true if the demand for the particular vehicle line(s) exceeded capacity

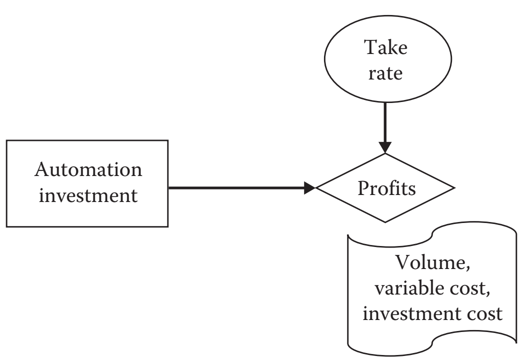

FIGURE 2.3: Automation investment.

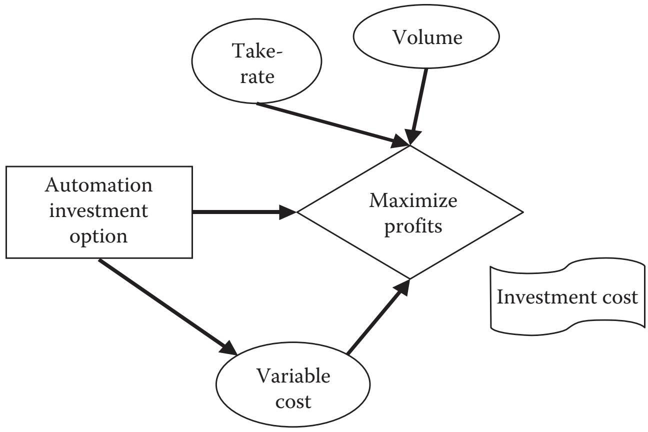

FIGURE 2.4: Automation investment expanded.

or if the company had a consistent policy of offering incentives to keep the lines running at full capacity. In other contexts, this total would also be a random variable and represented by a distinct random node, as seen from Figure 2.4. In theory, the two random nodes, take-rate and volume, could be combined into one, called sales. However, by keeping two separate nodes, the diagram better represents the sources of uncertainty. In addition, there may be uncertainty regarding the variable cost linked to the different investment alternatives. A random node reflects this uncertainty.

Notice that in Figure 2.4, there is an arrow from the decision box to variable cost but not to other random events. Why? The choice of investment options affects the value of the uncertainty associated with the variable cost of manufacturing. However, it does not affect the uncertainty surrounding the demand for vehicles or the take-rate.

2.4 Divide and Delay Decision: Plan an RSVP Theater Party

The Department of Industrial Engineering of Welcome State University is planning its first ever theater party for its faculty, staff, alumni, and special guests. They have purchased 100 tickets for the event and plan an afterglow. The total number of people on their first draft of an invitation list includes more than 500 names. Initially, the primary objective was to maximize the number of people actually attending the theater party. After some thought, however, it was determined that the primary objective was to maximize good will as depicted in Figure 2.5. The major difference in this reformulation is that good will is earned even by inviting people who choose not to attend. The primary uncertainty is the percent of people invited who would respond yes. A secondary uncertainty involves no-shows.

The chair of the department is concerned, since this is the inaugural event and he has no prior data on response rates. He is afraid that if he invites too many, the number of acceptances could exceed the number of tickets, with a resultant loss of goodwill. If too few are invited and the acceptance rate is low, there will be too few attendees, and the department will have missed out on an opportunity to build goodwill, primarily amongst the alumni.

A staff member with experience in planning events points out that the decision has been framed too narrowly. There is enough time before the date of the show to send out two waves of invitations, and, thus, there are two decisions, not one (see Figure 2.6). In the first wave, the number sent would be based on the most optimistic estimate of the percentage of people who will say yes, with a required RSVP window of 3 weeks. At the end of 3 weeks, they would know how many have said