Foundations of DECISION ANALYSIS

Mohamed Amine Hamdani

FOUNDATIONS OF
DECISION ANALYSIS

Mohamed Amine Hamdani

Toronto Academic Press

FOUNDATIONS OF DECISION ANALYSIS

Mohamed Amine Hamdani

Toronto Academic Press
4164 Lakeshore Road
Burlington ON L7L 1A4
Canada
www.tap-books.com

Email: orders@arclereducation.com

© 2025

ISBN: 978-1-77956-700-0 (e-book)

This book contains information obtained from highly regarded resources. Reprinted material sources are indicated and copyright remains with the original owners. Copyright for images and other graphics remains with the original owners as indicated. A Wide variety of references are listed. Reasonable efforts have been made to publish reliable data. Authors or Editors or Publishers are not responsible for the accuracy of the information in the published chapters or consequences of their use. The publisher assumes no responsibility for any damage or grievance to the persons or property arising out of the use of any materials, instructions, methods or thoughts in the book. The authors or editors and the publisher have attempted to trace the copyright holders of all material reproduced in this publication and apologize to copyright holders if permission has not been obtained. If any copyright holder has not been acknowledged, please write to us so we may rectify.

Notice: Registered trademark of products or corporate names are used only for explanation and identification without intent of infringement.

© 2025 Toronto Academic Press

ISBN: 978-1-77956-283-8

Toronto Academic Press publishes wide variety of books and eBooks. For more information about Toronto Academic Press and its products, visit our website at www.tap-books.com.

ABOUT THE AUTHOR

Mohamed Amine Hamdani, PhD in Finance and Econometrics, boasts over 12 years of experience in corporate finance. He has worked with various large companies and in academia, striving to bridge theoretical frameworks with practical applications through his diverse roles.

Mohamed Amine's international career has spanned North Africa, France, and Brazil, where he has honed his expertise in corporate finance and accounting. His academic journey includes a Master's degree from Ca' Foscari University of Venice and a DBA from the High Institute of Management and Planning in Algiers, Algeria. He has also participated in various research programs with the Aix-Marseille School of Economics in France, maintaining a strong connection with the latest technical updates in corporate finance.

Table of Contents

List of Figures

List of Tables

PREFACE

Decision analysis is a systematic and quantitative approach to decision-making that involves assessing and evaluating different alternatives to make informed choices. The foundations of decision analysis lie in the recognition that decision-making is often complex and involves uncertainty, multiple objectives, and conflicting priorities. Developed as an interdisciplinary field drawing from economics, mathematics, psychology, and management, decision analysis provides a structured framework to analyze decisions in a rational and logical manner. One key element is the identification of decision criteria and the quantification of uncertainties, allowing decision-makers to model and evaluate the potential outcomes of different choices. Decision trees, influence diagrams, and probability assessments are common tools used in decision analysis to represent and evaluate the possible consequences of decisions. By breaking down complex decisions into smaller, more manageable components, decision analysis enhances the decision-maker's ability to understand, compare, and ultimately choose the most favorable course of action.

This book, "Foundations of Decision Analysis," is divided into eight chapters, each focusing on a specific aspect of decision analysis. The simple format provides a straightforward way for readers to explore and understand the basics of this field.

The first chapter describes the history of decision analysis, introducing the Five Rules and illustrating their real-world application. In the second chapter, the focus is on decision theory, addressing theoretical questions and processes. The chapter explores different decision models, such as sequential and non-sequential, covering concepts like deciding, valuing, and expected utility.

Chapter three discusses effective problem identification and introduces taxonomies for decision analysis. Chapter four explores decision-making under uncertainty and risk, introducing tools like decision trees and influence diagrams. It provides practical insights into handling uncertain situations.

Chapter five delves into the decision context, discussing objectives and criteria. The sixth chapter explores decision-making using game theory, covering various game scenarios, and providing a practical understanding of strategic interactions.

Chapter seven focuses on effective communication strategies in decision-making. The final chapter discusses the role of ethics in decision-making, covering ethical distinctions and considerations in decision trees, offering insights into real-world ethical situations.

Designed with a focus on meeting the educational needs of students and scholars, this book aims to deliver comprehensive knowledge and foster a deep understanding of decision analysis. Our intention is for this book to serve as a valuable resource across various academic disciplines, providing clarity and insightful perspectives for readers seeking to navigate the complexities of decision-making scenarios.

—Author

CHAPTER 1

Introduction to Decision Analysis

LEARNING OBJECTIVES

After studying this chapter, you will be able to:

- Understand the historical development of decision analysis and its significance in decision-making processes.
- Comprehend the theoretical foundation of decision analysis through the Five Rules and their direct application.
- Explore the scope of decision analysis, including its taxonomy and terminology.
- Differentiate between single-objective and multiple-objective decision analysis.
- Analyze approaches to address value trade-offs and risk preferences in decision analysis.

INTRODUCTORY EXAMPLE

Picking the Best Project Pla

Imagine overseeing a team working on a new project. The task at hand is to determine the best way forward with limited resources. This is where decision analysis comes into play - a tool that aids in making informed choices.

Let's take a step back and delve into the origins of decision analysis. It is akin to understanding the foundations of a game before commencing play. Familiarizing oneself with its history allows for a better grasp of its significance in present-day decision-making.

Now, decision analysis is guided by a set of principles known as the Five Rules. Consider them as your decision-making playbook. We will witness these rules in action through a simple example, much like following a recipe to ensure a favorable outcome.

As we progress, decision analysis encompasses a wide range of topics. We will break it down into manageable sections, similar to examining a map to comprehend the various parts of a city.

Sometimes, decisions involve choosing between different goals. Other times, you might have just one goal but multiple ways to reach it. We will talk about these situations and figure out the best strategies.

Making decisions is a bit like a balancing act. We will discuss how to weigh your options and handle everyday risks. It is a bit like crossing a street—you need to navigate carefully.

Lastly, we will explore value-focused thinking. This is like putting on special glasses that help you see what really matters in your choices.

UNIT INTRODUCTION

Decision analysis is a subject that falls under the umbrella of operations research and management science (OR/MS). The aim of this tool is to aid decision-makers who are faced with difficult choices, various stakeholders with conflicting agendas, complex options, substantial uncertainty, and important consequences (Keefer et al., 2004).

To begin, let's explore the historical foundations of decision analysis. The principles of decision theory can be described by five essential guidelines of behavior that establish a comprehensive structure for making decisions in times of uncertainty while adhering to our preferences. Subsequently, this description will outline the extent of decision analysis, encompassing four key aspects:

i. Interacting with decision-makers

ii. Alternatives

iii. Preferences

iv. Uncertainty

Next, we will examine various approaches to decision analysis that have emerged over the past fifty years, emphasizing their similarities and differences. Finally, we will discuss an overview of Ralph Keeney's value-focused thinking (VFT), a significant philosophical viewpoint on decision analysis (Kassirer, 1976).

1.1. HISTORY OF DECISION ANALYSIS

Learning Objectives

- Trace the historical development of decision analysis and its evolution over time.
- Identify key milestones and contributors that have shaped the field of decision analysis.

The fields of probability, behavioral decision theory, mathematics, and interpersonal skills are where decision analysis initially emerged. The examination of uncertainty and the evaluation of subjective opinions regarding potential outcomes are assessed by probability. Mathematical decision theory can be utilized to scrutinize decisions made under uncertainty, by considering individual preferences.

The application of research findings from behavioral decision theory aims to comprehend the distinctions between group and individual decision-making, as well as the biases and strategies employed in assessing uncertainty and value. These research findings assist us in effectively evaluating probability distributions for uncertain variables. Ultimately, to construct models, gather data from subject matter experts, decision-makers, and other stakeholders, and convey findings to them, organizations develop and apply interpersonal skills (Keeney, 1982).

The seventeenth and eighteenth centuries are when probability theory first emerged. Blaise Pascal and Pierre de Fermat's research was referenced in Christiaan Huygens' 1657 paper, "On Reasoning in Games of Chance." Jacob Bernoulli incorporated permutations, combinations, and the law of large numbers in his 1713 publication "The Art of Conjecturing." Daniel Bernoulli proposed risk aversion and diminishing marginal utility as insurance-related stimulants in 1738. In addition, Bernoulli suggested maximizing the expected value of "moral expectation," which he defined as something other than wealth. The equations to update the probability of an outcome given new data were developed by the Reverend Thomas Bayes, who also created Bayes' law. The work was featured in "Essay Towards Settling a Problem in the Doctrine of Chance" (1763), a publication released after the author's death. Kolmogorov's 1933 work, "Foundations of the Theory of Probability," provided a comprehensive explanation of the axioms of probability theory (Edwards et al., 2007).

Although one of the pillars of decision analysis is probability, the evolution of the subjective perspective on probabilities was crucial. According to the objective perspective on probability, probabilities are considered as a state of the world. On the other hand, the subjective perspective, known as the Bayesian view, maintains that the probabilities assigned to possible outcomes are influenced by our state of information. The theoretical foundations of subjective probability were further developed by Bruno de Finetti in 1937, building upon the earlier work of Pierre-Simon Laplace (1812), who applied the Bayes approach and adopted a subjective view of probability in his work "Theorie Analytique des Probabilities." This perspective was expanded upon in 1931 by Frank Ramsey in his book "Truth and Probability" (Buchanan & O Connell, 2006).

Mathematical decision theory serves as the next foundational discipline. It was formalized and developed by John von Neumann and Oskar Morgenstern in 1944 with their publication "Theory of Games and Economic Behavior." The concept of maximizing expected utility by adhering to four axioms and considering risk aversion and risk-seeking behavior was first presented in this book. Leonard J. Savage integrated objective and subjective probability with quantitative decision theory in his book "Foundations of Statistics" (Smith & Von, 2004). Behavioral decision analysis is the third core discipline. With his two foundational works, "The Theory of Decision Making" and "Behavioral Decision Theory," Ward Edwards established behavioral decision research as a new study field in psychology. Three heuristics—representativeness, availability, and anchoring—that humans employ to make decisions regarding uncertainty were described in the 1974 paper "Judgment Under Uncertainty: Heuristics and Biases" by Amos Tversky and Daniel Kahneman. "The Framing of Decisions and the Psychology of Choice," published in 1981 by Tversky and Kahneman, described the significance of decision frames on how one thinks of the decision problem. Although these heuristics are generally effective, they can result in systemic bias, which one must consider when eliciting probabilities. This effort has impacted how one presents a decision opportunity in a big way. Despite not being an economist, Kahneman's work on prospect theory earned him the 2002 Nobel Prize in Economics. In contrast to expected utility theory, prospect theory develops a descriptive theory of decision-making using insights from behavioral decision analysis (Pauker & Kassirer, 2019).

1.2. THEORETICAL FOUNDATION OF DECISION ANALYSIS

Learning Objectives

- Understand the theoretical foundation of decision analysis through the exploration of the Five Rules.
- Apply the Five Rules in decision-making scenarios, with examples illustrating direct use and implications.

John von Neumann and Oskar Morgenstern laid the theoretical foundation for decision analysis in the 1940s. They demonstrated that rational behavior aligns with four axioms when decisions are based on expected utility. Since then, several individuals, most notably Leonard J. Savage and Ronald A. Howard (Chen et al., 1993), have developed alternative sets of axioms that also lead to decision-making based on expected utility.

Howard's decision theory is built upon five rules or axioms of behavior. Breaking any of these rules would be considered irrational, as they are self-evident and rooted in common sense.

Following two terms are used in the five rules statement:

a) **Prospect:** A possible future. A $100 reward (or, more precisely, living the future life after winning $100) is an example of a prospect.

b) **Deal:** A full range of prospects, each with a probability of occurrence. The opportunity to win $100 with a 50% probability and to receive nothing with a 50% probability is an example of a deal (Fivel, 2012).

1.2.1. The Five Rules

It is necessary to fully explain any deal in terms of possibilities and probabilities in order to adhere to the probability rule. A possibility is a precise and specific representation of an event that has the potential to occur or not. A set of possibilities, also known as an outcome space, is considered complete when each possibility is both mutually exclusive (only one can occur) and collectively exhaustive (at least one must occur). Probability is a numerical measure ranging from 0 to 1 that quantifies the likelihood of an event occurring based on one's perception. It is important to remember that probability, in the context of decision analysis, does not reflect a physical property of the real world that can be identified through repeated experimentation. Instead, probability is a measure of one's belief regarding the level of uncertainty surrounding a future event (Busemeyer & Townsend, 1993).

To adhere to the order rule, one must be able to rank any group of prospects from best to worst according to preference. Equal preference, or indifference, between two prospects is acceptable. This rule states that preference is transitive. If B is ranked higher than C and A is ranked higher than B, then A must be ranked higher than C, as it is not possible for C to be ranked both below and above A in the preference ranking (Snowden & Boone, 2007).

According to the equivalence rule, it is always possible to construct an uncertain deal with two prospects. One would be indifferent between receiving that deal or a third prospect that ranks in the middle of the two prospects' preference rankings in the deal. Therefore, if someone has a preference for A over B and B over C, there must exist a probability p where they are indifferent to the prospect of either (1) obtaining A with a probability of p and C with a probability of (1 – p), or (2) obtaining B (Yang & Xu, 2002). This probability p is known as a preference probability, as it is influenced by an individual's personal preferences rather than beliefs about the likelihood of real events. Prospect B is the certain equivalent of the deal between A and C, determined by the provided preference probability.

The substitution rule states that your preference for a prospect should remain unchanged when an uncertain deal within the prospect is substituted with its certain equivalent or vice versa (Kacelnik & Bateson, 1997).

The rule of choice dictates that when faced with two deals that offer the same prospects but different probabilities, one should select the deal that has a higher probability of achieving the more preferred prospect. Assume that someone has a preference for A over B and that they are presented with two distinct deals. In Deal 1, the individual would have a 40% probability of receiving A and a 60% probability of receiving B. In Deal 2, the individual would have a 25% probability of receiving A and a 75% probability of receiving B. The rule mandates that one should prefer Deal 1, due to the higher probability of the more preferred prospect A (Kangas & Kangas, 2004).

The choice that aligns with the five rules can be determined by directly applying those rules in every decision-making scenario:

a) Determine the potential outcomes of the decision. Determine the most favorable and unfavorable results (i.e., the two most and least preferred).
b) Evaluate the probability of each potential event based on the degree of belief in its occurrence, for each possible outcome.
c) Determine the preference probability one considers equivalent to each probable outcome's best vs worst scenario, for each possible outcome.
d) Replace these best-worst deals for all the outcomes. This leads to determining an equivalent deal for each alternative, which includes only the most best and worst outcomes.
e) For each alternative, employ probability calculations to determine the probability of obtaining the best outcome in the equivalent deal.
f) Select the alternative with the equivalent deal of highest

probability of achieving the best outcome (Fox & Clemen, 2005).

The preference probabilities derived in Step 3 can be considered as a metric that measures the attractiveness of each outcome. During Step 5, the computations involve determining the probability-weighted average of the metric, which is sometimes referred to as the Expected Value (EV), for each alternative. In Step 6, one can select the alternative that has the greatest Expected Value (EV) for that measure. The metric is known as "utility." It can be easily demonstrated that a linear transformation of the utility metric—achieved by adding and multiplying by a constant—does not alter its fundamental characteristic. The defining feature of this characteristic is that the alternative with the greatest expected value (EV) of the transformed utility measure is the alternative with the greatest EV of the preference probabilities (Martin, 1995).

Therefore, in order to recognize the five rules, it is essential to have a utility function (referred to as "u-curve" by Howard) that assigns prospect to a utility metric. Decision theory asserts that the best course of action is to make decisions that maximize the probability-weighted average of the utility metric while adhering to the five rules (Lutz et al., 2006).

1.2.2. Example of Direct Use of the Five Rules

The subsequent, greatly simplified example demonstrates the straightforward application of the Five Rules to identify the best alternative in a decision-making scenario. Acknowledging that this strategy is not commonly employed in practical applications is important. Alternatively, more effective techniques guarantee adherence to the Five Rules (Carvalho, 1988).

Assume that a corporation is strategizing manufacturing a commemorative T-shirt associated with a specific sporting event. There are just two options for the quantity of T-shirts produced: Many and Few. The T-shirt demand will vary between high and low, contingent upon various circumstances, including the actual participation of specific teams in the event (Yang, 2001).

Step 1 involves listing and ranking the possible outcomes, ranging from the best to the worst:

1 Many, High. High sales, abundant satisfied clientele, zero wastage (Best)
2 Few, Low. Low consumers, little sales, but everyone is satisfied, no waste
3 Few, High. Low sales, a lot of dissatisfied prospective clients, and no waste
4 Many, Low. Low sales and high-cost waste (worst)

The probability of high demand is evaluated at 40% in Step 2. During Step 3, an evaluation determines the probability of achieving the best outcome compared to the worst outcome, resulting in a deal equivalent to a Few, Low outcome (=50%). The Few, High outcome (30%) is evaluated using the same assessment criteria (Kunene & Weistroffer, 2008).

In Step 4, each outcome result in the decision tree is replaced with the equivalent best-worst deal. Step 5 involves computing the probability of the best outcome for each alternative. Making A Few T-shirts is the better alternative in Step 6 because it has a higher probability of getting the best outcome (42% as opposed to 40%).

When faced with a complicated issue, it can be difficult and time-consuming to identify the best alternative by directly implementing the five rules. Practically, one can utilize more efficient techniques designed to align with the five rules. A competent decision professional is assumed to consistently employ a decision-making process that aligns with the five rules. It is important to note that widely used decision-making systems, such as the Analytic Hierarchy Process, have the potential to violate the five rules (Mendoza & Martins, 2006).

Remember

In Decision Analysis, the Five Rules provide a theoretical foundation for making rational and sound decisions, ensuring a systematic approach to evaluating alternatives and their potential outcomes.

1.3. DECISION ANALYSIS SCOPE

Learning Objectives

- Define the scope of decision analysis and its applicability in various decision-making contexts.
- Analyze the broad scope of decision analysis and its potential impact on diverse decision scenarios.

The goal of decision analysis is to generate benefits for stakeholders and decision-makers. An OR/MS technique is employed to analyze decisions that involve complex alternatives, uncertainties about future consequences, and preferences, which encompass value, time, and risk.Various approaches from the fields of management science and operations research have been utilized to simulate intricate decision-making processes. Probability serves as a tool employed by numerous operations research and management science (OR/MS) methodologies to express uncertainty. These methodologies encompass stochastic optimization, queuing theory, applied statistics, simulation, and stochastic game theory. Decision analysis stands out by providing a systematic framework for making normative decisions. It incorporates the available alternatives, probabilistic beliefs regarding uncertain outcomes, and preferences for prospective consequences (Hedge et al., 2016).

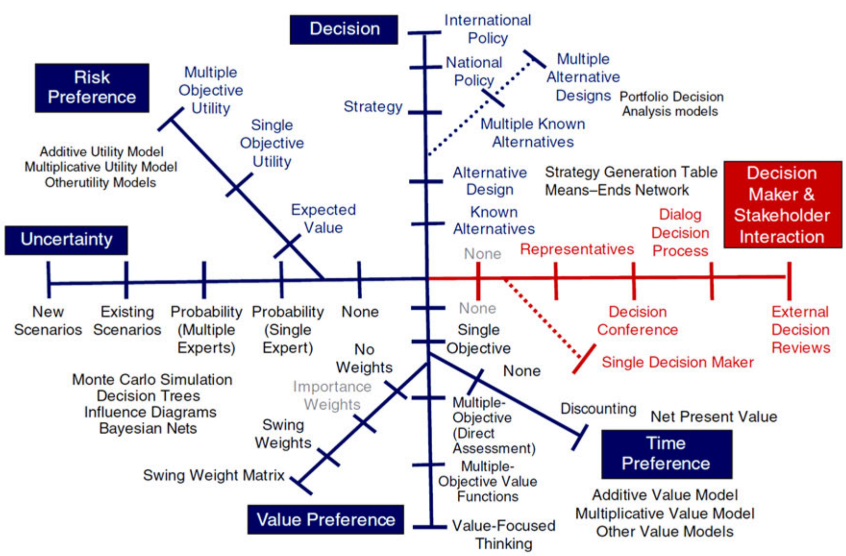

Figure 1.1. The scope of decision analysis (Source: Parnell, Creative Commons License)

Figure 1.1 is a diagram of the scope of decision analysis, adapted from Parnell's work in 2009. The figure encompasses four dimensions: engagement with decision-makers and stakeholders, value and time preference, uncertainty, and risk preference, and decision-making. The most basic techniques are located in the center of the diagram. The complexity level escalates as one moves further away from the center along the spokes. The spokes represent the layers that represent the decision analysis concepts. Using "importance weights" on the value spoke and setting a "none" level for decision maker and stakeholder involvement are not recommended practices (Howard, 1988).

1.4. TAXONOMY OF DECISION ANALYSIS PRACTICE

Learning Objectives

- Explore the terminology used in decision analysis and its significance in framing decision problems.
- Differentiate between single-objective and multiple-objective decision analysis, and analyze their respective applications.

A variety of methods that address values and objectives differently are included in decision analysis. The features of the decision problem to be handled, as well as the decision maker's experience and preferences, affect the method choice. They present a classification scheme (*See* Figure 1.2) that groups various approaches and emphasizes their differences and similarities (Cinelli et al., 2020).

1.4.1. Terminology

In this section, the following vocabulary will be used to ensure clear communication:

i. **Objective:** An explicit goal that is sought after.

ii **Performance Score:** A metric that evaluates the degree to which a goal is accomplished.

iii **Risk Preference:** A decision maker's attitude towards risk can be categorized into three types: risk-averse (the most common preference), risk-neutral (frequently observed in Government decision-making), or risk-preferring (Scherpereel, 2006).

iv. **Value metric:** A scale of numbers that evaluates the value of the degree of goal accomplishment as judged by stakeholders and decision makers.

v. **Value function:** A mapping of performance scores to the value metric. It can be a mapping from one performance score or from many performance scores to the value metric (Zachary, 1986).

vi. **Utility metric:** For the value measure, a numerical scale that expresses the decision maker's willingness to take risks. It is ideal for the optimal choice of the probability-weighted average of the utility measure to be the only factor considered when making decisions. Often, decision analysis uses only one utility metric (O'Leary, 2007).

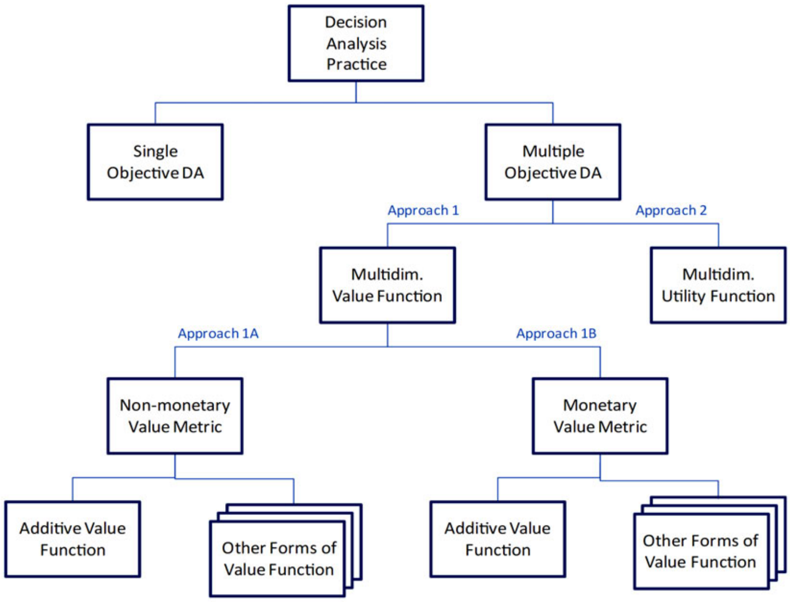

Figure 1.2. A taxonomy of decision analysis practice (Source: Parnell, Creative Commons License)

vii. **Utility function:** The conversion of the value metric to the utility metric occurs when dealing with a utility function that is either single-dimensional or multidimensional, where, in the latter instance, it involves all the performance scores (Rasmussen, 1994).

1.4.2. Multiple or Single Objectives

The taxonomy's initial classification is predicated on the number of objectives considered throughout the decision analysis. Only two scenarios are conceivable: one entails a solitary objective, while the other encompasses multiple objectives. The choices are influenced by the circumstances surrounding the decision. A single-objective decision analysis can be suitable if the decision-makers and other stakeholders are convinced that there is only one objective that should be maximized during the decision-making process. This is often the case for decisions made in private sector enterprises, as the primary aim is typically to maximize shareholder value. When key stakeholders and decision makers believe there are numerous objectives that should be optimized, the optimal course of action is to conduct a multiple-objective decision analysis (Cinelli et al., 2022).

1.4.3. Single-Objective Decision Analysis

The single objective type of decision analysis is shown in Figure 1.3. The main objective of a business decision is often to maximize the value of the shareholder. The net present value of future cash flows, discounted at a rate that reflects the company's time value of money, serves as the performance score used to evaluate shareholder value. The performance score in monetary units can serve as the value meter in this case. Therefore, the identity function is essentially the single-dimensional value function. However, there are scenarios where the performance score is presented in a way that makes it unsuitable for direct use as a value metric. In these situations, a unidimensional value function is constructed to associate the performance score with a suitable value metric (Johnson et al., 2014).

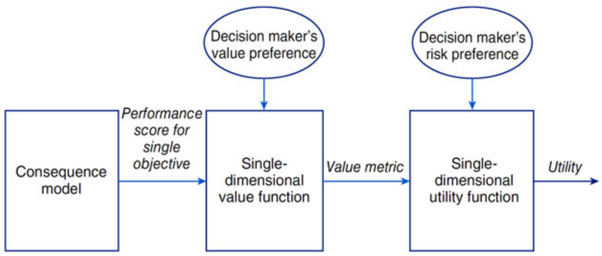

Figure 1.3. Single objective decision analysis (Source: Bresnick, Creative Commons License)

It is preferable to utilize a monetary scale instead of a unitless scale for the value measure in decision analysis where it is suitable; this is because it enables decision-makers to make more relevant comparisons. Each individual has acquired a lifetime of experience utilizing a monetary scale to measure comparative value.

Saying "Alternative A is 50 value units better than Alternative B" is not as important or informative as saying "Alternative A has a $5 million advantage over Alternative B." Additionally, using a monetary scale allows us to evaluate whether the costs connected with obtaining additional information to improve the decision are worth it (Schoemaker & Russo, 1993). Some other value measures possess the desirable features described for a monetary value metric. An example is a metric based on the duration of time spent or conserved to achieve a goal. Another factor that is relevant in certain military decision-making processes is determined by the quantification of lives lost or saved. The crucial attribute is that decision-makers may utilize the value metric to quantify both the benefits and costs (Bahl & Hunt, 1984).

It is possible to inquire whether it is always feasible to construct a value function that converts a non-monetary performance score into a monetary value measure. According to one of the Five Rules, arranging a group of prospects in a specific order based on preference is essential. This implies that having equal preference or indifference between two prospects is acceptable. The set of prospects for achieving different levels of the non-monetary performance score can be defined. In addition to the existing set of prospects, another set can be created by receiving varying amounts of money (Talley, 2011).

All of these prospects are prioritized in terms of preference, and additional monetary prospects can be included to ensure that each level of the non-monetary performance score has equally favored monetary prospects. This process enables the establishment of the desired value function that connects the non-monetary performance score to a monetary value metric. While it is theoretically possible to establish a monetary value metric, it may not be practically feasible due to the inability or unwillingness of decision-makers and stakeholders to conduct the necessary assessments. Certain governmental bodies are legally prohibited from assigning a monetary value to an individual's life (Watrobski et al., 2019).

In single-objective decision analysis, the decision maker's preferences for taking risks are represented by a utility function that is evaluated in relation to a value measure when the decision has a high level of risk. Evaluating the utility function necessitates the decision maker expressing their preferences between hypothetical choices that involve varying degrees of the value metric, where each pair of choices must have at least one uncertain deal (Savic, 2002).

For example, the decision maker may be presented with the following query: "Would one rather receive a guaranteed $10 million profit or take a risky option where there is a 50% probability of gaining $30 million and a 50% probability of gaining nothing?" A similar evaluation can be conducted for a nonmonetary value metric (Haddaway & Rytwinski, 2018).

When decision-makers are faced with risk-neutral scenarios or situations where risk is negligible, they do not believe that evaluating the utility function is necessary. This is because they are confident that a straight line will provide a reasonably accurate approximation of the utility function. In other words, the decision-maker in this scenario is essentially neutral with regard to risk, and the decision may be made by maximizing the probability-weighted average or expected value of the value metric (Zheng et al., 2019).

1.4.4. Multiple-Objective Decision Analysis

Multiple objectives are a characteristic of certain decision-making circumstances. For instance, a business may desire to select a manufacturing plan that minimizes environmental damage caused by operations while simultaneously maximizing shareholder value. Similarly, a government agency may aim to establish a space program that accomplishes various objectives, including fostering international collaboration, advancing scientific knowledge, enhancing national pride, and strengthening national defense (Wall & MacKenzie, 2015).

Distinguishing between fundamental (or ends) objectives and means objectives is of utmost importance. Howard employs the terms direct and indirect values to describe this differentiation. Means objectives, also referred to as indirect values, are valued solely because they serve as support for fundamental objectives. On the other hand, fundamental objectives, or direct values, are considered ultimate goals by decision makers. For example, if a company's primary objective is to increase shareholder value, then reducing manufacturing costs would be a means objective that is only significant because it advances the fundamental objective. Increasing the availability and dependability of a system are two common objectives in system decisions. Since availability is calculated using reliability, availability is the fundamental objective, while reliability is the means objective. The decision practitioner must ensure that the set of objectives for the choice consists solely of fundamental objectives. This is crucial in multiple-objective scenarios as it simplifies the mathematical form of the value function and prevents the double counting of values (Insua & French, 1991).

1.4.5. Addressing Value Trade-Offs and Risk Preference

The ultimate result of any decision analysis, including multiple objectives, is a single utility metric that serves as the standard for making a decision: the alternative with the highest expected utility is the one that should be preferred alternative. The decision makers' and important stakeholders' two distinct preferences must be considered in this one utility metric:

1. Preferences on the trade-offs between multiple objectives and the relative importance of achieving each objective.

2. Risk preference ("To what extent are individuals willing to sacrifice potential value to minimize risk?").

Whether the two kinds of preferences are treated separately or jointly influences the taxonomy's subsequent categorization. Approach 1 is used when the decision analysis takes each preference into account separately (*see* Figure 1.4) (Greogry, 2002).

Approach 1 is composed of two separate steps. The first step is to convert the performance scores for multiple objectives to a single value metric using a multidimensional value function. This function contains the preferences for the trade-offs between the performance scores. The single value metric is transformed to the utility metric in a single-dimensional utility function that represents preferences for risk taking in the second stage.

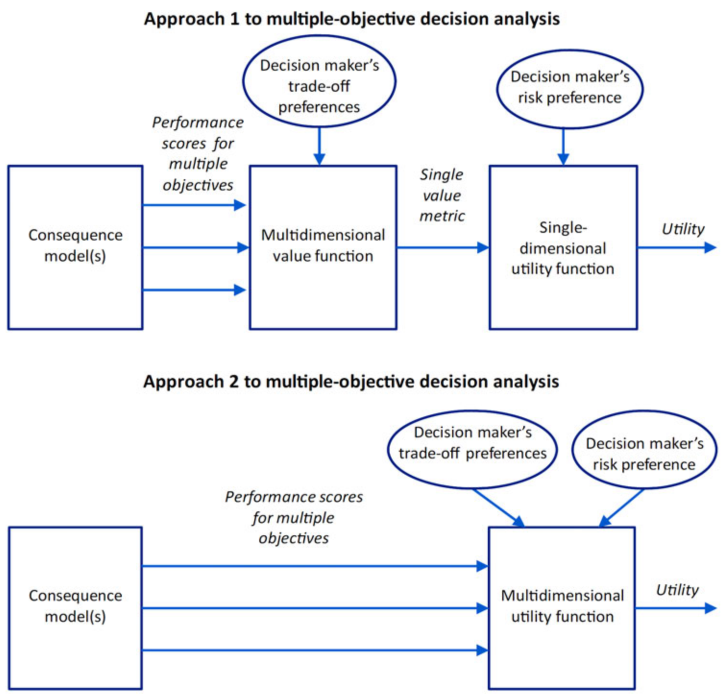

Figure 1.4. Two methods to multiple objective decision analysis (Source: Johnson, Creative Commons License)

In contrast, Approach 2 simplifies the process by utilizing a multidimensional utility function to map multiple performance scores to a utility measure. This function incorporates preferences for both trade-offs among performance scores and risk-taking (Keeney et al., 1979). Evaluating the single function in Approach 2, which needs to account for both preferences, can be challenging. In general, it involves expressing preferences regarding uncertain deals composed of different combinations of performance scores. Which deal is preferable? A 50% chance of obtaining 5 units of score X, 15 units of score Y, and 30 units of score Z, or a deal with a 50% chance of obtaining 15 units of score X, 25 units of score Y, and no units of score Z? Alternatively, is it better to have a guaranteed quantity of 10 units of score X, 20 units of score Y, and 40 units of score Z? (Law et al., 2018).

To overcome this challenge, one can employ a reduced version of a multidimensional utility function. Initially, a utility function limited to one dimension is evaluated individually for each performance score. The overall utility function is then determined by combining the single-performance score utility functions straightforwardly, such as through addition or multiplication. The accuracy of this modification of the multidimensional utility function depends on the fulfillment of independence requirements among the performance scores.

Approach 1 is predominantly favored over Approach 2 in most multiple objective decision analysis applications due to its comparatively simpler implementation. Approach 1 involves initially establishing a singular value metric that effectively orders the preference of different combinations of multiple performance scores. There are multiple methods available for creating this value metric. One often employed approach involves assigning a unique value scale to each performance score and subsequently aggregating these single performance score values into a comprehensive overall value metric (Konig & Wenzelburger, 2021).

Assuming there are N objectives and N performance scores, consider an N-dimensional space with indifference curves (or surfaces) defined by the performance score. These curves show equally preferable combinations of N performance scores. One of the Five Rules requires the existence of these indifference curves. Examples of indifference curves for a situation with two objectives and two performance scores are shown in Figure 1.5. These curves may exhibit discreteness or continuity.

It is crucial to emphasize that indifference curves are established without considering uncertainty, as they are derived by comparing value preferences for given prospects.

A multidimensional value function essentially assigns a specific value to each indifference curve. The value function is typically specified according to convention, where larger quantities of value are normally preferred over smaller quantities (Wilson et al., 2014).

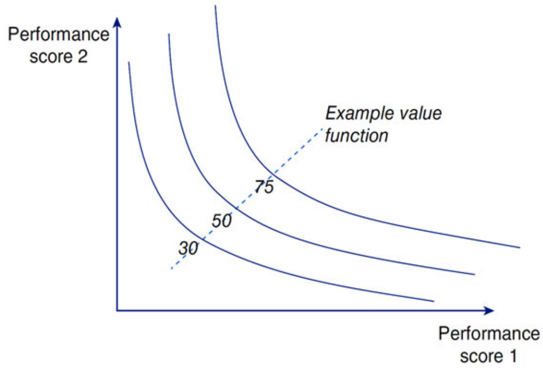

Figure 1.5. Example of indifference curves (Source: Johnson, Creative Commons License)

1.4.6. Monetary or Nonmonetary Value Metric

About Approach 1, the subsequent taxonomy classification is determined by whether the multi-dimensional value function yields a value metric on a monetary or non-monetary scale. The decision is frequently influenced by the characteristics of the decision situations. Some decision-makers, especially those in the public sector, might not be able or inclined to weigh the financial implications of different goals. For this situation, it is appropriate to utilize a non-monetary value metric. Approach 1A distinguishes itself from Approach 1B by employing a non-monetary value metric in a multiple objective decision analysis, while Approach 1B utilizes a monetary value metric (Dallimer et al., 2014).

Regardless of the circumstance, the decision maker's preference for trade-offs, the performance scores are represented by the multidimensional value function. As a result, it can take on any functional structure. However, it is often observed that a value function can be created to meet the requisite mathematical assumptions for a simple framework (Wam et al., 2016).

1.4.7. Level of Simplicity in Multidimensional Value Function

The most advanced level of categorization in the taxonomy is determined by the simplicity of the dimensional value function. Both Approaches 1A and 1B can utilize this option. One widely used and highly interesting approach to simplification is the additive value function. This function calculates the overall value by combining the value contributions from each performance score using weights and summing them. In order for an additive value function to be considered valid, each objective must be independent from all other objectives. According to decision-makers, the value of achieving one objective is not influenced by the degree of accomplishment of any other aim. Keeney and von Winterfeldt emphasize the importance of considering whether the objectives being employed are fundamental objectives rather than just means objectives. Furthermore, these objectives should meet specific criteria, particularly being nonredundant, meaning they do not overlap with other problems. A value function that incorporates additive value is likely to be legitimate (Cherfi & Prat, 2003).

Approach 1A utilizes an additive value function that assigns a unit-free value scale to every performance score using a one-dimensional value function. Additionally, a swing weight is evaluated for every performance score. The total worth is determined by multiplying the single-dimensional value for each performance score by that performance score's weight and summing across all performance scores. The Data Center illustrative example used throughout this handbook employs Approach 1A. In Approach 1B, an additive value function is defined by mapping each performance score to a monetary value scale. The total value is then calculated by summing the monetary values of all performance scores (Clarke, 1999).

PRACTICE PROBLEM

Contemplate a decision-making scenario in which a company is assessing two potential projects: Project A and Project B. The decision-makers must select between these projects based on multiple objectives. Project A possesses a superior anticipated monetary return, whereas Project B is projected to exhibit a swifter payback period. Determine the type of decision analysis (single or multiple objectives) and explore how the decision-makers might tackle the value trade-offs between monetary return and payback period.

SOLUTIONS TO PRACTICE PROBLEM

TYPE OF DECISION ANALYSIS: MULTIPLE-OBJECTIVE DECISION ANALYSIS

Discussion:

In this particular scenario, the individuals responsible for making decisions are taking into consideration both financial return and payback period as objectives, indicating a necessity for multiple-objective decision analysis. To tackle the value trade-offs, decision-makers could employ techniques such as multi-criteria decision analysis (MCDA) or utility functions. MCDA enables decision-makers to allocate weights to each objective based on their significance. They can subsequently assess the options using a weighted sum or other aggregation methods, aiding them in making a more informed decision that takes into account both monetary and time-related objectives.

SUMMARY

- This chapter provides an introductory overview of decision analysis, tracing its origins back to the 17th and 18th centuries.
- Modern decision analysis, rooted in core disciplines, emerged in the 1960s, incorporating probability theory, theory of decisions, behavioral decision theory, and soft expertise.
- Governed by five basic laws of behavior, decision analysis is designed to optimize expected utility in uncertain settings.
- The scope of decision analysis is defined by four key aspects: engagement with decision-makers, consideration of options, assessment of preferences, and evaluation of uncertainty.
- Various approaches to decision analysis have developed over the past fifty years, with differing objectives in terms of the quantity of goals and monetary/nonmonetary value metrics.
- Common elements in these approaches include effect models, value functions, achievement scores, and utility functions.

MULTIPLE CHOICE QUESTIONS

1. Which disciplines served as the foundation for the emergence of modern decision analysis in the 1960s?

a) Mathematics and Physics

b) Political Science and Sociology

c) Probability Theory, Theory of Decisions, Behavioral Decision Theory, and Soft Expertise

d) Economics and Philosophy

2. What role do the five rules play in the theoretical framework of decision analysis?

a) Establishing ethical guidelines

b) Providing a mathematical foundation

c) Ensuring legal compliance

d) Guiding decision-makers in risk assessment

3. In decision analysis, what is the primary objective of optimizing expected utility?

a) Maximizing profits

b) Minimizing decision complexity

c) Achieving the best possible outcome under uncertainty

d) Eliminating risk entirely

4. According to the chapter, what factors contribute to the scope of decision analysis?

a) Socioeconomic factors only

b) Cultural considerations only

c) Engagement with decision-makers, consideration of options, assessment of preferences, and evaluation of uncertainty

d) Political influences only

5. What distinguishes multiple-objective decision analysis from single-objective decision analysis?

a) The number of decision-makers involved

b) The complexity of the decision matrix

c) The presence of more than one decision criterion or objective

d) The use of different mathematical models

REVIEW QUESTIONS

1. What are the historical roots of decision analysis, and how has it evolved over time?
2. Explain the significance of the five rules as the theoretical foundation in decision analysis.
3. How does decision analysis aim to optimize expected utility, and what are the fundamental principles guiding this process?
4. Summarize the key aspects defining the scope of decision analysis, as outlined in the chapter.
5. Explore the various approaches to decision analysis discussed in the chapter and the objectives that differentiate them.

Answers to Multiple Choice Questions

1. (c) 2. (b) 3. (c) 4. (c) 5. (c)

REFERENCES

1. Bahl, H. C., & Hunt, R. G., (1984). Decision-making theory and DSS design. *ACM SIGMIS Database: The DATABASE for Advances in Information Systems*, *15*(4), 10–14.
2. Boithias, L., Terrado, M., Corominas, L., Ziv, G., Kumar, V., Marqués, M., & Acuña, V., (2016). Analysis of the uncertainty in the monetary valuation of ecosystem services—A case study at the river basin scale. *Science of the Total Environment*, *543*, 683–690.
3. Buchanan, L., & O Connell, A., (2006). A brief history of decision making. *Harvard Business Review*, *84*(1), 32.
4. Busemeyer, J. R., & Townsend, J. T., (1993). Decision field theory: A dynamic-cognitive approach to decision making in an uncertain environment. *Psychological Review*, *100*(3), 432.

5. Carvalho, F. J. C. D., (1988). Keynes on probability, uncertainty, and decision making. *Journal of Post Keynesian Economics*, *11*(1), 66–81.
6. Chen, Y. S., Pete, C. P., & Tong, Y., (1993). Theoretical foundation of the 80/20 rule. *Scientometrics*, *28*, 183–204.
7. Cherfi, S. S. S., & Prat, N., (2003). Multidimensional schemas quality: Assessing and balancing analyzability and simplicity. In: *Conceptual Modeling for Novel Application Domains: ER 2003 Workshops ECOMO, IWCMQ, AOIS, and XSDM, Chicago, IL, USA; Proceedings 22* (pp. 140–151). Springer Berlin Heidelberg.
8. Cinelli, M., Kadziński, M., Gonzalez, M., & Słowiński, R., (2020). How to support the application of multiple criteria decision analysis? Let us start with a comprehensive taxonomy. *Omega*, *96*, 102261.
9. Cinelli, M., Kadziński, M., Miebs, G., Gonzalez, M., & Słowiński, R., (2022). Recommending multiple criteria decision analysis methods with a new taxonomy-based decision support system. *European Journal of Operational Research*, *302*(2), 633–651.
10. Clarke, K. R., (1999). Nonmetric multivariate analysis in community-level ecotoxicology. *Environmental Toxicology and Chemistry: An International Journal*, *18*(2), 118–127.
11. Cribb, A., & Entwistle, V. A., (2011). Shared decision making: Trade-offs between narrower and broader conceptions. *Health Expectations*, *14*(2), 210–219.
12. Czembrowski, P., Kronenberg, J., & Czepkiewicz, M., (2016). Integrating non-monetary and monetary valuation methods–SoftGIS and hedonic pricing. *Ecological Economics*, *130*, 166–175.
13. Daams, M. N., Sijtsma, F. J., & Veneri, P., (2019). Mixed monetary and non-monetary valuation of attractive urban green space: A case study using Amsterdam house prices. *Ecological Economics*, *166*, 106430.
14. Dallimer, M., Tinch, D., Hanley, N., Irvine, K. N., Rouquette, J. R., Warren, P. H., & Armsworth, P. R., (2014). Quantifying preferences for the natural world using monetary and nonmonetary assessments of value. *Conservation Biology*, *28*(2), 404–413.
15. Edwards, W., Miles, R. F., & Von, W. D., (2007). *Advances in Decision Analysis* (Vol. 1, No. 1, pp. 1–20). Cambridge, New York.
16. Fivel, D. I., (2012). Derivation of the rules of quantum mechanics from information-theoretic axioms. *Foundations of Physics*, *42*, 291–318.
17. Fox, C. R., & Clemen, R. T., (2005). Subjective probability assessment in decision analysis: Partition dependence and bias toward the ignorance prior. *Management Science*, *51*(9), 1417–1432.
18. Gregory, R. S., (2002). Incorporating value trade-offs into community-based environmental risk decisions. *Environmental Values*, *11*(4), 461–488.
19. Gregory, R., Arvai, J., & McDaniels, T., (2001). Value-focused thinking for environmental risk consultations. *Environmental Risks: Perception, Evaluation, and Management*, *1*(1), 249–273.

20. Haddaway, N. R., & Rytwinski, T., (2018). Meta-analysis is not an exact science: Call for guidance on quantitative synthesis decisions. *Environment International*, *114*, 357–359.
21. Hegde, A., Ghosh, R., Mukherjee, T., & Sharma, V., (2016). Scope: A decision system for large scale container provisioning management. In: *2016 IEEE 9th International Conference on Cloud Computing (CLOUD)* (Vol. 1, No. 1, pp. 220–227). IEEE.
22. Henrion, M., Breese, J. S., & Horvitz, E. J., (1991). Decision analysis and expert systems. *AI Magazine*, *12*(4), 64–64.
23. Howard, R. A., (1988). Decision analysis: Practice and promise. *Management Science*, *34*(6), 679–695.
24. Insua, D. R., & French, S., (1991). A framework for sensitivity analysis in discrete multi-objective decision-making. *European Journal of Operational Research*, *54*(2), 176–190.
25. Kacelnik, A., & Bateson, M., (1997). Risk-sensitivity: Crossroads for theories of decision-making. *Trends in Cognitive Sciences*, *1*(8), 304–309.
26. Kajanus, M., Kangas, J., & Kurttila, M., (2004). The use of value focused thinking and the A'WOT hybrid method in tourism management. *Tourism Management*, *25*(4), 499–506.
27. Kangas, A. S., & Kangas, J., (2004). Probability, possibility, and evidence: Approaches to consider risk and uncertainty in forestry decision analysis. *Forest Policy and Economics*, *6*(2), 169–188.
28. Kassirer, J. P., (1976). The principles of clinical decision making: An introduction to decision analysis. *The Yale Journal of Biology and Medicine*, *49*(2), 149.
29. Keefer, D. L., Kirkwood, C. W., & Corner, J. L., (2004). Perspective on decision analysis applications, 1990–2001. *Decision Analysis*, *1*(1), 4–22.
30. Keeney, R. L., (1982). Decision analysis: An overview. *Operations Research*, *30*(5), 803–838.
31. Keeney, R. L., (1996). Value-focused thinking: Identifying decision opportunities and creating alternatives. *European Journal of Operational Research*, *92*(3), 537–549.
32. Keeney, R. L., (2008). Applying value-focused thinking. *Military Operations Research,1*(1), 7–17.
33. Keeney, R. L., Raiffa, H., & Rajala, D. W., (1979). Decisions with multiple objectives: Preferences and value trade-offs. *IEEE Transactions on Systems, Man, and Cybernetics*, *9*(7), 403–403.
34. Kenter, J. O., (2016). Deliberative and non-monetary valuation. In: *Routledge Handbook of Ecosystem Services* (Vol. 1, No. 1, pp. 271–288). Routledge.
35. König, P. D., & Wenzelburger, G., (2021). The legitimacy gap of algorithmic decision-making in the public sector: Why it arises and how to address it. *Technology in Society*, *67*, 101688.
36. Kunene, K. N., & Weistroffer, H. R., (2008). An approach for predicting and describing patient outcome using multicriteria decision analysis and decision rules. *European Journal of Operational Research*, *185*(3), 984–997.

37. Law, E. A., Bennett, N. J., Ives, C. D., Friedman, R., Davis, K. J., Archibald, C., & Wilson, K. A., (2018). Equity trade-offs in conservation decision making. *Conservation Biology*, *32*(2), 294–303.

38. Leon, O. G., (1999). Value-focused thinking versus alternative-focused thinking: Effects on generation of objectives. *Organizational Behavior and Human Decision Processes*, *80*(3), 213–227.

39. Martin, J. K., (1995). An exact probability metric for decision tree splitting and stopping. In: *Pre-proceedings of the Fifth International Workshop on Artificial Intelligence and Statistics* (Vol. 1, No. 1, pp. 379–385). PMLR.

40. Mendoza, G. A., & Martins, H., (2006). Multi-criteria decision analysis in natural resource management: A critical review of methods and new modeling paradigms. *Forest Ecology and Management*, *230*(1–3), 1–22.

41. Merrick, J. R., & Garcia, M. W., (2004). Using value-focused thinking to improve watersheds. *Journal of the American Planning Association*, *70*(3), 313–327.

42. O'Leary, D. E., (2007). Empirical analysis of the evolution of a taxonomy for best practices. *Decision Support Systems*, *43*(4), 1650–1663.

43. Parnell, G. S., Hughes, D. W., Burk, R. C., Driscoll, P. J., Kucik, P. D., Morales, B. L., & Nunn, L. R., (2013). Invited review—Survey of value-focused thinking: Applications, research developments and areas for future research. *Journal of Multi-Criteria Decision Analysis*, *20*(1–2), 49–60.

44. Pauker, S. G., & Kassirer, J. P., (2019). Decision analysis. *Medical Uses of Statistics*, *1*(1), 159–179.

45. Rasmussen, J., (1994). Taxonomy for work analysis. *Design of Work and Development of Personnel in Advanced Manufacturing*, *1*(1), 41–77.

46. Savic, D., (2002). *Single-Objective vs. Multiobjective Optimization for Integrated Decision Support, 1*(1), 1–20.

47. Scherpereel, C. M., (2006). Decision orders: A decision taxonomy. *Management Decision*, *44*(1), 123–136.

48. Schoemaker, P. J., & Russo, J. E., (1993). A pyramid of decision approaches. *California Management Review*, *36*(1), 9–31.

49. Selart, M., & Johansen, S. T., (2011). Understanding the role of value-focused thinking in idea management. *Creativity and Innovation Management*, *20*(3), 196–206.

50. Smith, J. E., & Von, W. D., (2004). Anniversary article: Decision analysis in management science. *Management Science*, *50*(5), 561–574.

51. Snowden, D. J., & Boone, M. E., (2007). A leader's framework for decision making. *Harvard Business Review*, *85*(11), 68.

52. Sorensen, J. A. T., & Chambers, D. A., (2008). Evaluating academic technology transfer performance by how well access to knowledge is facilitated—Defining an access metric. *The Journal of Technology Transfer*, *33*, 534–547.

53. Talley, J. L., (2011). Decision making in organizations. *JLTalley & Associates Bloomingdale's*, *1*(1), 14–15.

54. Wall, K. D., & MacKenzie, C. A., (2015). Multiple objective decision making. *Military Cost–Benefit Analysis: Theory and Practice*, *197,*1–20.

55. Wątróbski, J., Jankowski, J., Ziemba, P., Karczmarczyk, A., & Zioło, M., (2019). Generalized framework for multi-criteria method selection. *Omega*, *86*, 107–124.

56. Wilson, L., Loucks, A., Bui, C., Gipson, G., Zhong, L., Schwartzburg, A., & McCulloch, C., (2014). Patient centered decision making: Use of conjoint analysis to determine risk–benefit trade-offs for preference sensitive treatment choices. *Journal of the Neurological Sciences*, *344*(1, 2), 80–87.

57. Yang, J. B., & Xu, D. L., (2002). On the evidential reasoning algorithm for multiple attribute decision analysis under uncertainty. *IEEE Transactions on Systems, Man, and Cybernetics-Part A: Systems and Humans*, *32*(3), 289–304.

58. Yang, J. B., (2001). Rule and utility based evidential reasoning approach for multiattribute decision analysis under uncertainties. *European Journal of Operational Research*, *131*(1), 31–61.

59. Zachary, W., (1986). A cognitively based functional taxonomy of decision support techniques. *Human-Computer Interaction*, *2*(1), 25–63.

60. Zheng, J. H., Kou, Y. N., Jing, Z. X., & Wu, Q. H., (2019). Towards many-objective optimization: Objective analysis, multi-objective optimization, and decision-making. *IEEE Access*, *7*, 93742–93751.

CHAPTER

2

Decision Theory

LEARNING OBJECTIVES

After studying this chapter, you will be able to:

- Develop a fundamental understanding of Decision Theory by addressing key questions about decision processes.
- Recognize the interdisciplinary nature of Decision Theory, integrating insights from various fields.
- Differentiate between normative and descriptive theories in decision-making, distinguishing between ideal and practical decision scenarios.
- Explore the historical development of decision processes, from early contributions to contemporary models.
- Understand the role of preferences in decision-making and discover practical tools like numerical representation, utilities, and decision matrices.

.

INTRODUCTORY EXAMPLE

Optimizing Production Processes

Consider a manufacturing organization that must decide whether to implement a new production procedure. This decision will have a significant impact on overall operations, expenses, and efficiency. Let's begin by examining the theoretical aspects of the decision before delving into decision theory. What aspects need to be considered, and how can they be systematically examined to make the optimal decision?

Decision Theory is an interdisciplinary approach that incorporates ideas from various domains. Let's explore the differences between ideal (normative) and actual (descriptive) decision-making situations. Think of it as understanding the playbook before making a crucial play in a game.

Throughout the text, the reader is guided through the evolution of decision processes, from early contributions to the most recent models. This historical background provides valuable insights into the development of decision-making techniques.

Basic ideas like deciding and valuing are at the center of decision-making. We will translate these ideas into real-world contexts and discuss how choices can be made efficiently.

An important factor in decision-making is preference. We will explore how decision matrices, utilities, and numerical representation serve as useful tools for making defensible decisions.

Lastly, we will examine expected utility theory and learn how to assess the goodness or badness of a decision. We will also delve into Bayesianism and its impact on decision-making, particularly in the estimation of probabilities.

UNIT INTRODUCTION

The chapter explores decision processes using contemporary sequential and non-sequential models, as well as historical contributions such as those made by Condorcet. This background information serves as a basis for comprehending the stages of practical decision-making (North, 1968).

The concepts of deciding and valuing are important to the decision-making process, which include comparable value terms, completeness, and transitivity. These concepts serve as the foundation for making effective and efficient decisions. Furthermore, the chapter delves into the significance of preferences in the decision-making process, exploring numerical representation, utilities, decision matrices, and practical tools for creating decision structures (Kaplan, 1967).

In addition, the expected utility theory will be explored, along with the differentiation between objective and subjective utility criteria. Bayesianism and the evaluation of expected utility are investigated, with the goal of shedding insight into how Bayesian principles and probability estimations influence decision-making processes. Throughout this chapter, there will be an in-depth examination of Decision Theory, involving the dissection of its constituent parts and the demonstration of the practical ramifications of these components in the field of decision-making (Liese & Miescke, 2008).

2.1. DECISION THEORY

Learning Objectives

- Understand the fundamental concepts of decision theory and its relevance in various disciplines.
- Differentiate between normative and descriptive theories within the context of decision theory.

The topic lacks cohesion. However, there are various research traditions and approaches to decision theorizing. This text attempts to reflect some of the subject's diversity, focusing on the less mathematically complex components of decision theory (Peer & Gamliel, 2013).

2.1.1. Theoretical Questions About Decisions

Here are certain situations of decisions and the theoretical issues they raise:

1. **Are they planning to bring the umbrella today?** The decision depends on whether it will rain, which is something they do not know.
2. **The individual is seeking to purchase a home. Will they purchase this one?** This house appears fine, but if they search farther, they might discover a better one for the same amount of money. When are they going to quit searching?
3. **Will they light up another cigarette soon?** Smoking one cigarette is not an issue, but if they continue to make the same decision over and over, it might kill them.
4. **Whether or not the defendant is guilty must be determined by the court?** The court has two options: it can find someone guilty who is innocent, or it can find someone innocent who is guilty. If the court decides that the first error is more significant than the second, what rules should it follow?
5. **A committee must decide, yet its members cannot agree on anything.** What guidelines should they follow to make sure they can still get to a decision even when they disagree? (Zhang, 2012).

Almost all human actions entail making decisions. As a result, thinking theoretically about decisions is very similar to thinking theoretically about human activities. Decision theory is not quite as comprehensive, as it only focuses on a small portion of human behavior. It specifically examines how individuals exercise their freedom. Decision theorists analyze scenarios where individuals have options to consider and make deliberate, non-random decisions. In these circumstances, the decisions made are goal-oriented endeavors. Therefore, decision theory centers around goal-directed behavior in the presence of options (Hulin et al., 1985). One cannot make decisions all the time. The history of almost any activity consists of periods when most decisions are made and implementation takes place. Decision theory provides insights into these periods in various ways (Pogarsky, 2009).

2.1.2. An Interdisciplinary Subject

Since the mid-1900s, various academic disciplines have contributed to the development of modern decision theory. Researchers who identify as economists, statisticians, psychologists, political and social scientists, or philosophers usually explore decision theory, even though it is now evidently a distinct academic field (Yang, 2009).

Between these disciplines, there is some division of labor. A political scientist will probably research voting procedures and other facets of group decision-making. A philosopher will likely examine what constitutes rationality in decisions, whereas a psychologist will likely examine how people behave. There is a lot of overlap, though, and the field has benefited from the range of approaches used by scholars from various backgrounds to address the same or related issues (Ellis & Fouts, 2001).

Remember

Decision theory encompasses both normative and descriptive theories, providing a comprehensive framework for understanding how decisions are made and offering insights into the decision-making process.

2.1.3. Normative and Descriptive Theories

There is a relatively straightforward difference between normative and descriptive decision theories. A descriptive theory describes decisions, while a normative theory explains how decisions should be made.

There are various ways to interpret the word "should" in the above phrase. However, decision scientists generally agree that it pertains to the prerequisites for making rational decisions. In other words, a normative decision theory describes how rational decisions should be made (Suhonen, 2007).

In this context, the term "normative" has a narrow definition. Rationality norms are not the only, or even the most significant, norms to consider when making decisions. On the other hand, decision theory is sometimes used to consider external norms other than rationality norms.

The traditional view holds that decision theory does not come into play until after establishing political or ethical norms. It addresses the normative concerns that persist after the objectives have been established (Hilton, 1980).

Most of the remaining normative issues deal with what to do in situations with uncertainty and insufficient information. It also tackles the issues of how many individuals can coordinate their decisions in social decision-making processes and how a single person may coordinate their decisions over time.

The decision theorist aims to provide guidance to the general on how to achieve victory in war, if that is the desired outcome. However, the question of whether the general should even strive to win the war is not typically considered a decision-theoretical issue.

Similarly, decision theory offers strategies for an environmental organization to minimize toxic exposure and for a company executive to maximize profits. Nevertheless, the fundamental question of whether these strategies should be pursued is not addressed in decision theory.

Although the term "normative" in decision theory has a narrow definition, the boundary between norm (i.e., rationality-normative) and descriptive interpretations of choice theories can sometimes be unclear. When reading decision-theoretic literature, it is not uncommon to encounter unsettling uncertainties and discrepancies between normative and descriptive interpretations of the same theory (Rapoport, 1994).

Many of these misconceptions were likely preventable. It is acknowledged that distinguishing between normative and descriptive interpretations is more challenging in decision science than in many other fields. This is evident when one considers what qualifies as a decision theory falsification.

The criterion for a descriptive choice theory to be deemed false is rather evident.

1. **(F1):** If a decision problem can be identified where most human subjects perform contrary to the theory, then the decision theory is *falsified* as a descriptive theory. Falsification must refer to the rules of rationality since a normative decision theory specifies the behavior of a rational actor. The degree to which the theory and rational decision-making clash for the theory to be shown false is unclear.
2. (**F2**): When a decision theory is applied to a situation where an agent could act in a way that contradicts the theory without being regarded as irrational, the theory is said to be weakly falsified as a normative theory (Luce & Von, 1994).
3. **(F3):** A decision theory is strictly *falsified* as a normative theory if a decision problem exists where an agent who adheres to the theory cannot be considered a rational agent.

Let's consider a theory called T, claimed by its creator to be valid both as a normative and descriptive theory. Additionally, let's assume that through experiments, we have discovered that in decision problem P, many individuals do not adhere to T. In other words, condition F1 is met for T (Ihwe & Rieser, 1979).

The attitudes and behaviors of decision theoreticians are not known to diverge much from those of others.

Consequently, it is quite likely that at least a portion of them will share the same beliefs as most of the participants in the experiment. Subsequently, they will assert that both (F2) and maybe (F3) have been fulfilled. Hence, it is reasonable to anticipate that any descriptive falsifications of a decision theory will be accompanied by assertions that the theory lacks validity from a normative perspective. Indeed, this is a frequent occurrence (MacCrimmon, 1968).

2.2. DECISION PROCESSES

Learning Objectives

- Explore historical perspectives on decision processes, from Condorcet to modern sequential and non-sequential models.
- Analyze the phases involved in practical decision-making processes.

Most decisions are not made right away. It makes sense to divide them into discrete phases or stages because they require a significant amount of time.

2.2.1. Condorcet

The first comprehensive theory outlining the many stages of a decision-making process was proposed by the leading philosopher of the Enlightenment era, Condorcet. This theory was a key rationale behind the development of the French constitution in 1793. The decision procedure was separated into three phases. During the initial phase, individuals comprehensively analyze the fundamental concepts that will form the foundation for deciding on a general issue. They thoroughly evaluate the diverse facets of this issue and consider the potential outcomes of alternative decision-making approaches. At this stage, the opinions are subjective, and there is no effort to establish a consensus. After that, there is a second discussion where "the question is clarified, opinions approach and combine with each other to a small number of more general opinions." Thus, the decision is simplified to selecting from a limited number of viable options. The third stage involves the definitive selection among these alternatives (Over, 2004). The theory is wise and thought-provoking. Condorcet's differentiation between the first and second discussion appears highly advantageous. Nevertheless, his thesis regarding the phases of a decision-making process has been largely neglected and appears to have not been cited in contemporary decision theory.

2.2.2. Modern Sequential Models

However, modern discussion typically begins with John Dewey's explanation of problem-solving phases. Dewey posits that problem-solving is comprised of five sequential stages:

a) A perceived challenge
b) The characterization of that challenge
c) Proposed remedies
d) Assessment of the proposal
e) Additional observation and experimentation that are required to determine whether the recommendation should be accepted or rejected.

In 1960, Herbert Simon adjusted Dewey's list of five stages to align it with decision-making in organizational settings better. Simon states that the decision-making process has three main stages:

i. Identifying opportunities for making a decision.

ii. Generating possible courses of action.

iii. Selecting one from the available courses of action.

As referred to by Thrall et al. (1954), the initial step is termed "intelligence," drawing inspiration from the military definition of the term. The subsequent phases are labeled as "design" and "choice," respectively.

Another significant segmentation of the decision process is offered by a researcher, which consists of five distinct steps:

a) Problem identification

b) Acquisition of essential information

c) Generation of potential solutions

d) Assessment of these solutions

e) Selection of a performance strategy

The concepts proposed by Dewey, Simon, and Brim are characterized by their sequential nature, as they involve dividing decision processes into distinct portions that consistently follow a predetermined order or sequence. However, Witte (1972) and other scholars have expressed criticism against the notion that the decision-making process can be universally divided into sequential stages. His empirical data suggests that the "stages" are executed in parallel rather than sequentially (Rajagopalan et al., 1993) (Figure 2.1).

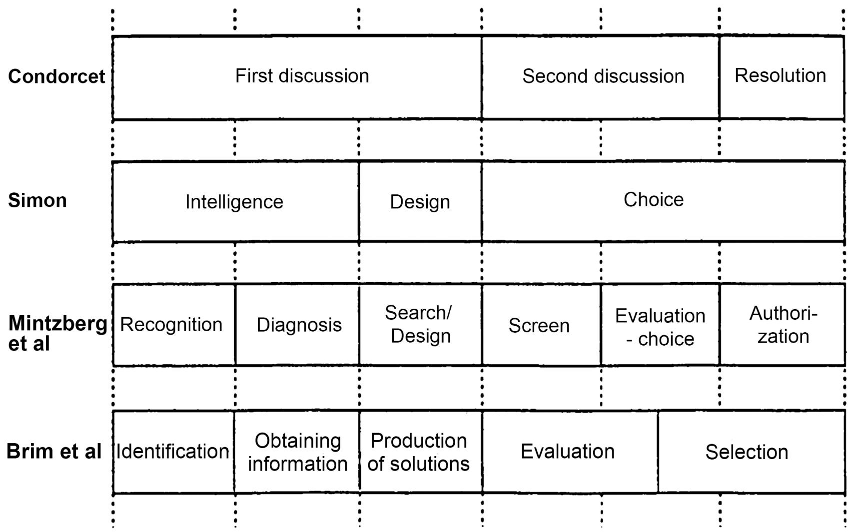

Figure 2.1. A comparison of the stages of the decision process (Source: Sven Ove Hansson, Creative Commons License)

"Researchers believe that humans are incapable of acquiring information without generating alternative possibilities. They are compelled to promptly assess these alternatives, which inevitably leads them to decide. This is a collection of procedures, and the sequence of these procedures over time forms the entirety of the decision-making process."

An improved model should accommodate the possibility of distinct components of the decision-making process occurring in varying sequences across different decisions (Puterman, 1990).

2.2.3. Non-SequentialModels

An influential model that meets this requirement was suggested by Mintzberg, Raizinghani, and Théorêt in 1976. These authors claim that the decision-making process consists of several phases, but that these phases do not necessarily occur in a simple sequential order. They utilized the same three initial phases as Simon, but gave them other names: identification, development, and selection (Swets et al., 1961).

The identification step, sometimes known as Simon's "intelligence," has two routines. First is decision recognition, which entails finding "problems and opportunities" among the bewildering streams of information that decision-makers are presented with, mostly verbal in nature. To clarify and define the issues at hand, the second step in this phase is diagnosis, which entails using the available channels of information as well as creating new ones (Wang et al., 2015).

The development phase, often referred to as Simon's "design," aims to establish and clarify the available choices. This stage also consists of two routines. The search routine is designed to locate pre-existing solutions, while the design routine focuses on creating new solutions or adapting existing ones. The final stage, known as the selection phase (Simon's "choice"), consists of three distinct routines. The first routine, the screening routine, is triggered when it is expected that the search will yield more pre-existing alternatives than can be thoroughly reviewed. During the screening routine, inferior options are discarded. The second routine, the evaluation-choice routine, involves selecting one alternative from a set of options. This process may involve utilizing one or more of three "modes": intuitive judgment, bargaining, and analysis. In the final routine, known as authorization, the chosen solution is granted approval from higher-ranking individuals within the hierarchy (Chahuara et al., 2016).

The relationship between these phases and routines is cyclical rather than linear. During the design phase, the decision-maker may conduct numerous analyzes to pinpoint the problem.

During the evaluation phase, they might then have to work through a challenging set of connected design and search tasks to come up with a solution. Additionally, they may choose between the stages of development and investigation to gain a deeper understanding of the problem they are attempting to solve. Finally, they may cycle between the stages of selection and development to align their goals with the available alternatives, ultimately achieving a harmonious balance between ends and means. Usually, if no satisfactory answer is identified, they will revert to the development phase.

Figure 2.2 shows the connections between these three stages and seven routines (Cuervo, 2011).

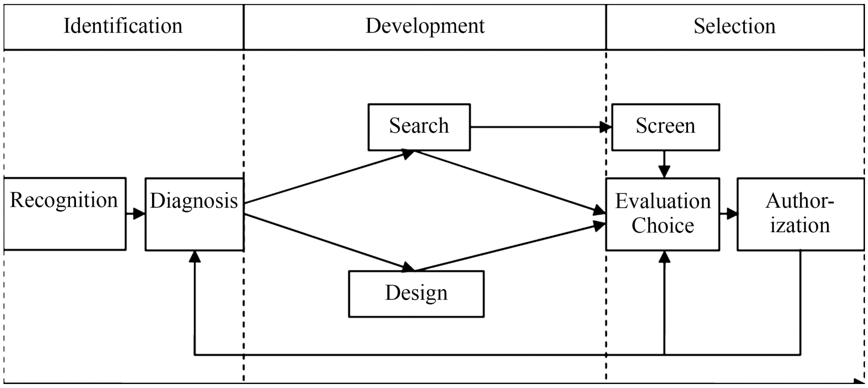

Figure 2.2. Model of decision-making process (Source: Mintzberg et al 1976, Creative Commons License)

2.2.4. The Phases of Practical Decisions

According to Simon, CEOs allocate a substantial amount of their time to intelligence-related tasks, a greater amount to design-related tasks, and a lesser amount to decision-making-related tasks. The empirical findings of Mintzberg et al. (1976) corroborated this. Among the 25 decision processes examined by the researchers and their students, the development phase prevailed in 21 of them.

In contrast, most research on decision-making has primarily focused on the evaluation-choice routine. While numerous empirical decision studies have encompassed the entire decision process, decision theory has exclusively concentrated on the evaluation-choice routine. Mintzberg and coauthors find it intriguing that this routine is not as crucial as diagnostic or design in the choice processes they analyzed (Bresadola et al., 2020).

This poses a significant criticism of decision theory. It could be argued in favor of the evaluation-choice routine that it is indispensable to the decision-making process. Through this routine, the process becomes a decision process, and the nature of the other routines is largely influenced by it. Therefore, it is imperative to give considerable consideration to the evaluation-choice routine. However, this should not justify the almost complete disregard for other routines, which is often the case with normative decision theory (Iwasa et al., 2020).

2.3. THE CONVENTIONAL APPROACH TO INDIVIDUAL DECISIONS

Learning Objectives

- Define and distinguish between alternatives, states of nature, and outcomes in decision-making.
- Explore the construction and application of decision matrices in analyzing choices.

This section introduces decision matrices, which are a common way that the mainstream theory of individual decision-making represents a decision problem. To fully grasp this concept, we need to understand several fundamental ideas from decision theory, such as alternatives, outcomes, and the state of nature (Barlex & Trebell, 2008).

2.3.1. Alternatives

When making a decision, one can select from various alternatives (options). Usually, alternatives are actions that the decision-maker has available to them at the time of decision or that they at least feel are available to them.

The range of alternatives may be rather well-defined. Certain decision-making situations are open-ended in that the decision-maker may come up with or find additional alternatives. An uncommon instance would be the decision of what to do this evening.

Other decision problems have a closed set of alternatives, meaning no more can be added. The decision of voting in the upcoming elections is a typical example. There are only a few alternatives (candidates or parties) from which one must select (Churchland et al., 2008).

A decision-maker can limit their scope of choice. One may decide that there are only two alternatives worth considering when determining how to spend this evening: remaining home or going to the movies. By doing this, they have eliminated one of their alternatives, leaving them to decide between the two items in that set.

There are two types of decisions with closed alternate sets: those that are closed willingly and those that are closed involuntarily. A set is voluntarily closed when the decision-maker decides to do so (as a first step in the decision-making process). When closure was imposed against one's will, it was because of external factors or other individuals. Open alternative sets are a typical occurrence in real life. However, alternative sets are typically taken to be closed in decision theory. Decision problems become far more amenable to theoretical treatment when closed. There is typically no conclusive answer to a decision problem when the alternative set is open (Yager, 2002).

Moreover, it is widely believed that the alternatives are mutually incompatible, meaning that none can be achieved simultaneously. The discourse that follows demonstrates why this is the case:

Bob:" I'm not sure what I should do tomorrow. I must decide between two alternatives. One of them is to attend the morning Kant lecture given by Professor Schleier. The other alternative is to attend the evening performance in the symphony venue."

Cynthia:" But, have you not considered doing both?"

Bob:" Yes, I could definitely do it."

Cynthia:" You have three options: you can choose to attend the lecture alone, the concert alone, or both."

Bob:" Yes, that is another way of saying it."

Cynthia mentioned three alternatives, but none of them can be implemented simultaneously, thus they are mutually exclusive. In decision theory, her representation of the circumstance is chosen since it is more detailed and understandable.

Because of this, it is widely accepted in decision theory that the set of alternatives is closed and that its components are mutually exclusive (Nutt, 1999).

2.3.2. States of Nature and Outcomes

The outcome of a decision is not solely determined by the selection of an alternative and its execution. It is also influenced by variables that are beyond the control of the decision-maker. Some of these variables are known and represent the decision-maker's background information, while others are unknown and depend on external factors such as the actions of others and natural phenomena.

For instance, consider the decision to attend or not attend an outdoor performance. The satisfaction of this decision depends on both human behavior, such as how the band performs, and natural factors like the weather (Balmford et al., 2003).

In decision theory, it is customary to group the unidentified external elements into different "states of nature." This concept can be illustrated through a simple example. Let's say I have to decide whether to bring an umbrella when I go out tomorrow. This decision will be influenced by whether it rains or not. From a decision-theoretic perspective, the two scenarios "it rains" and "it does not rain" can be considered as the natural states.

The combined effect of the chosen alternative and the resulting state of nature are referred to as the possible outcomes of a decision. For instance, if someone forgets to bring an umbrella and it starts raining, they will end up with a light suitcase and get wet. On the other hand, if they take an umbrella and it rains, they will have a larger suitcase and stay dry, etc. (Avant, 2004).

2.3.3. Decision Matrices

In (individual) decision theory, the evaluation-choice routine is typically presented as a decision matrix. The alternatives available to the decision-maker are tallied against the possible states of nature in a decision matrix. The rows of the matrix reflect the alternatives, and the columns represent the states of nature. Let's consider whether to carry an umbrella as an illustration. This is the choice decision:

	It rains	**It does not rain.**
Umbrella	Dry clothes, heavy suitcase	Dry clothes, heavy suitcase
No umbrella	Soaked clothes, light suitcase	Dry clothes, a light suitcase

The decision matrix designates an outcome (in our example, "dry clothes, heavy suitcase") for each alternative and state of nature.

Exercise: Draw a decision matrix that illustrates the decision whether or not to buy a ticket in a lottery.

In addition to the matrix itself, one also needs (1) information about how the outcomes are valued and (2) information about which of the states of nature will be realized to use a matrix to assess a decision (Hughes & Shupe, 2010).

The most popular method for representing outcome values is to give them utility values. Then, utility values in the matrix can take the role of verbal descriptions of the results:

	It rains	**It does not rain**
Umbrella	15	15
No umbrella	0	18

Almost all mainstream decision theory focuses on issues represented as utility matrices, which are a particular kind of matrix. Most contemporary decision-theoretic techniques require numerical data. In many real-world decision-making situations, one may have even less accurate value information, often expressed through an incomplete preference relation. However, developing techniques that can efficiently handle non-numerical data is far more challenging (Mullur et al., 2003).

2.3.4. Information about States of Nature

Utility matrices are coupled in decision theory with several kinds of information about the state of nature. As a limiting case, the decision-maker might know which state of nature would prevail. In the scenario above, if one knows that rain is expected, this simplifies the decision considerably. "Decision-making under certainty" refers to situations such as this one, in which only one state of nature needs to be considered. If you know, for each alternative, what will be the outcome if you choose that alternative, then you act under certainty. If not, then you act under non-certainty (Byrnes, 2013).

Non-certainty is commonly categorized as risk, uncertainty, and ignorance. The primary source for this categorization is Knight, who observed that the term 'risk,' as commonly used in everyday language and economic discourse, encompasses two distinct concepts that are fundamentally different in their causal relationships to the phenomena of economic organization. In certain instances, the term "risk" refers to "a quantity susceptible to measurement," whereas, in other instances, it denotes "something distinctly not of this character." He suggested using the phrase "uncertainty" to refer to situations that cannot be measured and "risk" to refer to situations that can be quantified (Fisher, 1958).

In one of the most influential textbooks in decision theory, the terms are defined as follows:

i. **Certainty**: if each action will inevitably result in a particular outcome. This concept is also expressed using terms such as prospect, stimulus, alternative, etc.

ii. **Risk:** refers to the possibility that each action will result in one of the possible specific outcomes, and each event has a known probability of occurring. The decision maker is considered to know the probability. For example, a particular conduct could result in a precarious outcome: a gain of $10 if a 'fair' coin lands on heads and a loss of $5 if it lands on tails. Of course, certainty can be considered a special example of risk in which the probability is either 0 or 1.

iii. **Uncertainty:** If either action or both actions result in a set of possible specified outcomes, the probabilities of these events are completely unknown or not meaningful (Saunders, 2005).

These three alternatives do not cover all possibilities. Many decision problems can be classified as falling within the spectrum between risk and uncertainty, as delineated by Luce and Raiffa. Consider, for example, my decision this morning to forgo bringing an umbrella. Due to the lack of knowledge on the probability of rain, the decision was not based on risk. However, I was not entirely unaware of the probability of rain. It was known that the probability fell between 5 percent and 99 percent.

The term "uncertainty" is often used to encompass circumstances with only a partial understanding of the probability involved. The stricter form of uncertainty, as Luce and Raiffa described, is sometimes called "ignorance." One can encounter the subsequent scale of knowledge scenarios in decision problems:

i. **Certainty:** deterministic knowledge;

ii. **Risk:** complete probabilistic knowledge-uncertainty;

iii. **Partial probabilistic knowledge ignorance:** no probabilistic knowledge.

It is common to categorize decisions into different types, such as decisions made "under risk" or "under uncertainty," among others.

In summary, the standard representation of a decision consists of (1) a utility matrix, and (2) information about the likelihood of each state of nature in that matrix. Therefore, in the case of decision-making under risk, the standard representation includes a probability assignment to each of the states of nature (i.e., to each column in the matrix) (Rosenthal, 2010).

2.4. EXPECTED UTILITY

Learning Objectives

- Differentiate between subjective and objective utility.
- Assess the appraisal of Expected Utility (EU) and understand how probability estimates contribute to decision-making.

The prevailing method for making decisions when faced with risk, specifically when probabilities are known, is expected utility (EU). Undoubtedly, this has been the dominant approach to decision-making since the Second World War, in both normative and descriptive application.

The expected utility can be more accurately called "probability-weighted utility theory." Expected utility theory assigns a weighted average of utility values to each alternative, considering distinct states of nature, with the probability of these states used as the weights (Tversky, 1975).

Let us once again utilize the umbrella example that has been mentioned in previous parts. The utilities are listed below:

	It rains	**It does not rain**
No Umbrella	0	18
Umbrella	15	15

Let's suppose that the probability of rain is 1. The expected (probability-weighted) utility of carrying the umbrella is 0.1´15 + 0.9´15 = 15, and that of not bringing the umbrella is 0.1´0 + 0.9´18 = 16.2. In accordance with the principle of Maximum Anticipated Utility (MEU), it is advisable not to bring the umbrella in this situation. However, if the probability of rain is 0.5, then the expected (probability-weighted) utility of carrying the umbrella is also 0.5´15 + 0.5 ´15 = 15, and that of not bringing the umbrella is 0.5´0+.5´18 =9.. If the goal is to optimize the expected utility, bringing the umbrella in this scenario is advisable.

This can also be expressed more broadly: Assume that there are n possible outcomes, each with a corresponding utility and probability. The outcomes are sequentially assigned numbers, such that the first outcome is associated with utility u_1 and probability $p_{1,}$ the second outcome is associated with utility u_2 and probability p_2, and so on. The expected utility is defined as follows:

$$p_1´u_1+p_2´u_2+\ldots+p_n´u_n$$

Although the phrase "expected utility" was coined later, the idea behind expected utility theory predates mathematical probability theory. The 17th century saw the creation of both games as a means of conducting research on parlor games. The Port-Royal Logic (1662) states that "to judge what one ought to do to obtain a good or avoid an evil, one must not only consider the good and the evil in itself, but also the probability that it will or will not happen and view geometrically the proportion that all these things have together." (Cappello et al., 2016).

2.4.1. Subjective and Objective Utility

Initially, the expected utility theory did not concern itself with utilities in the modern sense of the word, but rather focused on monetary outcomes. The recommendation was to participate in a game only if it yielded a greater expected financial profit; otherwise, it was urged to refrain from doing so. The indicated probabilities are objective frequencies, which can be directly observed on dice and other mechanical devices (Tversky, 1967).

Nicolas Bernoulli (1687–1759) presented a challenge for probability theory in 1713, currently referred to as the St. Petersburg conundrum. (It was published in the proceedings of a local academy). Let's examine the following game: A coin with an equal probability of landing on either side is repeatedly flipped until the first occurrence of a head. You will be awarded a gold coin if the first coin toss yields a head. You will be rewarded with 2 gold coins if the second toss results in a head. If it comes up on the third toss, you will be rewarded with 4 gold coins. Generally, if it occurs on the n^{th} toss, you will be rewarded with 2^n gold coins (Fransson et al., 2007).

The probability that the first head will occur on the n^{th} toss is $1/2n$.

Upon participation in the game, the expected wealth are 1/2´1+1/4´2+.....1/2n× 2n-1+ ...

A rational agent should be willing to pay any finite amount of money to play this game, especially if it means risking their entire fortune on a single St. Petersburg game run, as this sum equals infinity. This is in line with the maxim of maximizing expected wealth.

Daniel Bernoulli (1700–1782) put forth what is today considered the standard solution to the St. Petersburg puzzle in 1738. His main proposal was to substitute the maxim of maximizing expected wealth with that of maximizing expected (subjective) utility. An individual's utility of wealth increases at a decreasing pace rather than increasing linearly with the amount of money (Edwards, 1962).

Even if one is already a millionaire, their first $1000 is worth more than that $1000. (More specifically, Daniel Bernoulli suggested that the utility of wealth is a logarithmic function of wealth amount, with the utility of the next increase of wealth being inversely proportionate to the amount one already had). An individual with such a utility function would be reluctant to risk their savings in the St. Petersburg game, as is easily verifiable.

Subjective utilities are frequently employed in decision theory applications to economic issues. Welfare economics assumes that a person's utility is an increasing function with their money, yet this function may vary from person to person (Schmeidler, 1989). Conversely, objective utility is the predominant method in risk analysis. Multiplying the probability of a risk with its severity, to call that the expectation value, and to use this expectation value to compare risks, is a common method of measuring risk.

For example, the most severe reactor-meltdown accident, typically resulting in 50,000 fatalities and occurring with a probability of $10^{-}8$/reactor-year, accounts for only approximately two percent of the overall health consequences caused by reactor accidents. This form of expected utility possesses the benefit of intersubjective validity. Once the expected utilities, commonly employed in risk analysis, have been accurately ascertained for an individual, they are accurately ascertained for all individuals. Conversely, if utilities are considered subjective, the intersubjective validity is compromised, resulting in a significant reduction in the importance of expert opinion (Fischer, 1979).

2.4.2. Appraisal of Expected Utility

The primary rationale for advocating the maximization of objectivist expected utility is that it is a relatively secure approach to optimizing long-term outcomes. Assuming, for example, that the expected fatality count in traffic collisions within a specific area would be 300 annually under mandatory safety belt regulations and 400 annually if belt regulations are optional.

If these calculations are accurate, it is estimated that approximately 100 more individuals will be killed each year in the latter scenario compared to the former. When selecting one of these alternatives, users know whether it would result in fewer or more fatalities than the other alternative. By maximizing the expected utility, the predicted number of deaths can be decreased, as dictated by the law of large numbers (Bristow & Nellthorp, 2000).

The soundness of this argument depends on the large number of road accidents, which mitigates the random effects over an extended period. Thus, the argument lacks validity when applied to individual or exceedingly uncommon events. Consider, for example, a scenario where we are faced with the option of a 0.001 probability of an event resulting in the death of 50 individuals versus a 0.1 probability of an event resulting in the death of one person. In this scenario, the random effects will not be equalized, as in the case of the traffic belt (Hertin et al., 2008). Put simply, when selecting one of the options, it is uncertain if it will result in fewer fatalities than the other option. Under these circumstances, there is no compelling justification to maximize the expected utility when considered independently.

However, it is reasonable to choose the first option (with fewer expected deaths) in this case based on the application of expected utility theory. This decision can be justified if it is part of a larger group of decisions where a meta decision has been made to maximize expected utility. For example, it might be argued that a key factor in regulating chemical substances should be to maximize expected utility, which means limiting expected damage. By consistently applying this criterion to all individual regulatory decisions, the potential harm caused by chemical exposure can be minimized (Nilsson et al., 2008).

The larger the group of decisions encompassed by such a regulation, the more pronounced the leveling out effect becomes. But the larger the group of decisions, the more significant the potential for mitigating catastrophic effects. Nevertheless, a practical and absolute constraint exists to this phenomenon. The practical constraint is that decisions must be taken in manageable increments. When many problems are combined, the difficulties in processing information can result in losses greater than any anticipated benefits. Decisions can be divided into manageable groups in various ways, and the chosen method can significantly impact the results. For instance, the prioritization of worker safety against radiation may be elevated when it is categorized alongside other radiation-related concerns instead of being included in other work environment matters (Pearce & Seccombe, 2000).

The leveling-out effect has an absolute limit, which means that certain severe impacts, such as a nuclear war or a major ecological threat to human existence, cannot be leveled out, even if all human decision-making is focused on maximizing expected utility. An example of this can be observed in the Pentagon's implementation of covert utility assignments to mitigate the risk of accidental nuclear strikes and to address the potential failure to retaliate against a nuclear assault. These assignments serve as the foundation for developing command and control systems.

Even if the leveling-out argument for expected utility maximization is applicable, adherence to this principle is not mandated by rationality. Specifically, a rational agent can choose not to minimize overall harm to prevent the imposition of high-probability risks on individuals (Kassim, 1994).

To illustrate this concept, consider a scenario where a critical gas leak occurs in the machine room of a chemical factory, demanding a prompt decision between two remedial actions. One option is to immediately deploy the sole competent repairman, who faces a 90% probability of dying in an explosion following the necessary technical operations. Alternatively, the other choice involves releasing the gas into the environment, with the repairman facing no specific risk, but 10,000 individuals in the plant's vicinity each having a 0.1% chance of being fatally affected by the toxic gas. Adhering to the maxim of maximizing expected utility dictates sending in the repairman, accepting the sacrifice to minimize the overall number of deaths. However, it is debatable whether this is the only rational response, as a decision-maker guided by reason may opt against maximizing expected utility to avoid perceived unfairness to an individual and infringement of their rights.

It is crucial to note that expected utility maximization is only meaningful when comparing options within the same decision context. Notably, violations of this principle are evident in risk analysis, where expected utility calculations are often applied to compare risk factors that do not pertain to options within a single decision. For instance, risk analysts hired by proponents of certain risks might compare them to unrelated risks, arguing for acceptance based on relative magnitudes, such as claiming a smaller risk than being struck by lightning. Such comparisons, however, may not be universally rational, as illustrated by the example of accepting pesticide residues while rejecting them due to their smaller magnitude compared to natural carcinogens in food. It is not irrational to decline one risk while tolerating another that is more severe if these risks are not options within the same decision context. Embracing every proposed new risk smaller than an already accepted risk could lead to disastrous consequences.

In summary, the normative standing of expected utility maximization depends on the anticipation of a leveling-out effect. The strongest argument in favor of objectivist expected utility arises when numerous similar decisions adhere to a consistent decision rule.

2.4.3. Probability Estimates

To ascertain expected values, the accuracy of objective probability estimates becomes paramount. While certain applications of decision theory draw upon empirically known frequencies, exemplified by death rates stemming from asbestos exposure in epidemiological studies, the foundation of probability estimates in many risk assessments is notably less secure. Chemical risk assessments, for instance, often rely on indirect empirical evidence, introducing uncertainty into probability estimates. Similarly, the estimation of failure rates for technological components frequently lacks robust empirical support, accentuating the challenge of establishing reliable probabilities (Wakslak & Trope, 2009) (Figure 2.3).

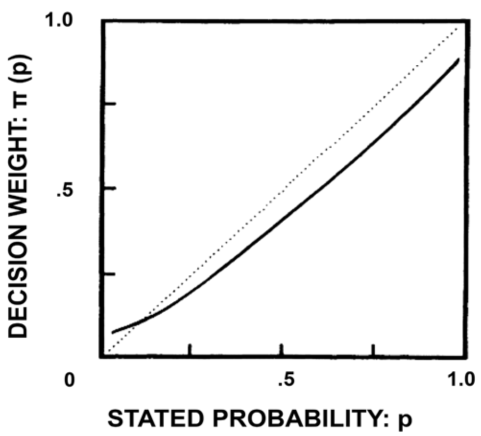

Figure 2.3. The decision weight as a function of objective probabilities (Source: Tversky and Kahneman, Creative Commons License)

The reliability of probability estimates depends on the alignment or divergence between objective probabilities and subjective estimates of these probabilities. Experimental psychology refers to this phenomenon as "lack of calibration." A well-calibrated probability estimate indicates that, over time, the proportion of true statements aligns with the assigned probability. Calibration studies, particularly those focused on general-knowledge questions, highlight a prevailing overconfidence bias among subjects. However, recent research suggests that the overconfidence effect may be influenced by biases in question selection, adding nuances to our understanding of this cognitive bias (Wallsten et al., 1997).

Certain domains demonstrate well-calibrated performance in expert predictions. Notably, professional weather forecasters and horse-race bookmakers excel in providing accurate probability estimates within their respective fields of expertise. In contrast, various other areas show significant overconfidence in expert predictions. Medical practitioners, for instance, often assign higher probability values to the correctness of their diagnoses than warranted. Geotechnical engineers may exhibit overconfidence in their estimates of the strength of a clay foundation. Even probabilistic predictions of public events, such as political and sporting outcomes, have consistently been shown to be overconfident (Zadrozny & Elkan, 2002).

The implications of expert overconfidence in probability estimates can have profound consequences, as exemplified by cases such as the Reactor Safety Study conducted by the U.S. Nuclear Regulatory Commission in 1975. In this study, a log-normal distribution of failure rate data was assumed at each level of analysis. However, research suggests that distributions constructed from assessments of the 5th and 95th percentiles may exhibit significant bias, potentially resulting in compounded errors. Given the high stakes associated with nuclear power plant failure, the cumulative impact of such errors could be substantial.

Interestingly, the effects of expert overconfidence may be less severe when communicated directly to the public compared to when processed by decision analysts. This paradoxical outcome can be attributed to the human tendency to assign greater weight to small probabilities, deviating from the expected utility model. Essentially, individuals may perceive a greater distinction between situations with, for example, a 0.1% and a 2% risk of disaster than the expected utility model suggests. While often regarded as an illustration of human irrationality, this compensatory mechanism partially mitigates the effects of expert overconfidence (Zadrozny & Elkan, 2001).

However, it is crucial to acknowledge the limitations of this compensatory mechanism. It is not entirely reliable and can introduce distortions, particularly concerning well-calibrated probabilities derived from objective frequencies. This nuance is vital, as relying solely on subjective estimates of probability values introduces an additional layer of complexity to decision-making (Maglio & Polman, 2016).

In conclusion, subjective estimates of objective probabilities frequently lack reliability,

raising questions about the unequivocal advocacy for maximizing expected utility when relying solely on subjective probability values. The interplay between expert overconfidence, compensatory mechanisms, and the potential for distorted probabilities underscores the intricate nature of decision-making in situations where probability estimation is crucial.

2.5. BAYESIANISM

Learning Objectives

- Evaluate the key concepts and principles of Bayesianism in decision theory.

Probabilities are described as frequencies that can be observed or potentially observed in the physical environment. Alternatively, probability can be limited to the domain of the human mind.

Subjective probability, a concept rooted in the foundations of probability theory, can be interpreted through two distinct perspectives – one grounded in the physical world and the other existing purely within the realm of the mind. This duality in understanding probability has been explored throughout history, with notable contributions dating back to the 18th century. In the influential work "Ars conjectandi" (1713), Jacques Bernoulli, a significant figure in the field of mathematics, laid the groundwork for the concept of probability as a subjective measure. Within this framework, probability was defined as a degree of confidence, a variable that could vary between individuals. Bernoulli's perspective, originating in the early 18th century, set the stage for the development of subjective probability.

The shift towards considering probabilities as mental phenomena gained further momentum in the 1930s, thanks to the pioneering work of Frank Ramsey. Ramsey, a key contributor to expected utility theory, delved into the integration of subjective utilities and subjective probabilities. This amalgamation, now commonly known as Bayesian decision theory or Bayesianism, pays tribute to Thomas Bayes, whose mathematical foundations greatly influenced probabilistic inference (Easwaran, 2011).

Four fundamental principles encapsulate the essence of Bayesianism. The initial trio focuses on the subject as a holder of probabilistic beliefs, while the fourth principle extends into the subject's role as a decision-maker.

Firstly, a Bayesian subject is characterized by possessing a coherent set of probabilistic beliefs. This coherence is defined in terms of formal compliance with the mathematical laws of probability. These laws, identical to those governing objective probability derived from frequencies in mechanical devices like dice and coins, serve as the benchmark for evaluating the rationality of subjective beliefs. An example of incoherence would be a Bayesian subject simultaneously assigning a subjective probability of 0.5 to rain tomorrow and 0.6 to either rain or snow, a contradiction that violates the laws of probability (Meacham, 2014). In contrast, some non-Bayesian decision theories, such as prospect theory, employ measures of belief that deviate from the laws of probability. These measures, referred to as "decision weights" by Schoemaker (1982), do not align with the principles of probability, emphasizing the distinction between Bayesian and non-Bayesian approaches. Secondly, a Bayesian subject is distinguished by possessing a complete set of probabilistic beliefs. Every proposition is assigned a subjective probability, reflecting the subject's degree of belief. This comprehensive coverage extends to all conceivable propositions, eliminating the concept of uncertainty or ignorance within the Bayesian framework. From this perspective, Bayesian decision-making operates exclusively under conditions of certainty or risk, rendering the conventional distinction between risk and uncertainty irrelevant. In contrast, non-Bayesian frameworks may permit the existence of uncertainty, allowing for decision-making in the absence of complete probabilistic beliefs. Bayesianism's insistence on completeness sets a rigorous standard, demanding that a Bayesian subject maintains a degree of belief about every possible proposition.

The third principle encapsulates the Bayesian subject's ability to adapt and revise beliefs in response to new evidence. When confronted with fresh information, the Bayesian subject dynamically adjusts their probabilistic beliefs in accordance with conditional probabilities. These conditional probabilities, denoted as $p(A|B)$ for the probability of A given B, serve as a mechanism for incorporating evidence.

As an illustrative example, consider A denoting the occurrence of rain in Stockholm the day after tomorrow and B denoting rain in Stockholm tomorrow. Following Bayesian principles, learning that B is true compels a revision of the prior estimate of $p(A)$ to align with the previous estimate of $p(A|B)$. The coherence of belief necessitates that all conditional probabilities adhere to the definition:

$$p(A|B) = p\ (A\&B)/p(B)$$

This formula ensures consistency and rational updating of beliefs in response to evolving information (Sober, 2002).

The Bayesian perspective on subjective probabilities is characterized by a division between subjective (personalistic) Bayesianism and objective (or rationalist) Bayesianism, with proponents like Savage, de Finetti, Jeffreys, and Jaynes offering contrasting views on the nature of rationality and probability assignments (Easwaran, 2011).

On the contrary, objective Bayesianism, supported by figures like Jeffreys and Jaynes, posits the existence of a unique admissible probability assignment based on the totality of information available to the subject. The principle of insufficient reason is invoked to mitigate the effects of information gaps, aiming to establish a subject-independent probability function. Even in this objective stance, however, the probabilities under consideration remain subjective, derived from the subject's available information rather than objective frequencies.

Both perspectives, despite their differences in the determinacy of probability assignments, share the fundamental premise that probabilities are subjective entities, tied to the information accessible to the decision-maker rather than grounded in external realities.

A pivotal aspect of Bayesianism is its assertion that rational decision-makers, both descriptively and normatively, adhere to certain criteria. Descriptively, the claim is that actual decision-makers conform to the Bayesian principles of coherence, completeness, and adaptability. Normatively, Bayesianism argues that rational decision-makers should satisfy these criteria. The ultimate goal of normative Bayesian decision analysis is to minimize a decision-maker's incoherence and align their behavior with the hypothetical rational agent, ensuring the maximization of expected utility after accounting for new evidence.

Subjective Bayesianism, in particular, does not mandate specific relations between subjective probabilities and objective frequencies or between subjective utilities and measurable values like money. The flexibility of this approach allows individuals to express their beliefs in a manner that suits their subjective perspectives (Timpson, 2008).

Harsanyi encapsulates the character of a Bayesian subject, highlighting the implicit assignment of numerical utilities and probabilities to alternative outcomes and contingencies. He suggests that even if individuals do not consciously and explicitly choose these values, adhering to certain rationality axioms will inevitably lead to the maximization of expected utility. The foundational claim of Bayesian theory lies not in prescribing conscious efforts to maximize expected utility but in the mathematical theorem asserting the inevitability of this maximization under specific rationality axioms.

Despite its popularity among statisticians and philosophers, Bayesianism faces challenges in practical decision science. Its operationality is perceived as limited compared to other expected utility theories that rely on objective utilities and/or probabilities, offering predictions that can be tested more readily.

The difficulty in testing Bayesianism stems from the requirement of identifying violations of rational preferences that specifically contradict the axioms of preference, making it more challenging to assess whether Bayesian principles are upheld or violated.

While plausible counter-examples to Bayesianism can be formulated, practical decision problems often lack clear indicators of whether Bayesian principles are being violated. The difficulty in operationalizing and testing Bayesianism contributes to its lesser popularity in more practically oriented decision sciences (Weisberg, 2011).

Did you know?

Bayesianism has found applications beyond traditional decision theory, extending into fields like machine learning and artificial intelligence. It serves as a foundation for updating models and predictions as new data becomes available, showcasing its versatility in various domains.

PRACTICE PROBLEM

A decision-maker is evaluating two investment options with different expected payoffs and associated probabilities. Let's discuss the key elements of expected utility theory and how a decision-maker can use it to make informed choices. I will provide a numerical example to demonstrate the calculation of expected utility.

SOLUTIONS TO PRACTICE PROBLEM

Key Elements of Expected Utility:

Expected utility theory combines subjective utility values and probabilities to quantify the desirability of outcomes. Decision-makers can utilize this theory to maximize their anticipated satisfaction or utility. For instance, if Option 1 has a 70% chance of yielding $10,000 and a 30% chance of yielding $0, while Option 2 has a 50% chance of yielding $15,000 and a 50% chance of yielding $5,000, the decision-maker can compute the expected utility for each option (based on their subjective utility values) and select the option with the highest expected utility to optimize their decision.

SUMMARY

- The chapter focuses on Decision Theory and its interdisciplinary nature. Theoretical questions about decisions are explored, distinguishing normative and descriptive theories.
- Decision processes, including Condorcet and modern sequential models, are discussed, along with non-sequential models and practical decision phases.
- The conventional approach defines alternatives, states of nature, outcomes, decision matrices, and information about states of nature.
- Expected Utility is examined, covering subjective and objective utility, along with the appraisal of expected utility and probability estimates.

MULTIPLE CHOICE QUESTIONS

1. What does Decision Theory primarily focus on?

a) Mathematics

b) Interdisciplinary nature

c) Statistics

d) Physics

2. Which model is discussed in the chapter as a non-sequential decision process?

a) Condorcet

b) Sequential Models

c) Bayesianism

d) Modern Sequential Models

3. What are the two types of utility discussed in the chapter?

a) Objective and Subjective

b) Tangible and Intangible

c) Predictive and Descriptive

d) Sequential and Non-Sequential

4. In the conventional approach, what is defined as possible courses of action?

a) States of Nature

b) Alternatives

c) Outcomes

d) Decision Matrices

5. What property emphasizes that a decision-maker's preferences should cover all possible comparisons?

a) Transitivity

b) Completeness

c) Rationality

d) Normativity

REVIEW QUESTIONS

1. Explain the difference between normative and descriptive theories in Decision Theory.
2. Discuss the phases of practical decisions as outlined in the chapter.
3. How do relations, comparative value terms, completeness, and transitivity play a role in decision-making?
4. Describe the components of the conventional approach to individual decisions, including decision matrices.
5. Examine the concept of Expected Utility, highlighting the differences between subjective and objective utility.

Answer to Multiple Choice Questions

1. (b) 2. (c) 3. (a) 4. (b) 5. (b)

REFERENCES

1. Ahituv, N., Igbaria, M., & Sella, A. V., (1998). The effects of time pressure and completeness of information on decision making. *Journal of Management Information Systems*, *15*(2), 153–172.
2. Albert, M., (2003). Bayesian rationality and decision making: A critical review. *Analyze & Kritik*, *25*(1), 101–117.
3. Anandalingam, G., & Chen, L., (1989). Linear combination of forecasts: A general Bayesian model. *Journal of Forecasting*, *8*(3), 199–214.
4. Arntzenius, F., Elga, A., & Hawthorne, J., (2004). Bayesianism, infinite decisions, and binding. *Mind*, *113*(450), 251–283.
5. Ashby, D., & Smith, A. F., (2000). Evidence-based medicine as Bayesian decision-making. *Statistics in Medicine*, *19*(23), 3291–3305.
6. Avant, D., (2004). Conserving nature in the state of nature: The politics of INGO policy implementation. *Review of International Studies*, *30*(3), 361–382.
7. Ballou, D. P., & Pazer, H. L., (2003). Modeling completeness versus consistency tradeoffs in information decision contexts. *IEEE Transactions on Knowledge and Data Engineering*, *15*(1), 240–243.
8. Balmford, A., Green, R. E., & Jenkins, M., (2003). Measuring the changing state of nature. *Trends in Ecology & Evolution*, *18*(7), 326–330.
9. Beck, J. M., Ma, W. J., Kiani, R., Hanks, T., Churchland, A. K., Roitman, J., & Pouget, A., (2008). Probabilistic population codes for Bayesian decision making. *Neuron*, *60*(6), 1142–1152.

10. Belton, V., (1986). A comparison of the analytic hierarchy process and a simple multi-attribute value function. *European Journal of Operational Research*, *26*(1), 7–21.
11. Berry, D. A., (1993). A case for Bayesianism in clinical trials. *Statistics in Medicine*, *12*(15, 16), 1377–1393.
12. Blavatskyy, P. R., (2012). Probabilistic subjective expected utility. *Journal of Mathematical Economics*, *48*(1), 47–50.
13. Boehnke, K. F., Scott, J. R., Litinas, E., Sisley, S., Clauw, D. J., Goesling, J., & Williams, D. A., (2019). Cannabis use preferences and decision-making among a cross-sectional cohort of medical cannabis patients with chronic pain. *The Journal of Pain*, *20*(11), 1362–1372.
14. Borcherding, K., Eppel, T., & Von, W. D., (1991). Comparison of weighting judgments in multiattribute utility measurement. *Management Science*, *37*(12), 1603–1619.
15. Briggs, A. H., Ades, A. E., & Price, M. J., (2003). Probabilistic sensitivity analysis for decision trees with multiple branches: Use of the Dirichlet distribution in a Bayesian framework. *Medical Decision Making*, *23*(4), 341–350.
16. Bristow, A. L., & Nellthorp, J., (2000). Transport project appraisal in the European Union. *Transport Policy*, *7*(1), 51–60.
17. Bröder, A., & Schiffer, S., (2003). Bayesian strategy assessment in multi-attribute decision making. *Journal of Behavioral Decision Making*, *16*(3), 193–213.
18. Byrnes, J. P., (2013). *The Nature and Development of Decision-Making: A Self-Regulation Model, 1*(1), 1–20.
19. Cappello, C., Zonta, D., & Glišić, B., (2016). Expected utility theory for monitoring-based decision-making. *Proceedings of the IEEE*, *104*(8), 1647–1661.
20. Ceballos, B., Lamata, M. T., & Pelta, D. A., (2016). A comparative analysis of multi-criteria decision-making methods. *Progress in Artificial Intelligence*, *5*, 315–322.
21. Chahuara, P., Fleury, A., Portet, F., & Vacher, M., (2016). On-line human activity recognition from audio and home automation sensors: Comparison of sequential and non-sequential models in realistic smart homes 1. *Journal of Ambient Intelligence and Smart Environments*, *8*(4), 399–422.
22. Chawla, N. V., & Cieslak, D. A., (2006). Evaluating probability estimates from decision trees. In: *American Association for Artificial Intelligence, 1*(1), 1–20.
23. Chen, G., & Ge, Z., (2018). Hierarchical Bayesian network modeling framework for large-scale process monitoring and decision making. *IEEE Transactions on Control Systems Technology*, *28*(2), 671–679.
24. Chiclana, F., García, J. T., Del, M. M. J., & Herrera-Viedma, E., (2013). A statistical comparative study of different similarity measures of consensus in group decision making. *Information Sciences*, *221*, 110–123.
25. Cho, K. T., (2003). Multicriteria decision methods: An attempt to evaluate and unify. *Mathematical and Computer Modeling*, *37*(9, 10), 1099–1119.
26. Churchland, A. K., Kiani, R., & Shadlen, M. N., (2008). Decision-making with multiple alternatives. *Nature Neuroscience*, *11*(6), 693–702.

27. Cuervo-Cazurra, A., (2011). Selecting the country in which to start internationalization: The non-sequential internationalization model. *Journal of World Business*, *46*(4), 426–437.

28. Dabić, M., Tipurić, D., & Podrug, N., (2015). Cultural differences affecting decision-making style: A comparative study between four countries. *Journal of Business Economics and Management*, *16*(2), 275–289.

29. Davis, R. L., (1953). The number of structures of finite relations. *Proceedings of the American Mathematical Society*, *4*(3), 486–495.

30. Easwaran, K., (2011). Bayesianism I: Introduction and arguments in favor. *Philosophy Compass*, *6*(5), 312–320.

31. Easwaran, K., (2011). Bayesianism II: Applications and criticisms. *Philosophy Compass*, *6*(5), 321–332.

32. Edwards, W., & Barron, F. H., (1994). SMARTS and SMARTER: Improved simple methods for multiattribute utility measurement. *Organizational Behavior and Human Decision Processes*, *60*(3), 306–325.

33. Edwards, W., (1962). Utility, subjective probability, their interaction, and variance preferences. *Journal of Conflict Resolution*, *6*(1), 42–51.

34. Edwards, W., (1977). How to use multiattribute utility measurement for social decision making. *IEEE Transactions on Systems, Man, and Cybernetics*, *7*(5), 326–340.

35. Ellis, A. K., & Fouts, J. T., (2001). Interdisciplinary curriculum: The research base. *Music Educators Journal*, *87*(5), 21–22.

36. Fijalkow, N., Gimbert, H., Kelmendi, E., & Oualhadj, Y., (2015). Deciding the value 1 problem for probabilistic leaktight automata. *Logical Methods in Computer Science*, *11*, 1–20.

37. Fischer, A. J., Threlfall, A., Meah, S., Cookson, R., Rutter, H., & Kelly, M. P., (2013). The appraisal of public health interventions: An overview. *Journal of Public Health*, *35*(4), 488–494.

38. Fischer, G. W., (1979). Utility models for multiple objective decisions: Do they accurately represent human preferences? *Decision Sciences*, *10*(3), 451–479.

39. Fisher, R., (1958). The nature of probability. *The Centennial Review of Arts & Science*, *2*, 261–274.

40. Fleming, S. M., & Daw, N. D., (2017). Self-evaluation of decision-making: A general Bayesian framework for metacognitive computation. *Psychological Review*, *124*(1), 91.

41. Gao, Y., Xu, A., Hu, P. J. H., & Cheng, T. H., (2017). Incorporating association rule networks in feature category-weighted naive Bayes model to support weaning decision making. *Decision Support Systems*, *96*, 27–38.

42. Gerrard, M., Gibbons, F. X., Houlihan, A. E., Stock, M. L., & Pomery, E. A., (2008). A dual-process approach to health risk decision making: The prototype willingness model. *Developmental Review*, *28*(1), 29–61.

43. Haig, B. D., (2009). Inference to the best explanation: A neglected approach to theory appraisal in psychology. *The American Journal of Psychology*, *122*(2), 219–234.

44. Hertin, J., Jacob, K., & Volkery, A., (2008). Policy appraisal. *Innovation in Environmental Policy? Integrating the Environment for Sustainability*, *1*(1), 24–48.

45. Hilbig, B. E., & Moshagen, M., (2014). Generalized outcome-based strategy classification: Comparing deterministic and probabilistic choice models. *Psychonomic Bulletin & Review*, *21*, 1431–1443.

46. Hilton, R. W., (1980). Integrating normative and descriptive theories of information processing. *Journal of Accounting Research*, *1*(1), 477–505.

47. Hirst, E., & Schweitzer, M., (1990). Electric-utility resource planning and decision-making: The importance of uncertainty. *Risk Analysis*, *10*(1), 137–146.

48. Hughes, L., & Shupe, D., (2010). *Creating Energy Security Indexes with Decision Matrices and Quantitative Criteria, 1*(1), 1–20.

49. Hulin, C. L., Roznowski, M., & Hachiya, D., (1985). Alternative opportunities and withdrawal decisions: Empirical and theoretical discrepancies and an integration. *Psychological Bulletin*, *97*(2), 233.

50. Ihwe, J. F., & Rieser, H., (1979). Normative and descriptive theory of fiction. Some contemporary issues. *Poetics*, *8*(1, 2), 63–84.

51. Iwasa, S., Kudo, T., Takahari, D., Hara, H., Kato, K., & Satoh, T., (2020). Practical guidance for the evaluation of disease progression and the decision to change treatment in patients with advanced gastric cancer receiving chemotherapy. *International Journal of Clinical Oncology*, *25*, 1223–1232.

52. Jepsen, D. A., & Dilley, J. S., (1974). Vocational decision-making models: A review and comparative analysis. *Review of Educational Research*, *44*(3), 331–349.

53. Kaplan, J., (1967). Decision theory and the factfinding process. *Stan L. Rev.*, *20*, 1065.

54. Kassim, H., (1994). Policy networks, networks and European Union policy making: A sceptical view. *West European Politics*, *17*(4), 15–27.

55. Katsikopoulos, K. V., & Gigerenzer, G., (2008). One-reason decision-making: Modeling violations of expected utility theory. *Journal of Risk and Uncertainty*, *37*, 35–56.

56. Keeney, R. L., (1977). The art of assessing multiattribute utility functions. *Organizational Behavior and Human Performance*, *19*(2), 267–310.

57. Kelly, C., Laird, J., Costantini, S., Richards, P., Carbajo, J., & Nellthorp, J., (2015). Ex post appraisal: What lessons can be learnt from EU cohesion funded transport projects? *Transport Policy*, *37*, 83–91.

58. Kida, T., Smith, J. F., & Maletta, M., (1998). The effects of encoded memory traces for numerical data on accounting decision making. *Accounting, Organizations and Society*, *23*(5, 6), 451–466.

59. Kihlander, I., & Ritzén, S., (2012). Compatibility before completeness—Identifying intrinsic conflicts in concept decision making for technical systems. *Technovation*, *32*(2), 79–89.

60. Kim, Y. J., Ahn, K. U., & Park, C. S., (2014). Decision making of HVAC system using Bayesian Markov chain Monte Carlo method. *Energy and Buildings*, *72*, 112–121.

61. Klaczynski, P. A., Byrnes, J. P., & Jacobs, J. E., (2001). Introduction to the special issue: The development of decision making. *Journal of Applied Developmental Psychology*, *22*(3), 225–236.

62. Klayman, J., (1985). Children's decision strategies and their adaptation to task characteristics. *Organizational Behavior and Human Decision Processes*, *35*(2), 179–201.

63. Lee, M. D., (2006). A hierarchical Bayesian model of human decision-making on an optimal stopping problem. *Cognitive Science*, *30*(3), 1–26.

64. Liese, F., & Miescke, K. J., (2008). Statistical decision theory. In: *Statistical Decision Theory: Estimation, Testing, and Selection* (Vol. 1, No. 1, pp. 1–52). New York, NY: Springer New York.

65. Luce, R. D., & Von, W. D., (1994). What common ground exists for descriptive, prescriptive, and normative utility theories? *Management Science*, *40*(2), 263–279.

66. Lurie, N. H., & Mason, C. H., (2007). Visual representation: Implications for decision making. *Journal of Marketing*, *71*(1), 160–177.

67. MacCrimmon, K. R., (1968). Descriptive and normative implications of the decision-theory postulates. In: *Risk and Uncertainty: Proceedings of a Conference Held by the International Economic Association* (Vol. 1, No. 1, pp. 3–32). London: Palgrave Macmillan UK.

68. Maglio, S. J., & Polman, E., (2016). Revising probability estimates: Why increasing likelihood means increasing impact. *Journal of Personality and Social Psychology*, *111*(2), 141.

69. Man-Son-Hing, M., O'Connor, A. M., Drake, E., Biggs, J., Hum, V., & Laupacis, A., (2002). The effect of qualitative vs. quantitative presentation of probability estimates on patient decision-making: A randomized trial. *Health Expectations*, *5*(3), 246–255.

70. Meacham, C. J., (2014). Impermissive Bayesianism. *Erkenntnis*, *79*, 1185–1217.

71. Meder, D., Kolling, N., Verhagen, L., Wittmann, M. K., Scholl, J., Madsen, K. H., & Rushworth, M. F., (2017). Simultaneous representation of a spectrum of dynamically changing value estimates during decision making. *Nature Communications*, *8*(1), 1942.

72. Meisch, S. P., Bremer, S., Young, M. T., & Funtowicz, S. O., (2022). Extended peer communities: Appraising the contributions of tacit knowledges in climate change decision-making. *Futures*, *135*, 102868.

73. Miller, D. C., & Byrnes, J. P., (2001). To achieve or not to achieve: A self-regulation perspective on adolescents' academic decision making. *Journal of Educational Psychology*, *93*(4), 677.

74. Mullur, A., Mattson, C., & Messac, A., (2003). Pitfalls of the typical construction of decision matrices for concept selection. In: *41st Aerospace Sciences Meeting and Exhibit* (Vol. 1, No. 1, p. 466).

75. Nilsson, M., Jordan, A., Turnpenny, J., Hertin, J., Nykvist, B., & Russel, D., (2008). The use and non-use of policy appraisal tools in public policy making: An analysis of three European countries and the European Union. *Policy Sciences*, *41*, 335–355.

76. Norris, D., & McQueen, J. M., (2008). Shortlist B: A Bayesian model of continuous speech recognition. *Psychological Review*, *115*(2), 357.

77. North, D. W., (1968). A tutorial introduction to decision theory. *IEEE Transactions on Systems Science and Cybernetics*, *4*(3), 200–210.

78. Nutt, P. C., (1999). Public-private differences and the assessment of alternatives for decision making. *Journal of Public Administration Research and Theory*, *9*(2), 305–350.

79. Over, D., (2004). Rationality and the normative/descriptive distinction. *Blackwell Handbook of Judgment and Decision Making*, *1*(1), 3–18.

80. Pearce, D. W., & Seccombe-Hett, T., (2000). *Economic Valuation and Environmental Decision-Making in Europe, 1*(1), 1–20.

81. Peer, E., & Gamliel, E., (2013). Heuristics and biases in judicial decisions. *Ct. Rev.*, *49*, 114.

82. Peters, E., Västfjäll, D., Slovic, P., Mertz, C. K., Mazzocco, K., & Dickert, S., (2006). Numeracy and decision making. *Psychological Science*, *17*(5), 407–413.

83. Phan, T. D., Smart, J. C., Stewart-Koster, B., Sahin, O., Hadwen, W. L., Dinh, L. T., & Capon, S. J., (2019). Applications of Bayesian networks as decision support tools for water resource management under climate change and socio-economic stressors: A critical appraisal. *Water*, *11*(12), 2642.

84. Pogarsky, G., (2009). Deterrence and decision making: Research questions and theoretical refinements. *Handbook on Crime and Deviance*, *1*(1), 241–258.

85. Poses, R. M., Cebul, R. D., Collins, M., & Fager, S. S., (1985). The accuracy of experienced physicians' probability estimates for patients with sore throats: Implications for decision making. *JAMA*, *254*(7), 925–929.

86. Purpura, D. J., & Lonigan, C. J., (2013). Informal numeracy skills: The structure and relations among numbering, relations, and arithmetic operations in preschool. *American Educational Research Journal*, *50*(1), 178–209.

87. Puterman, M. L., (1990). Markov decision processes. *Handbooks in Operations Research and Management Science*, *2*, 331–434.

88. Rajagopalan, N., Rasheed, A. M., & Datta, D. K., (1993). Strategic decision processes: Critical review and future directions. *Journal of Management*, *19*(2), 349–384.

89. Rapoport, A., (1994). Problems of normative and descriptive decision theories. *Mathematical Social Sciences*, *27*(1), 31–47.

90. Regenwetter, M., Dana, J., & Davis-Stober, C. P., (2011). Transitivity of preferences. *Psychological Review*, *118*(1), 42.

91. Rodríguez, R. M., Labella, Á., & Martínez, L., (2016). An overview on fuzzy modeling of complex linguistic preferences in decision making. *International Journal of Computational Intelligence Systems*, *9*(sup1), 81–94.

92. Rodríguez, R. M., Martıćnez, L., & Herrera, F., (2013). A group decision making model dealing with comparative linguistic expressions based on hesitant fuzzy linguistic term sets. *Information Sciences*, *241*, 28–42.

93. Rosenthal, J., (2010). The natural-range conception of probability. *Time, Chance, and Reduction: Philosophical Aspects of Statistical Mechanics*, *1*(1), 71–90.

94. Salmon, W. C., (1990). The appraisal of theories: Kuhn meets bayes. In: *PSA: Proceedings of the Biennial Meeting of the Philosophy of Science Association* (Vol. 1990, No. 2, pp. 324–332). Cambridge University Press.

95. Saunders, S., (2005). What is probability? In: *Quo Vadis Quantum Mechanics?* (Vol. 1, No. 1, pp. 209–238).

96. Schmeidler, D., (1989). Subjective probability and expected utility without additivity. *Econometrica: Journal of the Econometric Society*, *1*(1), 571–587.

97. Schwarz, J., & Heider, D., (2019). GUESS: Projecting machine learning scores to well-calibrated probability estimates for clinical decision-making. *Bioinformatics*, *35*(14), 2458–2465.

98. Sober, E., (2002). Bayesianism—Its scope and limits. In: *Proceedings-British Academy* (Vol. 113, pp. 21–38). Oxford University Press Inc.

99. Stillwell, W. G., Barron, F. H., & Edwards, W., (1983). Evaluating credit applications: A validation of multiattribute utility weight elicitation techniques. *Organizational Behavior and Human Performance*, *32*(1), 87–108.

100. Sugden, R., (2003). Reference-dependent subjective expected utility. *Journal of Economic Theory*, *111*(2), 172–191.

101. Suhonen, N., (2007). *Normative and Descriptive Theories of Decision Making Under Risk: A Short Review, 1*(1), 1–20.

102. Swets, J. A., Tanner, Jr. W. P., & Birdsall, T. G., (1961). Decision processes in perception. *Psychological Review*, *68*(5), 301.

103. Thrall, R. M., Coombs, C. H., & Davis, R. L., (1954). *Decision Processes, 1*(1), 1–20.

104. Timpson, C. G., (2008). Quantum Bayesianism: A study. *Studies in History and Philosophy of Science Part B: Studies in History and Philosophy of Modern Physics*, *39*(3), 579–609.

105. Tupala, M., (2019). Applying quantitative appraisal analysis to the study of institutional discourse: The case of EU migration documents. *Functional Linguistics*, *6*(1), 2.

106. Tversky, A., (1967). Additivity, utility, and subjective probability. *Journal of Mathematical Psychology*, *4*(2), 175–201.

107. Tversky, A., (1975). A critique of expected utility theory: Descriptive and normative considerations. *Erkenntnis*, *1*(1), 163–173.

108. Volans, P. J., (1976). Styles of decision-making and probability appraisal in selected obsessional and phobic patients. *British Journal of Social and Clinical Psychology*, *15*(3), 305–317.

109. Voorhoeve, A., & Binmore, K., (2006). Transitivity, the sorites paradox, and similarity-based decision-making. *Erkenntnis*, *64*(1), 101–114.

110. Wakslak, C., & Trope, Y., (2009). The effect of construal level on subjective probability estimates. *Psychological Science*, *20*(1), 52–58.

111. Wallsten, T. S., Budescu, D. V., Erev, I., & Diederich, A., (1997). Evaluating and combining subjective probability estimates. *Journal of Behavioral Decision Making*, *10*(3), 243–268.

112. Wang, C., Liu, Y., Wang, M., Zhou, K., Nie, J. Y., & Ma, S., (2015). Incorporating non-sequential behavior into click models. In: *Proceedings of the 38th International ACM SIGIR Conference on Research and Development in Information Retrieval* (Vol. 1, No. 1, pp. 283–292).

113. Weisberg, J., (2011). Varieties of Bayesianism. *Inductive Logic*, *10*, 477–551.

114. Weistroffer, H. R., Smith, C. H., & Narula, S. C., (2005). Multiple criteria decision support software. *Multiple Criteria Decision Analysis: State of the Art Surveys*, *78*, 989–1009.

115. Wu, T. F., Lin, C. J., & Weng, R., (2003). Probability estimates for multi-class classification by pairwise coupling. *Advances in Neural Information Processing Systems*, *16,* 1–20.

116. Wu, Z., & Tu, J., (2021). Managing transitivity and consistency of preferences in AHP group decision making based on minimum modifications. *Information Fusion*, *67*, 125–135.

117. Yager, R. R., (2002). On the valuation of alternatives for decision-making under uncertainty. *International Journal of Intelligent Systems*, *17*(7), 687–707.

118. Yang, M., (2009). Making interdisciplinary subjects relevant to students: An interdisciplinary approach. *Teaching in Higher Education*, *14*(6), 597–606.

119. Zadrozny, B., & Elkan, C., (2001). Obtaining calibrated probability estimates from decision trees and naive Bayesian classifiers. In: *ICML* (Vol. 1, pp. 609–616).

120. Zadrozny, B., & Elkan, C., (2002). Transforming classifier scores into accurate multiclass probability estimates. In: *Proceedings of the Eighth ACM SIGKDD International Conference on Knowledge Discovery and Data Mining* (Vol. 1, No. 1, pp. 694–699).

121. Zhang, J., (2012). The effects of evidence bounds on decision-making: Theoretical and empirical developments. *Frontiers in Psychology*, *3*, 263.

CHAPTER

3

Structuring Decision Problems for Decision Analysis

LEARNING OBJECTIVES

After studying this chapter, you will be able to:

- Understand taxonomies for problem identification in decision analysis.
- Explore methods for systematically selecting appropriate analytic structures for decision problems.
- Examine advances in formalizing decision structures to enhance precision in analysis.
- Learn the process of developing a prototypical structure for decision scenarios.
- Explore the landscape of decision analysis software, including an overview of available tools.

INTRODUCTORY EXAMPLE

Consider TechVantage Innovations, a forward-thinking manufacturing firm, facing a pivotal decision on adopting a cutting-edge production technology. In navigating this decision, a structured approach is crucial. The leadership employs systematic taxonomies to identify key factors—costs, efficiency gains, and risks linked to the technology. This breakdown forms the foundation for decision-making. Analytic structures are then customized to fit the nuances of the manufacturing industry, ensuring a tailored approach. Advanced methodologies simulate scenarios, aiding in risk anticipation and uncovering potential benefits. A versatile toolkit aids decision-makers in navigating specific contexts, fostering a robust process. Careful software selection further streamlines decision-making, aligning with the company's goals. In essence, this structured approach positions TechVantage Innovations to tackle the challenge of adopting new technology while preparing for future decision-making with confidence and clarity.

UNIT INTRODUCTION

Structuring decision problems in a comprehensible and manageable manner is arguably the most crucial phase in the decision-making process. Since there is still no reliable process for structuring, each analyst must still rely on their judgment and skill to complete this step. This chapter first introduces the broad idea of structure and then examines some recent developments in the field. These include novel tools like influence diagrams and interpretative structural modeling, as well as taxonomies for problem identification (Corner et al., 2001). This discussion leads to two conclusions: study structuring is still restricted to a few hierarchical concepts, and it often overlooks substantive problem features that define a problem in its real-world setting. Therefore, the disparities between typical problem types like regulation, siting, or budget allocation are not well covered by structural research. The idea of "prototypical decision analytic structures" is presented as an alternative. These kinds of structures are created to address the essential features of a particular issue (like establishing a particular LNG plant), but they are also sufficiently general to be used for other related issues (like placing industrial facilities). The creation of a prototypical analytic structure for environmental standard setting is discussed as an example. In conclusion, a few common problem classes are examined, and some specifications for prototypical structures are discussed (Belton & Stewart, 2010).

The four stages of decision analysis include problem structuring, formulating inference and preference models, utility and probability elicitation, and exploration of numerical model findings. Most decision analysis practitioners agree that the most crucial and challenging phase of the study is structuring. However, until recently, decision analytic research has largely overlooked structuring, instead focusing on modeling and elicitation issues. As a result, structuring has been and, in some ways, still is considered the "art" aspect of decision analysis (Alemi & Gustafson, 2006).

Trees are the most commonly used decision-analytic structures. For example, decision trees can be used to illustrate the sequential elements of a decision problem. Other examples include goal trees, which represent values, and event trees, which describe parts of inferential problems. Decision analytic structures are so heavily influenced by trees that structuring is often equated with building a tree (Kassirer, 1976).

In this context, structuring is the innovative and creative process of converting a vague problem into a collection of precise elements, relationships, and functions. Identifying or creating problem aspects (such as people, values, choices, events, etc.) and connecting them via influence relations, inclusion relations, hierarchical ordering, etc. are the fundamental structuring tasks. The process of structure aims to officially express the decision problem's environmental (objective) components as well as the decision makers' or experts' (subjective) viewpoints, beliefs, and values. There are many ways to depict problems, including graphs, maps, functional equations, matrices, trees, physical analogs, flow charts, and Venn diagrams. Such representations must support the following stages of modeling, elicitation, and numerical analysis to be effective structures for decision analysis (Marttunen et al., 2017).

3.1. TAXONOMIES FOR PROBLEM IDENTIFICATION

Learning Objectives

- To understand the taxonomic structures.
- To learn their hierarchical problem classifications using taxonomies.

The following taxonomies aim to categorize decision problems into distinct and comprehensive sets by classifying them based on analytic categories. These taxonomies serve two purposes: firstly, they facilitate the identification of an unknown element, such as a medical decision problem, by associating it with a specific class of problems, such as a diagnostic problem. Secondly, they assist in matching problem classes, like diagnostic problems, with appropriate analytical methods, such as signal detection structures. Therefore, problem taxonomies are valuable in the initial stages of structuring decision problems intentionally (McDermott, 1988). MacCrimmon and Taylor (1975) examine the relationship between solution strategies and decision problems in a broad sense. The classification of decision problems as ill-structured or well-structured depends on the decision maker's familiarity with the problem's initial state, terminal state, and the required transformations to achieve the desired terminal state. Ill-structuredness is primarily caused by three factors: uncertainty, complexity, and conflict. MacCrimmon and Taylor present various solution strategies for each category. These strategies include problem restructuring approaches, information gathering and processing methods, and techniques to reduce uncertainty perception (Aggarwal et al., 1992). Taylor (1974) expands upon this classification method by introducing four fundamental categories of problems: resource specification, goal specification, creative problems, and well-structured problems (see Table 3.1). The identification of problem categories is determined by the decision maker's level of acquaintance with the three subsections of the problem. Taylor examines the suitability of several decision processes for each problem category, such as brainstorming for imaginative problems and employing operations research methods for well-structured problems (Beaubien & Baker, 2002).

Table 3.1. Types of Problem Structures (Source: Taylor, Creative Commons License)

Problem Type	**Initial State**	**Terminal State**	**Transformation**
Type I, Resource Specification Problems	Varies	Varies	Varies
Type II, Goal Specification Problems	Varies	Unfamiliar	Varies
Type III, Creative Problems	Varies	Varies	Unfamiliar
Type IV, Well-Structured Problems	Familiar	Familiar	Familiar

Howell and Burnett (1978) recently created a classification system for tasks and types of events. Their goal was to evaluate the cognitive strategies used to interpret probabilistic information for each element in the classification. Uncertain events are categorized based on three dichotomies (Vakil, 1997):

i. Known data generator – unknown data generator;
ii. Frequentist – non-frequentist;
iii. Process external – internal to the observer.

Brown and Ulvila (1977) provide the most extensive endeavor to categorize decision issues to date. Their classification encompasses more than 100 potential attributes. Decision problems are classified based on their content and the decision-making process they entail. The primary taxonomic characteristics are mostly derived from the analytical qualities of the situation, specifically the level and nature of uncertainty, as well as the level and types of stakes and alternatives (Gnat et al., 2019).

Did you know?

The RAND Corporation, a U.S. think tank, played a pivotal role in the development of decision analysis. Notable figures like Howard Raiffa and Ronald A. Howard, associated with RAND, significantly contributed to the formalization of decision analysis methods.

3.2. METHODS FOR SELECTING AN ANALYTIC STRUCTURE

Learning Objectives

- To understand different methods for selecting an analytic structure in decision-making.
- To explore the criteria and considerations involved in choosing an appropriate analytic structure.

Typically, taxonomies utilize specific concepts or principles to align problems with analytical structures or models. MacCrimmon and Taylor made efforts to align their fundamental type of decision problems with cognitive solution strategies. Howell and Burnett speculated on the cognitive processes that may be activated by typical task/event classes in probability assessment. Von Winterfeldt and Fischer determined suitable multi-attribute utility models for each problem category. However, none of these provided clear matching principles or criteria to determine the quality of a match. Instead, matches are formed by using a priori logic to determine the suitability of a model, strategy, or cognitive method for a certain category of decision issues (Cheung & Chan, 2009).

Brown and Ulvila (1977) attempted to enhance the clarity of the selection procedure by developing an analytical taxonomy that aligns with the problem taxonomy. The analytic taxonomy categorizes the primary choices available to an analyst when organizing and modeling a decision problem. The taxonomy encompasses variables such as the user's preferences (amount allocated for analysis), input structure (kind of uncertainty), and elicitation methods (type of probability elicitation). The categories encompass various possibilities, including basic approaches (such as stimulation, optimization, and Bayesian inference models,) as well as specific strategies like reference gambles or the Delphi technique (Comrey, 1988).

Ulvila and Brown developed a third classification known as the "Performance measure taxonomy" to address issues related to analytic techniques. This classification assesses analytical methodologies based on criteria such as "Time and cost metrics," "Quality of option generation method," "Quality of communication or implementation," and more. Various problem types exhibit distinct priority profiles across performance measurement areas (Liu & Hai, 2005).

Distinct analytic methodologies exhibit varying scoring profiles when it comes to performance metrics. Brown and Ulvila examine the suitability of several analytic approaches for addressing specific problem requirements. They evaluate the "goodness of fit" of these strategies to different decision scenarios based on their performance metrics. They assert that employing a contingency-type analysis, which is a component of the analytic taxonomy, is suitable for decision issues that are recurrent and necessitate prompt action, as it enables swift computations based on the "Performance assessment taxonomy" (Kregzde, 1993).

Various writers have developed logical selection systems that can choose a suitable analytic model by considering certain problem attributes. MacCrimmon (1973) devised a sequential technique to choose a suitable methodology for multi-attribute evaluation. The initial inquiry to address is whether the evaluation serves a normative or descriptive aim. Additional inquiries encompass perhaps the issue type that has been shown recurrently in the past, if there are several decision-makers with divergent preferences, and whether alternatives are readily accessible or necessitate creation. The queries are all binary, requiring a simple yes or no response. Collectively, they form a flow chart that aids in the selection process among 19 different potential options. If the research aim is normative, if initial evaluations of preferences, such as ratings, are both valid and reliable, and if the problem has been encountered regularly in the past, then regression models or ANOVA-type procedures would be suitable (Schmitt et al., 2018).

Johnson and Huber (1977) and Kneppreth et al. (1977) outline a three-step process for selecting a method to evaluate usefulness in multiple attributes. The initial stage involves listing the attributes of the multi-attribute challenge, including the distinction between discrete and continuous aspects, the presence or absence of uncertainty, and the consideration of independence. The second phase involves characterizing the evaluation situation by assessing the difficulty of the task, the level of training required for assessment, the necessary face validity, the examination time, precision, and flexibility. In the third and final stage, the profile describing the evaluation problem is compared to a profile that defines five distinct overall assessment models or approaches. The most appropriate technique is chosen based on the profile of the circumstances. For example, lottery assessment techniques are suitable when evaluating problems that involve uncertainty, do not require high face validity, and require extensive training of the examiner (Chen & Xiao, 2016).

Both taxonomy-oriented and sequential selection strategies for matching problems and analysis have inherent limitations. As mentioned earlier, taxonomies often overlook significant components when considering decision problem characteristics. Therefore, an analyst may choose an analysis method that aligns with a falsely described problem category (Velicer & Jackson, 1990).

Remember

Decision analysis shares roots with game theory, a field that gained prominence during World War II. Both fields explore strategic interactions, with game theory focusing on conflicts and decision analysis extending to broader decision-making scenarios.

3.3. ADVANCES IN FORMALIZING STRUCTURES

Learning Objectives

- To comprehend recent advances in formalizing structures in decision analysis.
- To explore the applications of advanced formal structures in diverse decision-making contexts.

A more recent innovation in decision analytic architecture is the influence diagram. Influence diagrams, which do not overlay any hierarchical structure, provide a graphical representation of the interactions between variables in a decision model. Price (a decision variable), for instance, may "impact" demand, a state variable, and ultimately "influence" the effective launch of a new product into the marketplace. The primary purpose of influence diagrams is to serve as a preliminary pre-structuring tool for developing a cognitive map of a decision maker's or expert's perspective on a decision problem. Influence diagrams are currently transformed into hierarchical structures and subjected to conventional tool analysis. However, SRI International is currently researching the direct application of influence diagrams in EV or EU calculations (Pugh et al., 1968) (Figure 3.1).

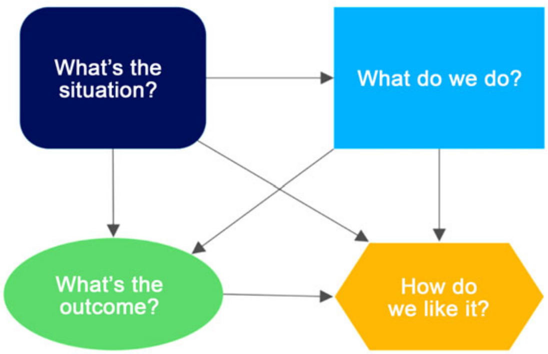

Figure 3.1. Illustration of an influence diagram (Source: Dr Dan, Creative Commons License)

Recently, computer tools have been developed to assist specialists or decision-makers in structuring decision problems. Humphreys (1980) and Kelly (1978) address some of these tools. These resources allow experts to analytically formulate their problems using blank structural notions such as decision trees, value trees, and inference trees. Special assistance includes decision triangle assistance for periodic decision problems focusing on shifting changing probabilities, EVAL for multi-attribute utility problems, and OPINT for somewhat complex issues that can be readily structured into a decision tree or matrix structure. In addition to tools for organization and evaluation, computerized tools that utilize influence diagrams and fuzzy set theory are also being developed (Kim et al., 2014). Computer assistance, ISM, and influence diagrams point to a trend in research organization and possibly in decision analysis. Without providing problem content, this tendency transforms the essentially void frameworks of decision trees, goal trees, and inference trees into more functional, computerized elicitation tools. This method has several obvious benefits, including broad applicability, adaptability, user input, rapidity, minimal training requirements, and suggestions, to mention a few. Additionally, it lessens the time constraints on the decision analyst (Alabastro et al., 1995).

3.4. DEVELOPING A PROTOTYPICAL STRUCTURE

Learning Objectives

- To understand the concept of developing a prototypical structure in decision analysis.
- To explore the steps and methodologies involved in creating a prototypical structure for decision-making.

The method of building a decision-aiding system for environmental standard setting and regulation is illustrated in the following scenario. The task was completed as a part of IIASA's normative project, which aimed to establish normative and descriptive criteria: what is the current process by which authorities set norms? What role may analytical models play in the method of developing standards? This broad approach to the standard-setting process allowed the research group to avoid pressure to swiftly develop viable models for decision problems. As a result, its participants were able to afford and were urged to dedicate significant energy to structuring (Li et al., 2022). Inputs into the structuring process were:

i. Previous models suggested for standard setting;
ii. Field studies of two ongoing standard-setting processes (oil pollution and noise standards).
iii. Retrospective case studies of specific standard processes of environmental protection agencies (Wang et al., 2022).

Furthermore, ongoing meetings with top officials from the US, Norway, Japan, and other ecological organizations were very beneficial to the structuring process. While the structuring work was oriented toward decision analysis, individuals in IIASA's standards-setting study team, including a pair of physicists (W. Hafele and R. Avenhaus), an environmental economist (D. Fischer), an environmental modeler (S. Ikeda), a game theorist (E. Hopfinger), and an ecological economist (D. Fischer), contributed significantly (Terban et al., 2018).

The primary query was: what is the most effective way to develop standard-setting problems into a decision-analytic layout and model so that the latter is both sufficiently broad to encompass a range of normative issues and specific enough to capture the key elements of a given standard-setting problem? Stated differently, what is a prototypical decision analytic structure for standard setting?

The original structuring focused on regulatory alternatives and objectives because it assumed that the regulator or governing body was the primary customer. A comprehensive but superficial alternative tree was once proposed, encompassing a range of regulatory alternatives such as direct actions, land use proposals, and emission standards. A simple MAU (Multi-Attribute Utility) approach could be used to evaluate each alternative in a decision analysis when combined with a well-defined tree of regulatory objectives (von Winterfeldt, 1980).

However, this straightforward and conventional structure was dismissed because it failed to consider the interactions between regulators and the regulated entities, and regulators rarely had to consider such a wide variety of options. Moreover, a basic MAU structure does not address the issue of standard application and tracking, which is of great interest to regulators (Picotte et al., 2019).

The subsequent design addressed an oil pollution problem and featured a deep but narrow decision tree. This tree includes the business's responses to new standards, the potential discovery of standards violations, and subsequent sanctions, in addition to the regulator's alternatives. This structure was designed to evaluate the ecological impacts and enhance the regulators' explanations of standard-level monitoring and sanction systems (e.g., the highest emission level). When it comes to the regulatory alternatives, the structure is specific. However, it overlooks a crucial issue in regulatory decision-making by treating industrial reactions as random events and excluding input from environmental organizations (Vallat et al., 2018) (Figure 3.2).

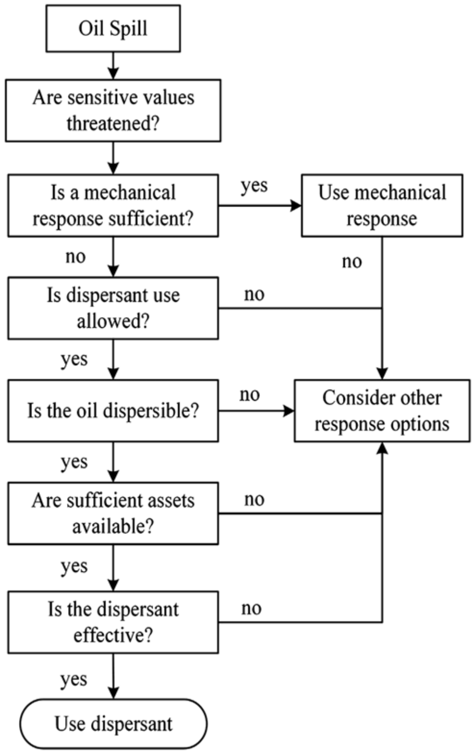

Figure 3.2. Flowchart for decision-making on using dispersants (Source: Zengkai, Creative Commons License)

The next model was a three-decision-maker model, wherein distinct decision analytic models represent the regulator, the industry/developer, and the environmentalists/impacted parties. A signal detector style model connects the business model to the regulator's decision-making process by potentially detecting infractions and penalty systems. The developer's decisions are connected to the impactees model through an event tree of pollution-generating events with effects (Meng et al., 2004).

The last structure examined was an expansion of the three-decision-maker model using game theory. This approach expressly assumes that the process of developing standards is ever-changing and considers all forms of feedback. Furthermore, changes from one stage to the next are probabilistic. A seven-phase variant of the model was used in a pilot study to determine the noise standard setting for fast trains. The static decision analytic model is solved by the game theoretical model; however, in doing so, it forfeits the ability to fine-tune and analyze in depth the compromises and probabilities. A detailed consideration of these factors would have rendered the model unusable. As a result, it is necessary to make assumptions about relatively arbitrary (linear) utility functions and straightforward transition probability models (Ario et al., 2013).

3.5. DECISION ANALYSIS SOFTWARE

Learning Objectives

- To understand the purpose and scope of decision analysis software in the decision-making process.
- To explore various decision analysis software tools.

Making educated decisions in the ever-changing field of decision analysis requires both individuals and companies to use advanced computing tools. A wide range of tools designed to improve analytical skills, expedite complicated decision-making processes, and offer a methodical way to assess possibilities are included in decision-analyzing software (Barcus & Montibeller, 2008) (Figure 3.3).

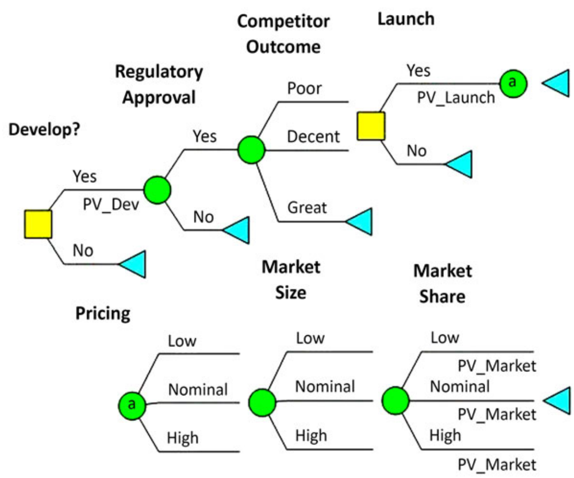

Figure 3.3. Illustration of decision trees (Source: Chris, Creative Commons License)

3.5.1. Overview of Available Tools

Following are the tools available to address the intricate landscape of decision-making.

a. **Monte Carlo Simulation Software:** Monte Carlo simulations generate random inputs to model uncertainty. They are made possible by tools such as Palisade

Decision Tools Suite, @RISK, and Crystal Ball. Simulations like these provide decision-makers with a nuanced view of the spectrum of potential results, enabling them to effectively address and manage uncertainty (Vrugt, 2016).

b. **Software for Multi-Criteria Decision Analysis**: Software for Multi-Criteria Decision Analysis (MCDA), such as Expert Choice, AHP-OS, and Promethee, are essential for making judgments with multiple criteria and preferences. These tools utilize computational models to assess and prioritize possibilities based on various standards, facilitating a comprehensive decision-making process (Pohekar & Ramachandran, 2004).

c. **Decision Tree Software:** Decision tree tools assist individuals in understanding complex decisions by visually representing multiple decision scenarios. Users can map out decisions and potential consequences using programs like TreeAge, Lucidchart, and Microsoft Visio, enhancing their understanding of decision paths (Rathore & Kumar, 2016) (Figure 3.4).

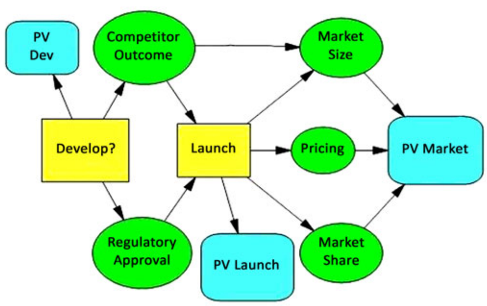

Figure 3.4. Representation of flow in decision analysis software (Source: Chris, Creative Commons License)

d. **Spreadsheet-Based Decision Tools:** A dependable foundation for decision analysis is offered by standard spreadsheet programs in conjunction with specialized add-ins like Solver and Palisade Decision Tools Suite for Excel. For users who are accustomed to spreadsheet interfaces, this method is helpful since it provides adaptability in decision modeling.

e. **Decision Support System (DSS):** It is an integrated system that integrates several decision-making tools, databases, and algorithms. Examples of DSS are FICO Decision Management Suite, IBM Watson Decision Optimization, and DicE. They provide a comprehensive method of decision assistance, which is especially helpful for intricate decision-making procedures involving coordination between many departments (Asemi et al., 2011).

3.5.2. Choosing the Right Software for the Task

Choosing the right software for the job is crucial in making effective decisions. This decision should be based on several important aspects:

i. **Cost and Licensing:** Evaluate the overall cost, including ongoing maintenance expenses and licensing fees. Select a tool that aligns with your financial requirements and offers a measurable return on investment.

ii. **Assistance and Education:** Assess the availability of customer service support and educational resources. Sufficient assistance and guidance are vital in ensuring a smooth software deployment process and ongoing user success.

iii. **Reviews and Suggestions:** Seek input from other users with similar needs when making decisions. Online evaluations, case studies, and recommendations provide valuable insights into the functionality and reliability of the software.

iv. **Decision Scope and Complexity**: Assess the decision's level of difficulty. Simple decision tree techniques may be sufficient for handling simple decisions, but more complex situations can call for the more sophisticated features of MCDA or DSS (Belardo & Pazer, 1985).

v. **User-Friendliness:** Evaluate how simple it is to use each software feature. Users' learning curves can be reduced, and the decision-analysis procedure can be accelerated with a simple interface and user-friendly functions.

vi. **Integration with Current Systems:** Consider if the program will work with the technology stack you currently have in place. Efficiency is increased and data accuracy is guaranteed by effortless integration with various tools and platforms.

vii. **Flexibility and Customization:** Seek software that can be tailored to the particulars of your decision-making process. To efficiently adapt the instrument to various settings, adaptability is essential.

Decision-makers may utilize a variety of decision-analytical resources and make well-informed decisions that are in line with their needs and corporate goals by mindfully taking these elements into account. Recall that a tool's efficacy goes beyond its features; it also includes how well it integrates into current workflows and how well it supports decision-making (Balbo et al., 2004).

PRACTICE PROBLEM

As a business proprietor seeking to broaden your range of products, you are faced with the task of choosing between two manufacturing methods (A and B) in order to maximize production efficiency. Process A boasts a lower initial expenditure, whereas Process B offers the potential for enhanced efficacy and reduced operational expenses. The crux of the matter lies in the uncertainty surrounding the market demand for the new product. Please outline the structure of this decision conundrum.

SOLUTIONS TO PRACTICE PROBLEM

Decision Variables:

a. Manufacturing Process Selection (Options: A, B)
b. Initial Cost
c. Operating Costs

Uncertainties:

Market demand (High, Medium, Low)

Objectives:

a. Minimize Initial Cost
b. Minimize Operating Costs
c. Maximize Profit (linked to market demand)

Structuring Method:

Decision Tree: Map out decision nodes for process selection, incorporating branches for initial and operating costs. Introduce a chance node for market demand influencing profit.

SUMMARY

- This chapter explores the fundamental aspects of structuring decision problems for effective decision analysis. Taxonomies for problem identification provide a foundational understanding, aiding in the identification and categorization of decision problems.
- Methods for selecting an analytic structure are discussed, offering insights into the systematic approaches for choosing appropriate analytical frameworks.
- Advances in formalizing structures highlight evolving techniques for rendering decision problems into structured formats, enhancing analytical precision. Developing a prototypical structure is examined, emphasizing the creation of representative models that can serve as templates for similar decision scenarios.
- Decision Analysis Software is explored, with an overview of available tools, showcasing the diversity of software options for decision analysis. Choosing the right software for the task is emphasized, detailing key considerations such as decision complexity, user-friendliness, integration, customization, cost, support, and user feedback.

MULTIPLE CHOICE QUESTIONS

1. What is the primary purpose of taxonomies for problem identification in decision analysis?

a. To provide financial forecasts

b. To identify and categorize decision problems

c. To create prototypical decision structures

d. To develop decision analysis software

2. What aspect does the process of formulating a prototype framework for decision scenarios emphasize?

a. Minimizing uncertainty

b. Enhancing creativity

c. Creating representative models

d. Maximizing risk

3. What does the concept of a "kit of prototypical decision analytical structures" imply?

a. A collection of standardized decision-making tools

b. A set of randomly generated decision structures

c. A toolkit for taxonomy analysis

d. An advanced decision analysis algorithm

4. In the context of decision analysis software, what is a key consideration for choosing the right tool?

a. Color scheme

b. Popularity on social media

c. User-friendliness

d. Entertainment Value

5. Why is the adoption of a new production technology a suitable example in this chapter?

a. To explore taxonomies for problem identification

b. To emphasize the importance of random decision-making

c. To showcase the use of decision analysis in financial forecasting

d. To study the impact of decision analysis software on market trends

REVIEW QUESTIONS

1. How can taxonomies aid in the identification and categorization of decision problems?
2. What are the systematic approaches for selecting an appropriate analytic structure for decision problems?
3. How do advances in formalizing decision structures contribute to enhanced precision in analysis?
4. What is the process involved in developing a prototypical structure for decision scenarios?
5. What factors should be considered when choosing decision analysis software?

Answers to Multiple Questions

1. (b) 2. (c) 3. (a) 4. (c) 5. (a)

REFERENCES

1. Aggarwal, A. K., Clayton, E. R., Rakes, T. R., & Baker, J. R., (1992). A problem identification taxonomy for classification and automated formulation of multiple objective linear programming models. *Annals of Operations Research*, *38*(1), 1–16.
2. Akaka, M. A., Koskela-Huotari, K., & Vargo, S. L., (2021). Formalizing service-dominant logic as a general theory of markets: Taking stock and moving forward. *AMS Review*, *7*(3), 1–15.
3. Alabastro, M. S., Beckmann, G., Gifford, G., Massey, A. P., & Wallace, W. A., (1995). The use of visual modeling in designing a manufacturing process for advanced composite structures. *IEEE Transactions on Engineering Management*, *42*(3), 233–242.

4. Alemi, F., & Gustafson, D. H., (2006). Introduction to decision analysis. *Decision Analysis for Healthcare Managers, 4*(2), 1–20.
5. Ario, I., Nakazawa, M., Tanaka, Y., Tanikura, I., & Ono, S., (2013). Development of a prototype deployable bridge based on origami skill. *Automation in Construction*, *32*, 104–111.
6. Asemi, A., Safari, A., & Zavareh, A. A., (2011). The role of management information system (MIS) and decision support system (DSS) for manager's decision-making process. *International Journal of Business and Management*, *6*(7), 164–173.
7. Balbo, S., Ozkan, N., & Paris, C., (2004). Choosing the right task-modeling notation: A taxonomy. *The Handbook of Task Analysis for Human-Computer Interaction*, *9*(3), 445–465.
8. Barcus, A., & Montibeller, G., (2008). Supporting the allocation of software development work in distributed teams with multi-criteria decision analysis. *Omega*, *36*(3), 464–475.
9. Beaubien, J. M., & Baker, D. P., (2002). A review of selected aviation human factors taxonomies, accident/incident reporting systems and data collection tools. *International Journal of Applied Aviation Studies*, *2*(2), 11–36.
10. Belardo, S., & Pazer, H. L., (1985). Scope/complexity: A framework for the classification and analysis of information-decision systems. *Journal of Management Information Systems*, *2*(2), 55–72.
11. Belton, V., & Stewart, T., (2010). Problem structuring and multiple criteria decision analysis. *Trends in Multiple Criteria Decision Analysis*, *5*, 209–239.
12. Caglio, A., (2003). Enterprise resource planning systems and accountants: Towards hybridization? *European Accounting Review*, *12*(1), 123–153.
13. Chen, G., & Xiao, L., (2016). Selecting publication keywords for domain analysis in bibliometrics: A comparison of three methods. *Journal of Informetrics*, *10*(1), 212–223.
14. Cheung, M. W., & Chan, W., (2009). A two-stage approach to synthesizing covariance matrices in meta-analytic structural equation modeling. *Structural Equation Modeling: A Multidisciplinary Journal*, *16*(1), 28–53.
15. Cohen, M. A., & Lee, H. L., (1988). Strategic analysis of integrated production-distribution systems: Models and methods. *Operations Research*, *36*(2), 216–228.
16. Comrey, A. L., (1988). Factor-analytic methods of scale development in personality and clinical psychology. *Journal of Consulting and Clinical Psychology*, *56*(5), 754.
17. Corner, J., Buchanan, J., & Henig, M., (2001). Dynamic decision problem structuring. *Journal of Multi-Criteria Decision Analysis*, *10*(3), 129–141.
18. Devadoss, P. R., Pan, S. L., & Huang, J. C., (2003). Structurational analysis of e-government initiatives: A case study of SCO. *Decision Support Systems*, *34*(3), 253–269.
19. Fehr, B., (1988). Prototype analysis of the concepts of love and commitment. *Journal of Personality and Social Psychology*, *55*(4), 557.

20. Gnat, S., Nowakiewicz, A., & Zięba, P., (2019). Taxonomy of dermatophytes–the classification systems may change but the identification problems remain the same. *Postępy Mikrobiologii-Advancements of Microbiology*, *58*(1), 49–58.
21. Kassirer, J. P., (1976). The principles of clinical decision making: An introduction to decision analysis. *The Yale Journal of Biology and Medicine*, *49*(2), 149.
22. Khan, Z., Anjum, A., Soomro, K., & Tahir, M. A., (2015). Towards cloud based big data analytics for smart future cities. *Journal of Cloud Computing*, *4*(1), 1–11.
23. Kim, J., Fischer, M., Kunz, J., & Levitt, R., (2014). Sharing of temporary structures: Formalization and planning application. *Automation in Construction*, *43*, 187–194.
24. Kregzde, M., (1993). A method of selecting the best implant prosthesis design option using three-dimensional finite element analysis. *International Journal of Oral & Maxillofacial Implants*, *8*(6), 8724.
25. Leopold, D. A., O'Toole, A. J., Vetter, T., & Blanz, V., (2001). Prototype-referenced shape encoding revealed by high-level aftereffects. *Nature Neuroscience*, *4*(1), 89–94.
26. Li, P., Xu, S., Xu, C., Du, F., & Cao, S., (2022). Development of a miniature dynamic stiffness measurement prototype toward structural health monitoring of space inflatable structures. *Measurement*, *194*, 111051.
27. Liu, F. H. F., & Hai, H. L., (2005). The voting analytic hierarchy process method for selecting supplier. *International Journal of Production Economics*, *97*(3), 308–317.
28. Marttunen, M., Lienert, J., & Belton, V., (2017). Structuring problems for multi-criteria decision analysis in practice: A literature review of method combinations. *European Journal of Operational Research*, *263*(1), 1–17.
29. McDermott, J., (1988). Preliminary steps toward a taxonomy of problem-solving methods. In: *Automating Knowledge Acquisition for Expert Systems* (Vol. 1, pp. 225–256). Boston, MA: Springer US.
30. Meng, X., Roberts, G., Dodson, A. H., Andreotti, M., Cosser, E., & Meo, M., (2004). Development of a prototype remote structural health monitoring system (RSHMS). In: *1st FIG International Symposium on Engineering Surveys for Construction Works and Structural Engineering* (Vol. 28, pp. 879–885).
31. Picotte, J. J., Dockter, D., Long, J., Tolk, B., Davidson, A., & Peterson, B., (2019). LANDFIRE remap prototype mapping effort: Developing a new framework for mapping vegetation classification, change, and structure. *Fire*, *2*(2), 35.
32. Pohekar, S. D., & Ramachandran, M., (2004). Application of multi-criteria decision making to sustainable energy planning—A review. *Renewable and Sustainable Energy Reviews*, *8*(4), 365–381.
33. Pugh, D. S., Hickson, D. J., Hinings, C. R., & Turner, C., (1968). Dimensions of organization structure. *Administrative Science Quarterly*, *4*(3), 65–105.
34. Rangaswamy, A., & Shell, G. R., (1997). Using computers to realize joint gains in negotiations: Toward an "electronic bargaining table." *Management Science*, *43*(8), 1147–1163.

35. Rathore, S. S., & Kumar, S., (2016). A decision tree regression based approach for the number of software faults prediction. *ACM SIGSOFT Software Engineering Notes*, *41*(1), 1–6.

36. Schmitt, T. A., Sass, D. A., Chappelle, W., & Thompson, W., (2018). Selecting the "best" factor structure and moving measurement validation forward: An illustration. *Journal of Personality Assessment*, *100*(4), 345–362.

37. Tah, J. H. M., & Carr, V., (2001). Towards a framework for project risk knowledge management in the construction supply chain. *Advances in Engineering Software*, *32*(10, 11), 835–846.

38. Terban, M. W., Banerjee, D., Ghose, S., Medasani, B., Shukla, A., Legg, B. A., & Billinge, S. J., (2018). Early stage structural development of prototypical zeolitic imidazolate framework (ZIF) in solution. *Nanoscale*, *10*(9), 4291–4300.

39. Vakil, A. C., (1997). Confronting the classification problem: Toward a taxonomy of NGOs. *World Development*, *25*(12), 2057–2070.

40. Vallat, B., Webb, B., Westbrook, J. D., Sali, A., & Berman, H. M., (2018). Development of a prototype system for archiving integrative/hybrid structure models of biological macromolecules. *Structure*, *26*(6), 894–904.

41. Velicer, W. F., & Jackson, D. N., (1990). Component analysis versus common factor analysis: Some issues in selecting an appropriate procedure. *Multivariate Behavioral Research*, *25*(1), 1–28.

42. Von, W. D., (1980). Structuring decision problems for decision analysis. *Acta Psychologica*, *45*(1–3), 71–93.

43. Vrugt, J. A., (2016). Markov chain Monte Carlo simulation using the DREAM software package: Theory, concepts, and MATLAB implementation. *Environmental Modeling & Software*, *75*, 273–316.

44. Wang, S., Mao, W., Wei, P., & Zeng, D. D., (2022). Knowledge structure driven prototype learning and verification for fact checking. *Knowledge-Based Systems*, *238*, 107910.

CHAPTER 4

Uncertainty and Risk Analysis

LEARNING OBJECTIVES

After studying this chapter, you will be able to:

- Understand the spectrum between pure uncertainty and certainty in decision-making.
- Identify and analyze sources of errors inherent in decision-making processes.
- Explore the influence of personality types on decision-making under pure uncertainty.
- Recognize the limitations associated with decision-making when faced with pure uncertainty.
- Comprehend the concept of decision-making under risk and calculate Expected Payoff.

INTRODUCTORY EXAMPLE

Consider the following scenario: TechInnovate Corp., a preeminent manufacturer, finds itself at a critical juncture, deliberating on the introduction of an innovative new product. The organization's decision-makers are faced with uncertainties about crucial elements including market demand, production expenses, and possible competitors. Amidst an environment characterized by absolute uncertainty, the task at hand is to arrive at informed decisions in the absence of precise data. Furthermore, the added complexity of the decision-making process is compounded by the diverse risk tolerances exhibited by decision-makers, which are in turn shaped by their personality types. When an organization shifts to risk-based decision-making, crucial considerations include the anticipated return on investment, the most likely future conditions, and the possibility of missing out on advantageous opportunities. To make informed strategic decisions in a dynamic market, TechInnovate Corp. is required to navigate these uncertainties by crafting decision trees and influence diagrams and utilizing tools such as the Bayesian Approach. This illustration establishes the foundation for an extensive examination of risk assessment and uncertainty within the decision-making procedures of a dynamic manufacturing organization.

UNIT INTRODUCTION

Two separate entities are involved in modeling for decision-making: the decision maker and the analyst, who builds the model. Aiding the decision-maker is the responsibility of the analyst. Consequently, an analyst must possess expertise that extends beyond mere analytical techniques. Experts in model construction are frequently enticed to investigate a problem before isolating themselves to create a complex mathematical model for the manager's (i.e., the decision maker's) use. Unfortunately, the manager might not comprehend this model and consequently either blindly implement it or reject it utterly. The specialist might perceive the manager as ignorant and unsophisticated to fully comprehend the model, whereas the manager might perceive the specialist as if they live in an ideal world of irrational presumptions and superfluous mathematical language. To prevent such miscommunication, the manager should collaborate with the specialist to construct an initial model that offers a rudimentary yet comprehensible analysis (Nilsen & Aven, 2003).

After the manager develops confidence in this model, further intricacy and refinement may be introduced, albeit incrementally at first. This procedure necessitates the manager dedicating time and the specialist demonstrating genuine interest in resolving the manager's actual concern, as opposed to constructing and attempting to explain complex models. As it is important for the effective execution of a decision model, this method of constructing progressive models is frequently called the bootstrapping approach. Additionally, the bootstrapping methodology streamlines the challenging task of validating and verifying models (Abrahamsson, 2002).

Deterministic models evaluate the quality of a decision solely based on its outcome. Conversely, within probabilistic models, the decision-maker is preoccupied not solely with the value of the outcome, but also with the degree of risk associated with each decision. To illustrate the distinction between probabilistic and deterministic models, consider both the past and the future. While it is impossible to alter the past, each action one takes has the potential to shape and influence the future, albeit the future is inherently uncertain. Much more captivating to managers is shaping the future than the past (Kunreuther, 2002).

Probabilistic modeling is predominantly founded on the utilization of statistical methods to evaluate the risk associated with decisions and the probability of uncontrollable events (or factors). The initial concept underlying statistics was the compilation of data about and for the state. The term "statistics" originates from the Italian word for "state" rather than any classical Greek or Latin root. Probability has a significantly more extensive past. The word probability comes from the verb "probe," which means to "discover" information that is not readily available or comprehensible. The term "proof" derives from the same word that furnishes the requisite information to comprehend what is asserted to be true. Probabilistic models are viewed as similar to that of a game; actions are based on expected outcomes. The center of interest is shifting from deterministic to probabilistic models for estimation, testing, and prediction utilizing subjective statistical techniques. Risk is defined as uncertainty in probabilistic modeling in which the probability distribution is known. As a result, risk assessment refers to an investigation to find the decision's outcomes along with their probabilities (Suslick et al., 2009).

Rarely do decision-makers have access to an adequate quantity of data. Probability assessment measures the discrepancy between the existing knowledge and the knowledge required to make an optimal decision. Probabilistic models are implemented to mitigate the negative effects of uncertainty and capitalize on propitious uncertainties. In probability assessment, difficulties arise from insufficient, ambiguous, inconsistent, or conflicting information. A more natural and realistic statement is "the probability of a power outage falls between 0.3 and 0.4," than its "exact" counterpart "the probability of a power outage is 0.36342" (Flage et al., 2014).

A variety of decision models are available for analyzing distinct circumstances. The three most frequently employed categories vary according to the extent and quantity of knowledge possessed:

i. Decision-making under pure uncertainty.
ii. Making decisions under risk.
iii. Decision making by buying information (pushing the issue toward the deterministic "pole") (Hoffman & Hammonds, 1994).

4.1. DECISION MAKING UNDER PURE UNCERTAINTY

Learning Objectives

- To understand the continuumbetween pure uncertainty and certainty in decision-making.
- To understand the sources of errors in decision-making under pure uncertainty.
- To understand the concept of Expected Payoff and its application in decision-making under risk.

When making decisions under pure uncertainty, the decision-maker is unaware of the possible outcomes of any state of nature, and/or acquiring the necessary information is prohibitively expensive. When this occurs, the decision-making process is solely determined by the personality type of the decision-maker (Mukerji & Tallon, 2004).

4.1.1. Continuum of Pure Uncertainty and Certainty

The sphere of models for decision analysis is situated between two extremes. This is contingent on the level of awareness we possess regarding the outcomes of our actions, as illustrated in Figure 4.1 (Rubin, 2010).

Figure 4.1. Representation of uncertainty and certainty domain (Source: M.T. Taghavifard, Creative Commons License)

On this spectrum, one "pole" represents determinism, while the opposing "pole" signifies pure uncertainty. Between these extremes lie issues categorized as being under risk. The crux of the matter is that, for a given problem, the certainty level varies among managers based on their knowledge of the same problem. This discrepancy results in each individual advocating for a different solution. Probability functions as a

Did you know?

The concept of uncertainty in decision-making dates back to ancient Greece, where philosophers like Thales acknowledged the unpredictable nature of certain events.

tool to gage the likelihood of an event's occurrence. When utilizing probability to express uncertainty, the deterministic end is assigned a probability of one (or zero), whereas the other end maintains a flat (equally probable) probability distribution. For instance, if one is unequivocally certain about the occurrence (or non-occurrence) of an event, a probability of one (or zero) is applied (Guenther et al., 2019) (Figure 4.2).

Figure 4.2. Diagram of decision-making and errors (Source: Robbins, Creative Commons License)

When an individual expresses uncertainty by stating "I don't know," there is a 50% probability that the event will occur or not. The Bayesian perspective posits that the evaluation of probability is inherently subjective. In other words, the knowledge of the decision-maker consistently influences the probability. When an individual possesses complete knowledge, the probability will diverge to either one or zero. The largest risk decision situations are those characterized by flat uncertainty. To illustrate, let's consider a scenario containing two possible outcomes, one of which possesses a probability denoted as p (Taghavifard et al., 2009). Therefore, p×(1-p) represents the variation in the state of nature. The greatest variation occurs when p is set to 50% and all outcomes are given an equal chance. Under such circumstances, the information is of the utmost poor quality. The quality of information and variation are inversely related, according to statistics science. Specifically, greater variability in data indicates data of inferior quality (Ezrow et al., 2014).

4.1.2. Source of Errors in Decision Making

Errors in risky decision-making issues are predominantly caused by incorrect assumptions, imprecise estimations of probabilities, reliance on expectations, challenges associated with utility function measurement, and forecast errors (Johnson et al., 2013). Let's consider the subsequent example of stereotypical investment decision-making. To condense the description, the example is displayed in Table 4.1.

Table 4.1. The Investment Decision-Making Example (Source: M. T. Taghavifard, Creative Commons License)

Actions	**States of Nature**				
		Growth	**Medium G**	**No Change**	**Low**
		G	**MG**	**NC**	**L**
	Bonds	12%	8	7	3
	Stocks	15	9	5	-2
	Deposit	7	7	7	7

The states of nature are the states of the economy during one year. The problem is to decide what action to take among three possible courses of action with the given rates of return as shown in the body of the table (Dörner & Schaub, 1994).

4.1.3. Personality Types and Decision-Making

Pessimism, or Conservative (Max/Min): Worst-case scenario. Bad things always happen to me (Zare et al., 2018) (Table 4.2).

Table 4.2. Max/Min Course of Action (Source: M.T.Taghavifard, Creative Commons License)

	B	12	
a) Write max # in each action now,	S	15	*
b) Choose max # and do that action	D	7	

Optimism, or Aggressive (Max/Max): Good things always happen to me (Afek et al., 1996) (Figure 4.3, Table 4.3).

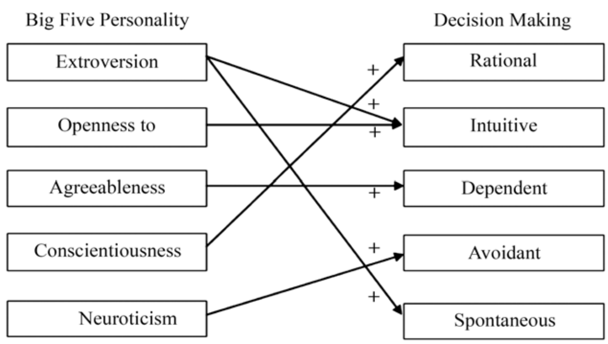

Figure 4.3. Diagram of personality traits and decision-making (Source: Radwan, Creative Commons License)

Table 4.3. Max-Max Course of Action (Source: M.T. Taghavifard, Creative Commons License)

	B	12	
a) Write max # in each action row,	S	15	*
b) Choose max # and do that action	D	7	

Optimism Coefficient (Hurwicz's Index): The center of the road: I maintain an optimistic-pessimistic balance.

a) Select α from the range of zero to one. One represents optimism and zero represents pessimism.

b) Determine the maximum and minimum numbers for each action.

c) Multiply the largest payoff (row-wise) by α and the minimum payoff by (1–α).

d) Select the action with the largest sum.

For instance, for α = 0.7, see, Table 4.4 (Liu & Ma, 2019).

Table 4.4. Coefficient of Optimism Course of Action (Source: Khalili Damghani, Creative Commons License)

B(.7*12).. + (.3*3)..=..9.3…
S (.7*15).. + (.3*-2)..=..9..*
D(.7*7).. + (.3*7)..=..7…

This approach utilizes a linear combination of all natural outcomes and is readily extensible to k nature states and n outcomes, each accompanied by its corresponding value i, i=1,2,3,…,k….

Certain managers adopt a strategic perspective, driven by a preference to minimize regrets. Their decision-making framework is predicated on the notion that choices should be optimal to the extent that they warrant repetition. The criterion for engaging in specific actions is predicated on the manager's perception that these actions are amenable to repeated execution. This approach is designed to mitigate the probability of encountering regret, disappointment, or undesirable surprises as outcomes.

Regret, within this context, is construed as the disparity between the payoff associated with the theoretically best decision given prevailing circumstances and the actual payoff stemming from the decision made in those specific circumstances. Consequently, the initial procedural step entails the establishment of a comprehensive regret table, serving as a structured framework for evaluating potential decision outcomes (Table 4.5). Therefore, the first step is to set up the regret table:

a. Take the largest number in each state of nature column (say, L).

b. Subtract all the numbers in that state of nature column from it (i.e.,–L – Xi,j).

c. Choose a maximum number of each action.

d. Choose the minimum number from step (d) and take that action (Fu et al., 2020).

Table 4.5. The Regret Matrix (Source: Khalili Damghani, Creative Commons License)

	G	MG	NC	L	
Bonds	(15–12)	(9–8)	(7–7)	(7–3)	4*
Stocks	(15–15)	(9–9)	(7–5)	(7+2)	9
Deposit	(15–7)	(9–7)	(7–7)	(7–7)	8

4.1.4. Limitations of Decision-Making Under Pure Uncertainty

In general, decision analysis operates under the assumption that the individual making the decision is confronted with a decision problem in which they must select a single option from a given set. This constraint may be surmounted in certain circumstances by redefining uncertainty-induced decision-making as a zero-sum two-person game (Kay, 2023). When making decisions under pure uncertainty, the decision-maker is not informed of the "most probable" state of nature. Given their probabilistic ignorance regarding the state of nature, they are incapable of harboring either an optimistic or pessimistic outlook. When this occurs, the decision-maker invokes security considerations. It should be noted that any technique employed in decision-making amidst pure uncertainties is only suitable for private life decisions. Furthermore, for the public entity, to forecast the probabilities of the different states of nature, a basic understanding of the state of nature is required. In this situation, the decision maker is incapable of reaching reasonable and valid decisions otherwise (Antuori & Richoux, 2019).

4.2. DECISION MAKING UNDER RISK

Learning Objectives

- To assess expected payoffs based on different outcomes and their probabilities.
- To identify the most probable states of nature to inform decision-making.

Risk entails an element of uncertainty and the lack of complete authority over the results or consequences of undertaking said action. Nevertheless, the mitigation of a single risk may occasionally result in the escalation of other risks. To properly manage risk, its assessment and ensuing influence on the decision-making process must be considered. Before decision making, the decision-maker can assess different approaches through the utilization of the decision process. The procedure consists of the following steps (Mishra, 2014):

a) After defining the problem, all viable alternatives are considered. The potential outcomes associated with each alternative are assessed.

b) The discussion of outcomes pertains to their financial returns or net benefits in terms of resources or time.

c) Probabilities are utilized to quantify a variety of uncertainties.

d) The caliber of the assessments is critical for determining the optimal course of action. It is the responsibility of the decision-maker to determine and assess the optimal strategy's receptivity to critical factors (Post et al., 2008).

When the decision maker possesses an understanding of the states of nature, they may be capable of estimating the subjective probability of each state occurring. In such cases, the issue is categorized as decision-making under risk. Probabilities can be assigned by the decision maker based on the occurrence of states of nature. The risk-based decision-making procedure consists of the following steps:

a. Utilize the available information to assign subjective probabilities, or beliefs, to each state of nature denoted as p(s).

b. Assign a payoff to each action associated with each state of nature denoted as X(a,s).

c. Calculate the expected payoff, or return (R), for every action.

d. Acknowledge the principle that the expected payoff should be minimized (or maximized), and

e. Carry out the action that lessens (or maximizes) R(a) (Christopoulos et al., 2009).

Remember

Decision analysis, a pivotal element of uncertainty and risk analysis, exerted an influence on economics, resulting in the conferral of the Nobel Prize in Economic Sciences upon Daniel Kahneman and Vernon L. Smith in 2002.

4.2.1. Expected Payoff

The actual outcome will deviate from the expected value. The contrary of what one anticipates, or the "Great Expectations!" (Table 4.6).

a. Multiply the probability and payoff for each action;
b. Compute the sum of the results row by row; and
c. Select the action with the highest possible payoff (Watson et al., 2002).

Table 4.6. The Expected Payoff Matrix (Source: Khalili Damghani, Creative Commons License)

	G(0.4)		MG/0.3		NC/0.2		L(0.1)		Exp. Value
B	0.4(12)	+	0.3(8)	+	0.2(7)	+	0.1(3)	=	8.9
S	0.4(15)	+	0.3(9)	+	0.2(5)	+	0.1(-2)	=	9.5*
D	0.4(7)	+	0.3(7)	+	0.2(7)	+	0.1(7)	=	7

4.2.2. The Most Probable States of Nature

This approach is straightforward for risk-based decision-making, but it is more suitable for non-repetitive decisions. This methodology comprises the following stages:

a) Select the state of nature that has the highest probability (break any ties subjectively), and
b) Select the action in that column that offers the greatest payoff.

Given the 40% probability of growth in the numerical example, one must purchase stocks with a payoff of 15% and an expected payoff of 0.6 (Gilboa & Schmeidler, 1989).

4.2.3. Expected Opportunity Loss

This methodology comprises the subsequent stages (Table 4.7):

a. Construct a loss payoff matrix by taking the largest number in each state of nature column (say L), and subtract all numbers in that column from it, –L – Xij.

i. Multiply the probability and loss, and then add up for each action.

ii. Select the action with the smallest EOL (Davis et al., 1985).

Table 4.7. The Expected Opportunity Loss Matrix (Source: Khalili Damghani, Creative Commons License)

Loss Payoff Matrix								
	G(0.4)		**MG(0.3)**		**NC(0.2)**		**L(0.1)**	**LOL**
B	0.4(15–12)	+	0.3(9–8)	+	0.2(7–7)	+	0.1 (7–3)	1.9
S	0.4(15–15)	+	(0.3)9–9	+	0.2(7–5)	+	0.1 (7+ 2)	1.3*
D	0.4(15–7)	+	0.3(9–7)	+	0.2(7–7)	+	0.1 (7–7)	3.8

Note that the result coincides with the Expected Payoff and Most Probable States of Nature (Su & Tung, 2012).

4.2.4. Computation of the Expected Value of Perfect Information (EVPI)

EVPI assists in determining the value of an informant with flawless information. Always keep in mind that EVPI equals EOL.

a) Determine the maximum payoff associated with each state of nature.

b) Multiply each case by the corresponding probability for that state of nature and add them up.

c) Deduct the expected payoff from the resulting value designated as Expected Payoff (Canessa et al., 2015).

Hence, EVPI = 10.8 minus Expected Payoff = 10.8 minus 9.5 equals 1.3. Confirm that EOL is equal to EVPI. 100% is the efficacy of perfect information (EVPI/(Expected Payoff)). Do not purchase the information if its price exceeds 1.3% of the initial investment. For instance, in the case of an intended investment of $100,000, the information can be obtained for a maximum cost of $1,300, which we get by 100,000 x 1.3% (Lianwen & Poole, 1993) (Table 4.8).

Table 4.8. EVPI Computation Matrix (Source: R. Tavakkoli, Creative Commons License)

G	15(0.4)	=	6.0
MG	9(0.3)	=	2.7
NC	7(0.2)	=	1.4
L	7(0.1)	=	0.7
	+		10.8

4.2.5. The Laplace Equal Likelihood Principle

Each state of nature possesses an equivalent probability. Given the current state of nature knowledge, the probability of occurrence for each state of nature is equivalent throughout.

a) Assign an equal probability (i.e., a Flat Probability) to each state of nature;

b) Multiply each number by the corresponding probability.

c) Add action rows and insert the sum into the Expected Payoff column;

d) Select the action with the maximum value in step (c) and execute it (Mabel & Olayemi, 2020) (Table 4.9).

Table 4.9. Laplace Equal Likelihood Principle Matrix (Source: R. Tavakkoli, Creative Commons License)

	G	MG	NC	L	Exp. Payoff
Bonds	0.25 (12)	0.25 (8)	0.25(7)	0.25 (3)	7.5*
Socks	0.25(15)	0.25 (9)	0.25 (5)	0.25 (-2)	6.75
Deposit	0.25 (7)	0.25(7)	0.25 (7)	0.25 (7)	7

4.2.6. Expected Opportunity Loss

The comparative analysis of decision outcomes against their alternatives stands out as a crucial facet of the decision-making process. A pivotal emotional element in this assessment is regret, which manifests when the result of a decision is juxtaposed against the potential outcome had a different decision been made. This stands in contrast to disappointment, wherein the evaluation stems from comparing one outcome to another because of the same decision. Notably, substantial disparities with counterfactual results exert a disproportionate impact on the decision-making process (Alleva, 2015).

Regret is contingent upon comparing a decision outcome with the potential alternative outcome, hinging on the feedback available to decision-makers regarding the alternative option's likely outcome. Manipulating uncertainty resolution to alter the potential for regret reveals that decision-making behavior, ostensibly indicative of risk aversion, can be more accurately attributed to regret aversion (Wöss, 2020).

The distinction between acts and omissions appears to be a pertinent factor in the manifestation of regret. Research suggests that regret tends to be more intense following an action compared to an omission. For instance, a study demonstrated that participants perceived a decision maker who switched stock funds from one company to another and incurred losses as experiencing greater regret than another decision maker who opted against the switch but also incurred losses. This inclination to assign higher value to an inferior outcome resulting from an act rather than an omission is presumed to be a mechanism to counteract potential regret associated with the action taken (Chick & Wu, 2005).

4.3. BAYESIAN APPROACH

Learning Objectives

- To understand the Bayesian Approach, one must consider the process of updating probabilities by incorporating prior knowledge and new information.
- To understand iterative refinement: continuous adjustment of subjective beliefs.

In numerous instances, decision-makers find it imperative to seek expert judgment to refine their uncertainties pertaining to the probable likelihood of each state of nature. This necessity becomes evident when confronted with decision problems such as the one faced by a company contemplating the development of a new product (Friedman & Koller, 2003) (Table 4.10):

Table 4.10. Buying Reliable Information (Source: R. Tavakkoli, Creative Commons License)

States of Nature				
		High sales	**Med. sales**	**Low sales**
		A(0.2)	B(0.2)	C(0.3)
A1	(Develop)	3000	2000	-6000
A2	(Don't develop)	0	0	0

The probabilities associated with various states of nature reflect the level of uncertainty and subjective assessment of the decision maker (e.g., manager) regarding the probability of each state occurring. These subjective probability evaluations shall henceforth be denoted as "pr" probabilities (Lampinen & Vehtari, 2001).

The anticipated benefit of every action is:

The organization chooses option A2 due to the anticipated losses associated with A1, and subsequently decides against its development. However, the manager is hesitant to make this decision. Considering the adage "nothing ventured, nothing gained," the organization is considering engaging the services of a marketing research firm.

Through a survey, the marketing research company will determine the market potential of the product.

The manager is currently faced with a new dilemma: which marketing research firm should be approached for consultation? The manager is responsible for assessing the reliability of the consulting firm. By sampling and analyzing the consultant's previous performance, a reliability matrix can be constructed (Humphreys & Jacobs, 2015) (Table 4.11).

Table 4.11. Reliability Matrix (Source: R. Tavakkoli, Creative Commons License)

	What happened in the past?			
		A	B	C
What did the consultant predict?	Ap	0.8	0.1	0.1
	Bp	0.1	0.9	0.2
	Cp	0.1	0.0	0.7

Marketing research firms universally maintain records, also known as historical information, detailing the efficacy of their previous predictions. These records are made available without fee to their clients. To generate a reliability matrix, it is imperative to consider the marketing research firm's track record of success in delivering comparable products that achieved substantial sales. Subsequently, determine the proportion of products that the marketing analysis company accurately predicted would generate negligible sales (C), moderate sales (B), and high sales (A) (Lindley et al., 1978) (Figure 4.4).

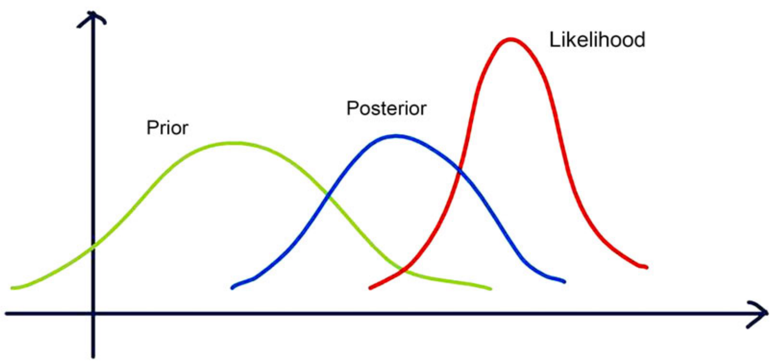

Figure 4.4. Representations of the Bayesian approach (Source: Mario, Creative Commons License)

The table displays their respective percentages as follows: P(Ap|A) = 0.8, P(Bp|A) = 0.1, and P(Cp|A) = 0.1, in the very first column. It is imperative to perform an analogous analysis to assemble the other columns of the reliability matrix. Please ensure that the sum of the values in each column of the reliability matrix above is one for the sake of consistency. Although this matrix presents conditional probabilities, such as P(Ap|A) = 0.8, the critical data required by the organization is the inverse form of said probabilities (Mockus & Mockus, 1989). What is the precise numerical value of P(A|Ap) in the given example? More precisely, what is the probability that the marketing firm's prediction that A will occur will come true? Following is an application of the Bayes Law that yields this vital information:

a. Multiply the probabilities "down" in the aforementioned matrix.
b. Compute the sum of the rows across.
c. Normalize the values (i.e., ensure that the sum of the probabilities is one) by dividing the number of each column by the sum of the row obtained in Step b.

To illustrate the procedure, note the calculation of P(A|Ap). The results are shown in the table below.

Many managerial problems, such as this example, involve a sequence of decisions.

When a decision situation requires a series of decisions, the payoff table cannot accommodate the multiple layers of decision-making. Thus, a decision tree is needed (Holder & Lewis, 2003) (Table 4.12).

Table 4.12. Bayes Law (Source: Arsham, Creative Commons License)

0.2	0.5	0.3	
A	**B**	**C**	**SUM**
02(0.8)=0.16	0.5(0.1)=0.05	0.3(0.1)=0.03	0.24
0.2(0.1)=0.02	0.5(0.9)=0.45	0.3(0.2)=0.06	0.53
0.2(0.1)=0.02	0.5(0)=0	0.3(0.7)=0.21	0.23
A	**B**	**C**	
(.16/.24)=.667	(.05/.24)=.208	(.03/.24)=.125	
(.02/.53)=.038	(0.45/.53)=.849	(.06/.53)=.113	
(.02/.23)= .087	(0/.23)=0	(0.21/.23)=.913	

4.4. DECISION TREE AND INFLUENCE DIAGRAM

Learning Objectives

- To understand the Decision Tree Approach for mapping decision pathways.
- To understand Influence Diagrams for visualizing decision problem relationships.

Influence diagrams and decision trees are influential instruments for decision analysis. A decision tree is a visual depiction that arranges decision pathways; in this case, the nodes symbolize final decisions or attribute tests, the branches represent possible outcomes, and the leaves denote decisions (Owens et al., 1997). In artificial intelligence and decision-making contexts, they are extensively implemented. Conversely, influence diagrams furnish a graphical and mathematical representation of decision-making problems through decision nodes, chance nodes representing uncertainties, and value nodes representing outcomes. The directed arcs connecting these nodes serve to depict the interconnections and reliance among various factors, thereby facilitating the structuring and comprehension of intricate decision scenarios. Both methodologies make substantial contributions to the decision-making process through the provision of lucid depictions of alternatives, uncertainties, and their consequences (Jae & Park, 1994).

4.4.1. Decision Tree Approach

The decision process is represented in chronological order by a decision tree. The network is composed of two distinct kinds of nodes: states of nature (chance) nodes, which are represented by circles, and decision (choice) nodes, which are denoted by square shapes. Construct a decision tree by applying the problem's logic. Ensure that the sum of the probabilities along each outgoing branch is one for the chance nodes. Determine the expected payoffs by performing a backward roll of the tree, commencing at the right and progressing to the left. One might envisage operating a vehicle while beginning at the base of the decision tree and traversing the branches to the right. You have one decision at each control square before turning onto the steering wheel of your vehicle (Cramer et al., 1976). At each circle, fortune assumes control of the wheel, rendering you helpless. A detailed explanation of the process for constructing a decision tree follows:

a) Construct the decision tree using squares to represent decisions and circles to represent uncertainty.
b) Evaluate the decision tree to ensure that it includes all possible outcomes.
c) Perform the tree value calculations from right to left.
d) Calculate the values of nodes representing uncertain outcomes by multiplying the

outcome values by their respective probabilities or expected values (Dey, 2002).

The value of a node on the tree can be determined by obtaining the values of every node that follows it. The value of a choice node is determined by which node immediately follows it and has the greatest value. The expected value of the nodes succeeding a given chance node is calculated by applying the probability of the arcs to that value. By regressing the tree from its branches to its root, it is possible to calculate the value of every node, including the root. Display the numerical outcomes in conjunction with the decision tree outcomes in a graphical format, as illustrated below. Determine the optimal decision for the tree by starting at its root and progressing laterally. Our decision, deduced from the preceding decision tree, is as follows (Delen et al., 2013):

- Employ the consultant and subsequently await the report provided by the consultant. Proceed with product manufacturing if the forecast indicates high or moderate sales quantities. Otherwise, the product should not be manufactured (Sahin et al., 2013).
- Determine the efficacy of the consultant by calculating the subsequent ratio:

$$\text{Consultant's Efficiency Rate} = \frac{\text{Expected payoff using consultant dollars amount}}{\text{EVPI}}$$

Using the decision tree, the expected payoff if the consultant is hired will be:

$$EP = 1000 - 500 = 500,$$

$$EVIP = 0.2(3000) + 0.5(2000) + 0.3(0) = 1600$$

Hence, the efficiency of this consultant is: 500/1600 = 31% (Fan et al., 2006) (Figure 4.5).

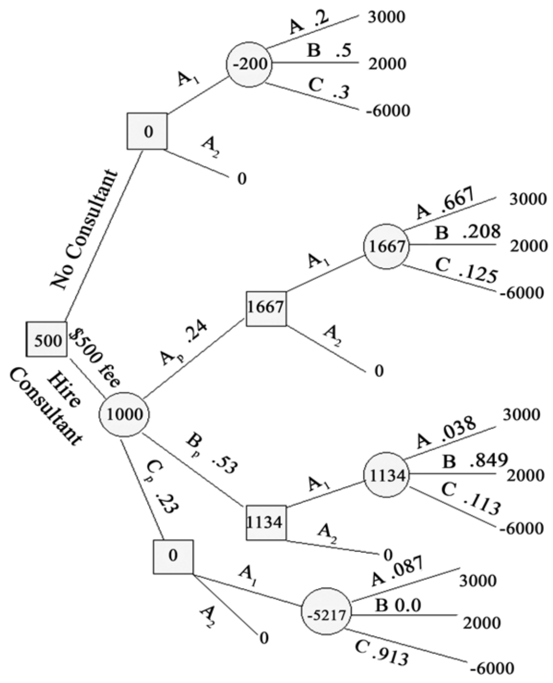

Figure 4.5. Representation of a typical decision tree (Source: R. Tavakkoli, Creative Commons License)

If the manager intends to rely solely on the recommendations provided by the marketing research firm, a flat prior probability is assigned (in contrast to the values of (0.2, 0.5, 0.3) utilized in our numerical illustration). The producer has concerns about using the decision tree to assess the risk associated with the decision (Harrison et al., 2018).

It is crucial to consider multiple consulting firms rather than relying exclusively on a single firm during the planning phase of decision-making. The risk-based decision tree is an essential tool that every consulting firm should develop to assess and compare risks before making a final determination regarding implementation (Cho & Kurup, 2011).

4.4.2. Influence Diagrams

The complexity of the branch and node descriptions in sequential decision problems is frequently evident, as demonstrated by the decision tree examples. There are times when depicting the tree in a way that maintains the relationships that influence the decision becomes extremely challenging (Pearl, 2005). The requirement to uphold validation, coupled with the frequent escalation in intricacy that results from the extensive implementation of recursive structures, combined to make it challenging to articulate the decision-making process to others (Diffenbach, 1982). The complexity arises from the fact that the computational mechanism employed to evaluate the tree is physically implemented within the branches and trees. At each node, the probabilities and values necessary for computing the expected result of the subsequent branch are specified explicitly. In addition to serving as an alternative visual depiction of decision trees, influence diagrams are also used in the design of decision models. Regarding our numerical example, the influence diagram is illustrated in the Figure 4.6 (Tatman & Shachter, 1990). The influence diagram presented above employs squares and circles to represent the decision nodes and chance nodes, respectively. Probabilistic relationships are implied by arcs (arrows). Ultimately, decision trees and influence diagrams serve as effective decision-making tools due to the following reasons (Bielza et al., 2011):

i. Articulate the problem precisely to facilitate a comprehensive examination of all available options.

ii. Enable a thorough analysis of potential decision outcomes, allowing for a detailed understanding of the consequences.

iii. Provide a structured framework for quantifying the values associated with various outcomes and the probabilities associated with their realization.

iv. Facilitate informed decision-making by leveraging existing information and informed estimations, thereby aiding in the identification of optimal choices.

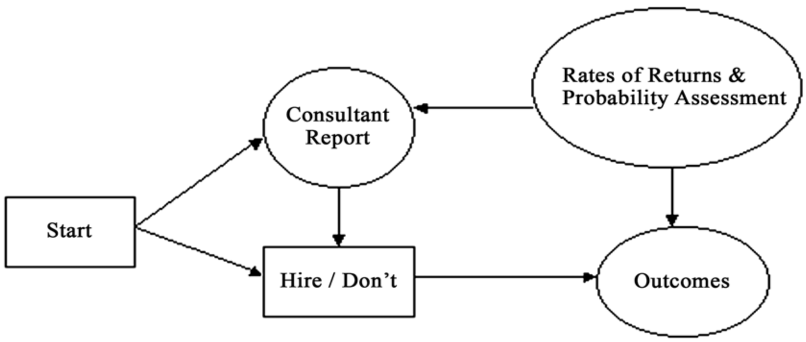

Figure 4.6. Influence diagram for the numerical example (Source: R. Tavakkoli, Creative Commons License)

PRACTICE PROBLEM

The aim of a marketing manager is to ascertain whether to introduce a fresh product line into a highly competitive market. With regards to consumer preferences and the level of competition, the manager is unsure. Analyze the sources of mistakes that may arise during the decision-making process when confronted with pure uncertainty, and suggest methods to mitigate these errors.

SOLUTIONS TO PRACTICE PROBLEM

Sources of inaccuracies in decision-making under absolute uncertainty in this scenario may encompass inadequate information on consumer preferences, unforeseeable market dynamics, and ambiguity regarding competitor actions. To alleviate these inaccuracies, the manager could carry out comprehensive market research, collect consumer feedback through surveys, and analyze competitors' strategies. Furthermore, employing scenario analysis and sensitivity analysis can assist the manager in comprehending potential outcomes and uncertainties, thereby providing a more knowledgeable foundation for decision-making.

SUMMARY

- The majority of individuals make decisions based on habit or tradition, rather than systematically following the steps of the decision-making process. Instances where peer pressure or time constraints impede a thorough evaluation of the alternatives and their repercussions may influence decision-making. When a decision is being made, an individual's emotional state may exert an influence on that decision.
- Individuals who are deficient in knowledge or abilities may arrive at suboptimal conclusions. Despite the availability of time and information, individuals frequently fail to adequately comprehend the probabilities associated with potential outcomes.
- Despite being informed of statistical data, individuals are more inclined to place trust in personal experience rather than probabilistic information. The crux of decision-making resides in the integration of probabilistic information with data about desires and interests.
- This chapter described the process of decision analysis for both public and private sectors, taking into account various information types, qualities, and criteria. The fundamental components of decision alternative and choice analysis were delineated, along with the guiding principles and objectives of the decision-making process.
- A concise introduction to the stages of the methods under discussion is provided at the outset of each section. This tutorial has been crafted using straightforward literature to assist managers in comprehending decision-making concepts and executing more effective decisions under uncertain circumstances; doing so will provide them with a fresh perspective.

MULTIPLE CHOICE QUESTIONS

1. **What characterizes the continuum between pure uncertainty and certainty in decision-making?**
   a. Absolute certainty
   b. Ambiguity
   c. Risk
   d. Randomness
2. **In Decision Making Under Pure Uncertainty, what are the potential sources of errors in decision-making?**
   a. Limited information
   b. Unpredictable market dynamics
   c. Uncertain competitor actions
   d. All of the above

3. What is the Laplace Equal Likelihood Principle used for in Decision Making Under Risk?
   a. Calculating expected payoffs
   b. Assessing opportunity loss
   c. Equal probability assignment
   d. Bayesian probability analysis

4. What does the Expected Value of Perfect Information (EVPI) represent in Decision Making Under Risk?
   a. The value of having perfect information
   b. The expected payoff of a decision without perfect information
   c. The likelihood of making the right decision
   d. The Laplace principle

5. In a Decision Tree Approach, what does a decision node represent?
   a. Uncertain events
   b. Outcomes
   c. Decision points
   d. Probability distributions

REVIEW QUESTIONS

1. What is the continuum between pure uncertainty and certainty in decision-making, and how does it impact decision analysis?
2. Identify and explain three potential sources of errors in decision-making under pure uncertainty.
3. Define Expected Payoff in the context of decision-making under risk. Provide a practical example to illustrate its computation.
4. What is the Laplace Equal Likelihood Principle, and how is it used in decision-making under risk?
5. Explain the concept of Expected Value of Perfect Information (EVPI) and discuss its relevance in decision-making under risk.

Answers to Multiple Questions

1. (b) 2. (d) 3. (c) 4. (a) 5. (c)

REFERENCES

1. Abrahamsson, M., (2002). *Uncertainty in Quantitative Risk Analysis-Characterization and Methods of Treatment* (Vol. 1, pp. 8–70). Univ.

2. Afek, Y., Mansour, Y., & Ostfeld, Z., (1996). Convergence complexity of optimistic rate based flow control algorithms. In: *Proceedings of the Twenty-Eighth Annual ACM Symposium on Theory of Computing* (Vol. 1, pp. 89–98).
3. Agarwal, S., Pandey, G. N., & Tiwari, M. D., (2012). Data mining in education: Data classification and decision tree approach. *International Journal of e-Education, e-Business, e-Management and e-Learning, 2*(2), 140.
4. Alleva, B. J., (2015). Minimizing the risk of opportunity loss in the social security claiming decision. *The Journal of Retirement, 3*(1), 67–86.
5. Antuori, V., & Richoux, F., (2019). Constrained optimization under uncertainty for decision-making problems: Application to real-time strategy games. In: *2019 IEEE Congress on Evolutionary Computation (CEC)* (Vol. 2, pp. 458–465). IEEE.
6. Aven, T., (2010). Some reflections on uncertainty analysis and management. *Reliability Engineering & System Safety, 95*(3), 195–201.
7. Bielza, C., Gómez, M., & Shenoy, P. P., (2011). A review of representation issues and modeling challenges with influence diagrams. *Omega, 39*(3), 227–241.
8. Canessa, S., Guillera-Arroita, G., Lahoz-Monfort, J. J., Southwell, D. M., Armstrong, D. P., Chadès, I., & Converse, S. J., (2015). When do we need more data? A primer on calculating the value of information for applied ecologists. *Methods in Ecology and Evolution, 6*(10), 1219–1228.
9. Chick, S. E., & Wu, Y., (2005). Selection procedures with frequentist expected opportunity cost bounds. *Operations Research, 53*(5), 867–878.
10. Cho, J. H., & Kurup, P. U., (2011). Decision tree approach for classification and dimensionality reduction of electronic nose data. *Sensors and Actuators B: Chemical, 160*(1), 542–548.
11. Christopoulos, G. I., Tobler, P. N., Bossaerts, P., Dolan, R. J., & Schultz, W., (2009). Neural correlates of value, risk, and risk aversion contributing to decision making under risk. *Journal of Neuroscience, 29*(40), 12574–12583.
12. Cramer, G. M., Ford, R. A., & Hall, R. L., (1976). Estimation of toxic hazard—A decision tree approach. *Food and Cosmetics Toxicology, 16*(3), 255–276.
13. Davis, D., Duckstein, L., & Szidarovszky, F., (1985). Opportunity losses due to uncertainty in multiobjective decision problems. *Applied Mathematics and Computation, 17*(1), 69–91.
14. Delen, D., Kuzey, C., & Uyar, A., (2013). Measuring firm performance using financial ratios: A decision tree approach. *Expert Systems with Applications, 40*(10), 3970–3983.
15. Dey, P. K., (2002). Project risk management: A combined analytic hierarchy process and decision tree approach. *Cost Engineering, 44*(3), 13–27.
16. Diffenbach, J., (1982). Influence diagrams for complex strategic issues. *Strategic Management Journal, 3*(2), 133–146.
17. Dörner, D., & Schaub, H., (1994). Errors in planning and decision-making and the nature of human information processing. *Applied Psychology, 43*(4), 433–453.
18. Ezrow, L., Homola, J., & Tavits, M., (2014). When extremism pays: Policy positions,

voter certainty, and party support in postcommunist Europe. *The Journal of Politics, 76*(2), 535–547.

19. Fan, G. Z., Ong, S. E., & Koh, H. C., (2006). Determinants of house price: A decision tree approach. *Urban Studies, 43*(12), 2301–2315.
20. Flage, R., Aven, T., Zio, E., & Baraldi, P., (2014). Concerns, challenges, and directions of development for the issue of representing uncertainty in risk assessment. *Risk Analysis, 34*(7), 1196–1207.
21. Friedman, N., & Koller, D., (2003). Being Bayesian about network structure. A Bayesian approach to structure discovery in Bayesian networks. *Machine Learning, 50*, 95–125.
22. Fu, Y., Sui, Y., Luo, H., & Han, B., (2020). Application of social choice theory to modify the value measure of health systems. *Social Indicators Research, 148*, 1005–1019.
23. Gilboa, I., & Schmeidler, D., (1989). Maxmin expected utility with non-unique prior. *Journal of Mathematical Economics, 18*(2), 141–153.
24. Harrison, P. A., Dunford, R., Barton, D. N., Kelemen, E., Martín-López, B., Norton, L., & Zulian, G., (2018). Selecting methods for ecosystem service assessment: A decision tree approach. *Ecosystem Services, 29*, 481–498.
25. Hoffman, F. O., & Hammonds, J. S., (1994). Propagation of uncertainty in risk assessments: The need to distinguish between uncertainty due to lack of knowledge and uncertainty due to variability. *Risk Analysis, 14*(5), 707–712.
26. Holder, M., & Lewis, P. O., (2003). Phylogeny estimation: Traditional and Bayesian approaches. *Nature Reviews Genetics, 4*(4), 275–284.
27. Humphreys, M., & Jacobs, A. M., (2015). Mixing methods: A Bayesian approach. *American Political Science Review, 109*(4), 653–673.
28. Jae, M., & Park, C. K., (1994). On the tools of decision trees and influence diagrams for assessing severe accident management strategies. *Nuclear Engineering and Technology, 26*(2), 168–178.
29. Johnson, D. D., Blumstein, D. T., Fowler, J. H., & Haselton, M. G., (2013). The evolution of error: Error management, cognitive constraints, and adaptive decision-making biases. *Trends in Ecology & Evolution, 28*(8), 474–481.
30. Kay, J. A., (2023). The limitations of growth-optimal approaches to decision making under uncertainty. *Econ Journal Watch, 20*(2), 314.
31. Kunreuther, H., (2002). Risk analysis and risk management in an uncertain world 1. *Risk Analysis: An International Journal, 22*(4), 655–664.
32. Lampinen, J., & Vehtari, A., (2001). Bayesian approach for neural networks—Review and case studies. *Neural Networks, 14*(3), 257–274.
33. Lee, C. C., Mower, E., Busso, C., Lee, S., & Narayanan, S., (2011). Emotion recognition using a hierarchical binary decision tree approach. *Speech Communication, 53*(9, 10), 1162–1171.
34. Lianwen, N. Z., Qi, R., & Poole, D., (1993). Incremental computation of the value of perfect information in stepwise-decomposable influence diagrams. In: *Uncertainty in Artificial Intelligence* (Vol. 2, pp. 400–407). Morgan Kaufmann.

35. Liu, F., & Ma, N., (2019). Multicriteria ABC inventory classification using the social choice theory. *Sustainability, 12*(1), 182.

36. Mabel, O. A., & Olayemi, O. S., (2020). A comparison of principal component analysis, maximum likelihood, and the principal axis in factor analysis. *American Journal of Mathematics and Statistics, 10*(2), 44–54.

37. Mishra, S., (2014). Decision-making under risk: Integrating perspectives from biology, economics, and psychology. *Personality and Social Psychology Review, 18*(3), 280–307.

38. Mockus, J., & Mockus, J., (1989). *The Bayesian Approach to Local Optimization* (Vol. 2, pp. 125–156). Springer Netherlands.

39. Mukerji, S., & Tallon, J. M., (2004). An overview of economic applications of David Schmeidler's models of decision making under uncertainty. *Uncertainty in Economic Theory, 13*, 283–285.

40. Nilsen, T., & Aven, T., (2003). Models and model uncertainty in the context of risk analysis. *Reliability Engineering & System Safety, 79*(3), 309–317.

41. Owens, D. K., Shachter, R. D., & Nease, Jr. R. F., (1997). Representation and analysis of medical decision problems with influence diagrams. *Medical Decision Making, 17*(3), 241–262.

42. Pearl, J., (2005). Influence diagrams—Historical and personal perspectives. *Decision Analysis, 2*(4), 232–234.

43. Post, T., Van, D. A. M. J., Baltussen, G., & Thaler, R. H., (2008). Deal or no deal? decision making under risk in a large-payoff game show. *American Economic Review, 98*(1), 38–71.

44. Rubin, V. L., (2010). Epistemic modality: From uncertainty to certainty in the context of information seeking as interactions with texts. *Information Processing & Management, 46*(5), 533–540.

45. Sahin, Y., Bulkan, S., & Duman, E., (2013). A cost-sensitive decision tree approach for fraud detection. *Expert Systems with Applications, 40*(15), 5916–5923.

46. Shachter, R. D., (1988). Probabilistic inference and influence diagrams. *Operations Research, 36*(4), 589–604.

47. Su, H. T., & Tung, Y. K., (2012). Minimax expected opportunity loss: A new criterion for risk-based decision making. *The Engineering Economist, 57*(4), 247–273.

48. Suslick, S. B., Schiozer, D., & Rodriguez, M. R., (2009). Uncertainty and risk analysis in petroleum exploration and production. *Terrae, 6*(1), 30–41.

49. Syed, Z., Shabarchin, O., & Lawryshyn, Y., (2020). A novel tool for Bayesian reliability analysis using AHP as a framework for prior elicitation. *Journal of Loss Prevention in the Process Industries, 64*, 104024.

50. Taghavifard, M. T., Damghani, K. K., & Moghaddam, R. T., (2009). Decision making under uncertain and risky situations. *Society of Actuaries,* 7(4), 1–31.

51. Tatman, J. A., & Shachter, R. D., (1990). Dynamic programming and influence diagrams. *IEEE Transactions on Systems, Man, and Cybernetics, 20*(2), 365–379.

52. Watson, H. J., Goodhue, D. L., & Wixom, B. H., (2002). The benefits of data warehousing: Why some organizations realize exceptional payoffs. *Information & Management, 39*(6), 491–502.

53. Wöss, H., (2020). Damages and loss of a chance or loss of opportunity. *New York Dispute Resolution Lawyer, 13*(1), 33–35.

54. Yang, H., Iida, Y., & Sasaki, T., (1991). An analysis of the reliability of an origin-destination trip matrix estimated from traffic counts. *Transportation Research Part B: Methodological, 25*(5), 351–363.

55. Zare, M. H., Özaltın, O. Y., & Prokopyev, O. A., (2018). On a class of bilevel linear mixed-integer programs in adversarial settings. *Journal of Global Optimization, 71*(1), 91–113.

CHAPTER

5

Objectives and Criteria for Decision Problem

LEARNING OBJECTIVES

After studying this chapter, you will be able to:

- Understand the decision context and its significance in the decision-making process.
- Identify and define decision objectives, incorporating the criteria of completeness, non-redundancy, conciseness, specificity, and understandability.
- Recognize challenges associated with generating objectives in decision problems.
- Explore various methods for effectively generating objectives in decision analysis.
- Apply the concept of objectives to real-world context through an example in environmental management.

INTRODUCTORY EXAMPLE

Imagine a city planning committee faced with a critical decision – the selection of a sustainable public transportation system. The decision context involves considerations such as environmental impact, cost-effectiveness, and community accessibility. In navigating this complex decision, the chapter unfolds the importance of clearly defined objectives and criteria. These objectives, ranging from minimizing carbon emissions to optimizing commuter convenience, serve as guiding principles for the committee. The criteria for effective decision problem formulation become evident as decision-makers strive for a comprehensive, non-redundant, concise, specific, and understandable set of objectives. The example illustrates how a well-structured decision problem, centered on clear objectives, is essential in steering the committee toward informed and impactful choices in the realm of urban transportation planning.

UNIT INTRODUCTION

An objective is a justification for favoring one alternative over another. There can be no decision when the values are absent, and all alternatives are considered equal. According to Keeney, values should be given priority over accessible alternatives, as they are more important in decision-making. By considering values, one can understand the structure of the decision in relation to the decision-maker's objective. Subsequently, one can determine if these goals are essential to the current decision or merely a means to an end (Hwang & Masud, 2012).

Clemen defines an objective as "a specific thing that individuals want to achieve." An objective can be expressed as a verb that indicates the desired direction for improving the quality of the alternative, along with a noun that characterizes its quality. For instance, in many business decisions, the potential monetary gains from a certain alternative are valued, and the aim is to optimize these gains. In this case, profit represents the quality of the alternative, while maximize indicates the preferred direction (Ballestero et al., 1998).

Ultimately, one may want to achieve objectives by carefully selecting the optimal course of action or alternative. It is necessary to carefully evaluate the range of alternatives and make distinctions between them in order to determine the best option.

According to Xu & Yang (2001), Leon identifies five benefits of choosing among options using a comprehensive set of objectives:

i. Consideration of more innovative alternatives.
ii. Consideration of a wide range of alternatives.
iii. Decision-making with long-term effects in mind.
iv. Integration of alternatives that may not have been initially considered.
v. Consideration of more favorable outcomes.

This chapter examines the ability of decision makers to formulate a comprehensive set of objectives and offers suggestions for enhancing the process (Carlsson &Fullér, 1995).

5.1. THE DECISION CONTEXT

Learning Objectives

- Understand the impact of external factors on decision outcomes within a given context.
- To apply knowledge of decision context to enhance strategic decision-making in diverse scenarios.

Keeney employs the concept of a decision context to clarify the decisions individuals make. A decision context encompasses the available alternatives and the objectives that a decision maker seeks to accomplish during the decision process. The objectives can be classified into three categories: means, fundamental, and strategic. A means objective is a method or strategy used to accomplish another objective. A fundamental objective refers to an objective that guides the decision maker's choice in a certain decision environment. A strategic objective represents the long-term aspirations of a decision maker's organization. Numerous decisions made inside an organization might impact the achievement of a strategic target. According to Keeney, a frequent error in making trade-offs between alternatives is a failure to fully comprehend the decision context (Gorddard et al., 2016) (Figure 5.1).

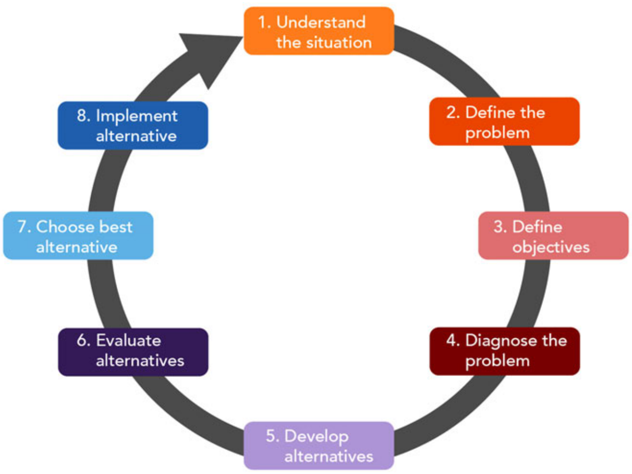

Figure 5.1. Diagram of decision-making process (Source: Lumen, Creative Commons License)

The specific objectives we aim to achieve can vary based on the contextual framework of the decision at hand. Take, for instance, the decision to purchase a car. Initially, the primary objectives may involve minimizing the upfront purchase cost and reducing monthly fuel expenses. However, when broadening the decision scope to encompass the daily commute to work, the array of alternatives expands to include various cars, routes, and transportation modes like public transit and carpooling. In this broader context, the focal objective shifts towards minimizing overall monthly commuting costs (Shepherd & Rudd, 2014).

An essential consideration is determining whose values and perspectives should be considered. Using the example of a public utility company, Keeney illustrates the divergent objectives of minimizing electricity costs for ratepayers and maximizing returns for company shareholders. When faced with alternatives that present a trade-off between low cost and low return versus high cost and high return, understanding whose viewpoint is being considered becomes crucial. Ratepayers may favor the former, shareholders the latter, and the public utility commission might seek a compromise between the two (Das & Teng, 2001).

The timeline of the decision is also a pivotal factor to grasp. Consider a scenario where one is choosing between two job offers, with the key objectives being to maximize salary and minimize weekly working hours. Opting for a job with a high salary but demanding 80 hours of work per week may be acceptable if it is for a limited duration, such as during a doctor's residency or the early stages of legal or management consulting careers (Das & Teng, 2001). However, the same choice may be less appealing if there is no endpoint to the extended working hours. The temporal aspect significantly influences the desirability of certain decision outcomes (Simon & Houghton, 2002).

Did you know?

The formalization of setting objectives and criteria in decision problems has roots in ancient philosophical discourse. Thinkers like Aristotle explored the foundations of decision-making, laying the groundwork for contemporary decision analysis.

5.2. DECISION OBJECTIVES

Learning Objectives

- To understand objectives and their fundamental role in guiding the decision-making process.
- To apply the principles of decision objectives to construct well-defined and impactful goals within a given decision context.

Keeney proposes five criteria for a good set of objectives:

i. Completeness

ii. No redundancy

iii. Conciseness

iv. Specificity

v. Understandability

The set of objectives in decision-making must be comprehensive, ensuring that all relevant aspects of the problem are considered. Failure to include a crucial objective may lead to selecting the wrong alternative or overlooking potential consequences. For instance, when purchasing a car, considering factors like purchase cost, ongoing expenses, visual appeal, reliability, drivability, and cargo space while omitting comfort could result in an incomplete assessment (Chatterjee et al., 2006).

Avoiding redundant objectives is imperative to prevent double counting the benefits of an alternative. For example, in the context of the car-buying decision, including both “maximize miles per gallon” and “minimize monthly fuel cost” as objectives may overlap. Instead, objectives should be refined to capture distinct aspects, such as “maximize miles per gallon” alongside “minimize price per gallon of fuel required” or simply “minimize monthly fuel cost” (Colson & De Bruyn, 1989).

Conciseness is crucial, as a large set of objectives may lead to decision-making paralysis. It is essential that each objective is measurable or allows for meaningful comparison among alternatives. Objectives should be specific and clear to eliminate ambiguity in their evaluation. While some objectives, like “maximize aesthetic appeal” or “minimize pain level,” may be challenging to measure directly, efforts should be made to define and quantify them appropriately (Roijers et al., 2013).

Furthermore, the set of objectives should be decomposable, enabling the assessment of each part independently. This decomposition simplifies the judgment task and enhances the evaluation of alternatives. For example, in choosing a hotel room, the ability to evaluate comfort and room size separately contributes to a more nuanced and effective decision-making process. This concept is further explained in the article titled "Problem Structuring for Multicriteria Decision Analysis Intervention" in this encyclopedia (Siebert & Keeney, 2015).

5.2.1. Completeness

When it comes to choosing a set of objectives for decision problems, completeness guarantees that the selected set of objectives fully considers all pertinent aspects of the current decision. This criterion necessitates a thorough analysis of the decision space, considering all relevant variables. A comprehensive set of objectives establishes the foundation for a strong decision analysis, allowing decision-makers to consider all relevant factors and possible consequences (Leung, 2008).

Remember

Precise goals and criteria play a crucial role in shaping significant public policies. Governments and international organizations employ structured decision analysis to tackle intricate matters such as climate change, showcasing the tangible effects of clearly defined objectives.

5.2.2. Non-redundancy

The requirement that each objective provides distinct and important information to the decision-making process is emphasized by the criterion of no redundancy. Confusion and inefficiency can result from redundant objectives, or those that transmit similar information. Ensuring that every objective offers unique perspectives or factors to consider allows decision-makers to maximize resource utilization and expedite their analytical processes (Tan & Lim, 2019).

5.2.3. Conciseness

The objectives must be stated in a brief manner to be concise. It is essential to use plain language to prevent misunderstandings and confusion. Decision-makers can concentrate on the essential components of the decision problem with the help of concise objectives, which encourage effective analysis and avoid unnecessary complications that might obstruct the decision-making process (Marttunen et al., 2019).

5.2.4. Specificity

To ensure specificity in objective-setting, every target must be well-defined and unambiguous. Clearly defined objectives give decision-makers a clear path to follow when analyzing and assessing options. Specific objectives remove uncertainty and guarantee that all parties involved understand the objectives, which promotes better decision-making (Geers, 2010).

5.2.5. Understandability

The understandability criterion emphasizes the importance of communicating objectives in a manner that all parties involved in the decision-making process can comprehend. Decision-makers can enhance their communication effectiveness and establish a shared understanding of priorities and objectives by having a clear set of objectives. Clear communication fosters teamwork and ensures that diverse perspectives can make a meaningful contribution to the decision-making process (Kaya, 2010).

Keyword

Redundancy: It refers to the inclusion of unnecessary or repetitive elements within a system, process, or set of information. In decision analysis, redundancy can manifest when there are overlapping or duplicate components, criteria, or objectives that do not contribute distinct value to the decision-making process. Avoiding redundancy is important in optimizing decision efficiency, as it ensures that each element serves a unique purpose, preventing unnecessary complexity and facilitating a more streamlined and focused analysis. In essence, eliminating redundancy enhances the clarity and effectiveness of decision models and frameworks.

5.3. PROBLEMS WITH GENERATING OBJECTIVES

Learning Objectives

- To understand common challenges associated with the process of generating objectives in decision analysis.
- To analyze how problems in generating objectives can impact the clarity and effectiveness of decision-making.

The process of determining decision maker objectives in a given context often involves interviews with decision makers and stakeholders. However, Bond et al. highlight a challenge wherein decision makers may struggle to articulate their objectives effectively. Decision makers tend to simplify their environment, offering objectives cued by an incomplete mental representation of the situation (Jozefowiez et al., 2008). To investigate this phenomenon, Bond et al. conducted three studies. In each study, participants were asked to generate a list of objectives for a specified decision context. Subsequently, they were provided with a pregenerated list of objectives, considered complete, and asked to identify which objectives they deemed important. Participants were then categorized into two groups: those who recognized objectives from the provided list (recognized objectives) and those who had already generated the same objectives before seeing the list (self-generated objectives). The participants then assessed the importance of all identified objectives (Stewart et al., 2021). The results revealed a consistent pattern across experiments. While participants generated their own objectives, a significant number of important objectives were not self-generated. Interestingly, the importance ratings for self-generated objectives were higher than those for recognized objectives. However, the practical difference in importance was not substantial (Ishibuchi et al., 2014). A real-world case study involving a professional elicitation for Seagate Software supported these findings. Decision makers did not autonomously generate a complete list of objectives. The analysis of this case study, alongside the experimental results, emphasized that decision makers may lack depth in thinking about certain categories of objectives while concentrating on others, indicating an anchoring effect within a subset of possible categories (Aubert et al., 2022). Additionally, Leon conducted a study comparing decision makers' ability to generate objectives when focusing on specific alternatives versus when focusing on values and objectives. Results showed that the value-focused group, guided by a set of value-focused questions, generated a larger and more comprehensive set of objectives organized hierarchically compared to the alternative-focused group (Abbass et al., 2001) (Figure 5.2).

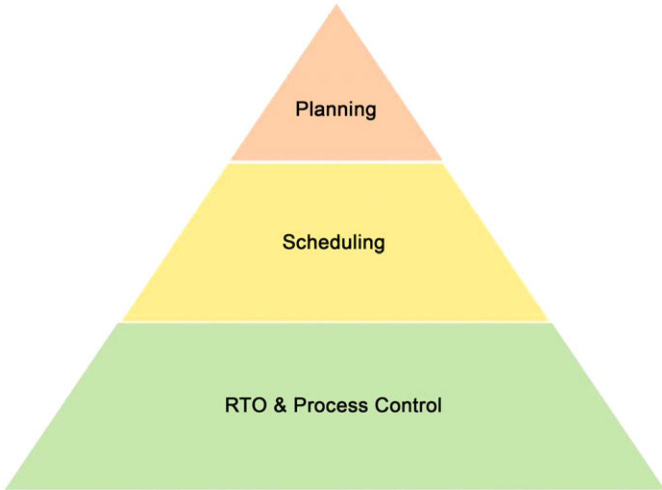

Figure 5.2. Representation of decision-making hierarchy (Source: Lisia, Creative Commons License)

Leon requested a new group of thirty decision makers to evaluate the two representative hierarchies from the first study in a follow-up investigation. The second group of participants evaluated which of the two hierarchies fulfilled the five requirements for a practical hierarchy. The outcomes supported the value-focused hierarchy statistically significantly in each instance. Additionally, the two hierarchies were rated by the 30 decision makers based on their completeness, operationalize, conciseness, and understandability. Except for conciseness, where the results were not statistically significant in either direction, the results were statistically significantly in favor of the value-focused hierarchy (Erol & Ferrell, 2003).

5.4. METHODS FOR GENERATING OBJECTIVES

Learning Objectives

- To understand various methods employed in generating objectives for decision analysis.
- To evaluate the strengths and limitations of different objective-generation techniques.

Keeney offers the following list of devices to use in generating objectives:

i. A wish list: What are your desires? What do you value? What should you desire?
ii. Alternatives: What is the ideal alternative, the worst alternative, or any logical alternative? What are the good and bad aspects of each?
iii. Problems and Shortcomings: What aspects of your company are in good or bad shape? What needs to be fixed?
iv. Consequences: What good or unpleasant things have happened recently? What matters to you that might happen?
v. Goals, Constraints, and Guidelines: What goals do you have? What restrictions are imposed on you?
vi. Different Perspectives: What worries would your constituents or your rivals have? When such a moment comes, what would worry you?
vii. Strategic Objectives: What are your ultimate goals? Which core principles do you hold significant?
viii. Generic Objectives: What goals do you have for yourself, your shareholders, your staff, and your customers? Which goals - environmental, social, economic, or safety and health - are crucial?
ix. Structuring Objectives: Observe relationships between means and ends: why is that goal essential, and how can you get there? Give specifics: explain what you mean by this goal.
x. Quantifying Objectives: How would you assess whether this goal has been met? Why is goal A three times more crucial than goal B (Lobo & Arthur, 2005)? (Figure 5.3).

Figure 5.3. Diagram of how to select best alternative for an effective decision making (Source: Ken, Creative Commons License)

To understand the advantages of adhering to this list, let's examine a facilitation conducted by the author. The aim of the facilitator was to understand the decision-maker's objective in an oil shipping corporation regarding safety performance. A summary of the methods employed by participants in their interviews will be provided (Marler & Arora, 2005).

i. **A Wish List**. A comparative study was conducted by asking a group of crew members from different boats what qualities they look for in a new crew and what they would describe as a fully functioning vessel and crew. The crew described a flawless crew and vessel, and the group looked at the characteristics they thought best represented such a vessel. They also looked at a vessel and crew that were particularly dangerous (Davydenko & Peetz, 2020).

ii. **Alternatives.** A group questioned the crew members regarding the ships they had worked on and the crews they had come from, asking what they liked and did not like about them. The crew members discussed their experiences working with different crews, both good and poor, and what variables influenced their performance (Alencar et al., 2017) (Figure 5.4).

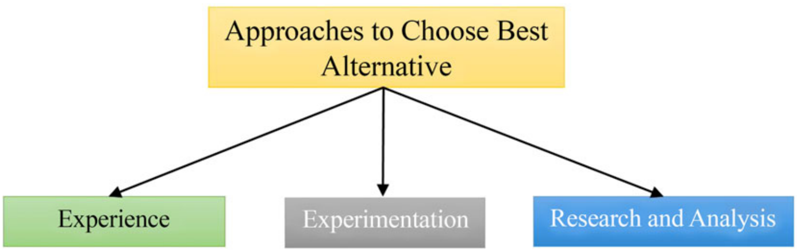

Figure 5.4. Representation of how to choose best alternative (Source: Vandy, Creative Commons License)

iii. **Problems and Shortcomings**. A group discussed several issues they encountered and how to prevent them (Dahooie et al., 2019).

iv. **Consequences.** The group inquired about any mishaps or near misses that occurred on the ships they were assigned to, as well as what could have been done to prevent these incidents.

v. **Goals, Constraints, and Guidelines.** They evaluated the company's safety protocols and federal and international safety laws to determine the goals they provide as minimal requirements (Hannan et al., 2020).

vi. **Different Perspectives.** In their interviews, the group included members of the engineering, deck, and bridge crews. They comprised shore side managers and vessel inspectors in addition to senior and subordinate staff.

vii. **Strategic Objectives.** This involves determining how to reduce mishaps, near misses, mistakes made by individuals, mechanical issues, and other previous incidents (Schaefer et al., 2021).

viii. **Generic Objectives**. They took into fundamental consideration the company's goal statement and other general principles (Kristina et al., 2004).

ix. **Structuring Objectives**. The group followed the chains of means-ends interactions to generate further objectives after considering each objective and its purpose. Discussions about training often emerged, as training is a tool for improving performance. They examined various training initiatives and their goals (Smith & Shaw, 2019).

x. **Quantifying Objectives**. To further define each target, the group discussed how to quantify them. They also considered the data they had gathered and the metrics they had used to measure the targets (Wilke et al., 2019) (Figure 5.5).

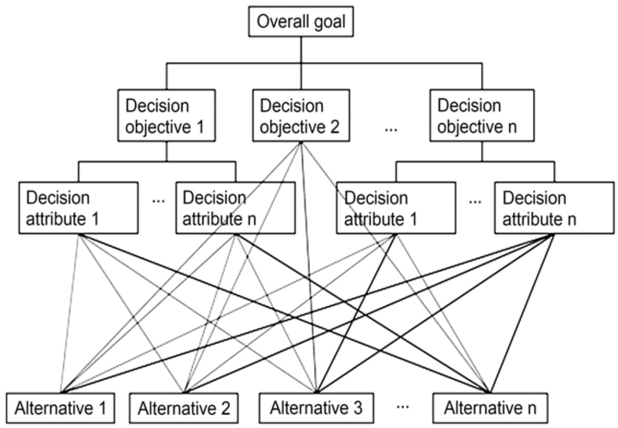

Figure 5.5. Diagram of decision problems multi-criteria (Source: Annika, Creative Commons License)

To assist decision makers in identifying their objectives, Leon provides a list of questions. Upon closer examination, it is clear how the questions relate to the above-mentioned list of gadgets.

i. What are your desired outcomes?

ii. What needs that are currently unmet would be met?

iii. After obtaining it, what are the desired outcomes of using and enjoying it?

iv. What are the unfavorable results?

v. What limitations apply to obtaining it?

vi. Which option, if there were no constraints, would you pick? What quality makes it the option you would select?

vii. Which option, and why, would you not choose?

viii. What factors do you believe need to be considered when making the decision?

ix. Among the options that come to mind, which distinctions stand out the most?

x. If you had to conduct a study from the user's perspective and ensure their pleasure, what factors would you consider?

Interviews with decision makers are often considered the "Platinum Standard" for formulating objectives, as highlighted by Parnell et al. However, alternative methods, categorized by their influence and involvement levels, include deriving objectives from approved documentation like vision, policy, or strategy (referred to as the "Gold Standard") and conducting interviews with individuals who inform or assist the decision maker (known as the "Silver Standard"). These approaches are also applicable when examining literature for objectives or interviewing those providing decision support without making the final decision (Sharma & Gupta, 1995).

Bond et al. conducted experiments to evaluate techniques for enhancing the breadth and depth of objective generation. The first two experiments focused on generating objectives for writing a dissertation or choosing an MBA program. Interventions in the second session aimed at expanding the list included providing category cues or requesting a specific number of additional objectives. The third experiment, centered on generating objectives for selecting an internship, incorporated a second session with interventions.

The results yielded valuable insights. Providing example objectives in the second experiment anchored subjects and impeded objective generation. Category cues, when provided immediately, were ineffective, but they proved beneficial when used in a second session aimed at expanding the list.

Requesting a specific number of additional objectives was effective in the third experiment, whereas a general request for more objectives was not. Moreover, stating that subjects could generally add more objectives set an expectation that subjects actively sought to fulfill (Gu et al., 2015).

5.5. AN EXAMPLE FROM ENVIRONMENTAL MANAGEMENT

Learning Objectives

- To understand the application of decision objectives in a real-world context, specifically within the field of environmental management.
- To connect theoretical knowledge of decision objectives to practical decision-making challenges in environmental scenarios.

For the Upham Brook Watershed, a set of objectives was created to demonstrate how this method can be utilized to address a complex environmental management issue. The development of the model involved an interdisciplinary team consisting of faculty members and graduate students from Virginia Commonwealth University, along with support from a hydrologist from the U.S. Geological Survey (USGS), a water quality regulator from the DEQ, a community organizer, and a wetlands specialist. Over a period of eight months, the team convened every two weeks for two-hour meetings. Despite the team's considerable expertise, they were not considered stakeholders (Khalili & Duecker, 2013) (Figure 5.6). Every member of the multidisciplinary team listed 10–15 action verbs and nouns that indicate objectives for enhancing the watershed's quality on a post-it note. To create an affinity diagram and ascertain the group's objectives, related objectives were grouped together. Throughout the session, Keene's ten devices from the previous section were employed to help each person come up with as many goals as they could (Janssen, 2012). Upon reviewing the developed objectives, the interdisciplinary team observed that certain objectives were merely means to an end, leading to the accomplishment of other primary objectives. "Increase citizen participation in watershed improvement" is one such initiative. Increasing participation does not directly improve the watershed's quality, even though certain actions, like clearing obstructions from streams and cleaning up the banks, can. These objectives were taken out of the value hierarchy but kept in reserve in case they were needed to discover other options for making decisions later. After that, the fundamental objectives were arranged in a value hierarchy (Gregory et al., 2006).Determining the project's overarching goal is the first stage in the procedure. Aim for "Maximize the quality of the Upham Brook Watershed's as the overarching goal. This situation necessitates a broad decision context. Creating a collection of objectives that expand on the meaning of the overall goal is the second stage in the process (Munda et al., 1994).

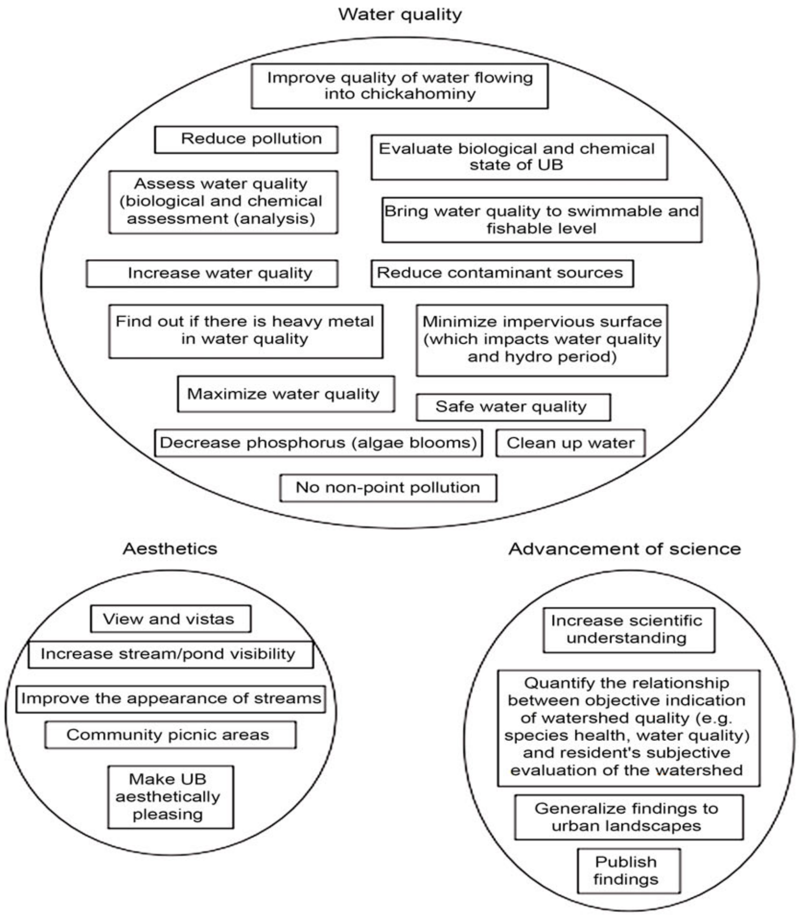

Figure 5.6. Illustration of initial groups of objectives (Source: Jason, Creative Commons License)

To do this, the group first eliminated redundancy from the fundamental objectives by sorting through them. Next, using the affinity diagram, they identified which higher-level objective each combination of fundamental objectives represented. The overarching goal is defined by the collection of higher-level objectives. Although they were not required in our application, other layers in the value hierarchy can be used (Lahdelma et al., 2000).

The group members were taken aback by the depth of thought required for this procedure and the numerous challenges to their own mental models posed by the members' varied backgrounds (Polasky et al., 2011). The value hierarchy took nine two-hour meetings to construct. The hierarchy underwent multiple iterations as the committee worked to define what constitutes a high-quality watershed. The final value hierarchy was created after the original hierarchy was revised. One way to conceptualize the interdisciplinary team's idea of watershed quality is through the value hierarchy (Kiker et al., 2005).

The hierarchy separates a watershed's quality goals into two categories: enhancing the habitat quality for wildlife and enhancing the habitat quality for humans. Each of the five objectives for the wildlife habitat corresponds to a kind of wildlife species that may be found in the Upham Book Watershed. Below each class of species are the same five lowest level objectives (Mardani et al., 2017). The interdisciplinary team postulated that distinct single-dimensional value functions and varying degrees of relevance for each class of species would be associated with the five objectives. The two goals of the human habitat are to maximize the value of the residential area and the commercial/industrial area. Then, these two goals are divided into four lowest level goals, each of which had a different significance but were still suited for both (Achillas et al., 2013).

PRACTICE PROBLEM

A city is planning a major infrastructure project for a new public transportation system. The decision involves considerations such as environmental impact, cost-effectiveness, and accessibility for citizens. Formulate a set of decision objectives for the city's planning committee to ensure a well-structured decision-making process.

SOLUTIONS TO PRACTICE PROBLEM

Minimize Environmental Impact: Implementing a public transportation system that significantly reduces carbon emissions and environmental footprint.

Cost-Effectiveness: Optimize budget allocation to ensure the public transportation project is financially viable and provides value for money.

Enhance Accessibility: To enhance citizen accessibility, it is crucial to design the transportation system in a manner that effectively serves key areas and meets the needs of different demographics.

SUMMARY

- It is evident that individuals do not generate exhaustive lists of goals for the purpose of making more informed choices. The research conducted by Bond et al. suggests that the most comprehensive and wide-ranging set of objectives can be developed by involving groups of stakeholders and decision makers.
- However, the findings of Bond et al. also highlight the importance of caution when implementing the group process. It is crucial to avoid having the goals of one group member serve as a reference point for other stakeholders. Initially, group members should be encouraged to formulate their own objectives before utilizing the 10 Keeney devices and Leo's questions to expand the scope and depth of the brainstorming process.
- Furthermore, prior to engaging in any group interaction, a second phase that focuses on gathering more information should be implemented. Stakeholders should be instructed to create at least as many new objectives in the second phase as they did in the first. Additionally, category cues can be employed in alignment with the goals established by the entire group during the first phase, as well as relevant vision, policy, or strategy literature.
- Following two stages of goal creation, the team can collaborate to eliminate duplicates and come up with a final list. Leon also makes a strong case for asking the stakeholders to consider their values and goals at every stage of the process rather than forcing them to choose between particular options.

MULTIPLE CHOICE QUESTIONS

1. What is the primary purpose of setting clear objectives in decision analysis?

a. To streamline and guide decision analysis

b. To complicate the decision-making process

c. To introduce ambiguity and confusion

d. To delay the decision-making timeline

2. Why is non-redundancy crucial when formulating decision objectives?

a. To optimize decision-making efforts

b. To introduce redundancy for clarity

c. To slow down the decision analysis process

d. To increase complexity

3. Which characteristic ensures that decision objectives are expressed with clarity and brevity?

a. Risk amplification

b. Risk avoidance

c. Risk transfer

d. Risk acceptance

4. In the classification of risks, which category encompasses challenges related to internal processes, systems, and human factors?

a. Redundancy

b. Completeness

c. Conciseness

d. Non-redundancy

5. Why is specificity important when defining decision objectives?

a. To introduce ambiguity

b. To complicate decision analysis

c. To provide a precise roadmap for decision-making

d. To slow down the decision-making process

REVIEW QUESTIONS

1. Explain the importance of clear and well-defined objectives in decision analysis, citing examples of their impact on effective decision-making.
2. Define the concept of non-redundancy in decision objectives. How does avoiding redundancy contribute to the efficiency of decision analysis?
3. Discuss how conciseness enhances the effectiveness of decision objectives. Provide examples of how clear and brief articulation facilitates decision-making.
4. Highlight the significance of specificity in formulating decision objectives. Offer real-world examples where specific objectives influenced successful decision outcomes.

Answers to Multiple Questions

1. (b) 2. (b) 3. (c) 4. (c) 5. (b)

REFERENCES

1. Abbass, H. A., Sarker, R., & Newton, C., (2001). PDE: A Pareto-frontier differential evolution approach for multi-objective optimization problems. In: *Proceedings of the 2001 Congress on Evolutionary Computation (IEEE Cat. No. 01TH8546)* (Vol. 2, pp. 971–978). IEEE.
2. Achillas, C., Moussiopoulos, N., Karagiannidis, A., Banias, G., & Perkoulidis, G., (2013). The use of multi-criteria decision analysis to tackle waste management problems: A literature review. *Waste Management & Research*, *31*(2), 115–129.
3. Alencar, M. H., Priori, Jr. L., & Alencar, L. H., (2017). Structuring objectives based on value-focused thinking methodology: Creating alternatives for sustainability in the built environment. *Journal of Cleaner Production*, *156*, 62–73.

4. Aubert, A. H., Mcconville, J., Schmid, S., & Lienert, J., (2022). Gamifying and evaluating problem structuring: A card game workshop for generating decision objectives. *EURO Journal on Decision Processes*, *10*, 100021–100023.
5. Ballestero, E., Romero, C., Ballestero, E., & Romero, C., (1998). Multiple criteria decision making: An introduction. *Multiple Criteria Decision Making and its Applications to Economic Problems*, *8*(4), 1–10.
6. Bansal, H. S., & Voyer, P. A., (2000). Word-of-mouth processes within a services purchase decision context. *Journal of Service Research*, *3*(2), 166–177.
7. Bhardwaj, A., Joshi, M., Khosla, R., & Dubash, N. K., (2019). More priorities, more problems? Decision-making with multiple energy, development, and climate objectives. *Energy Research & Social Science*, *49*, 143–157.
8. Carlsson, C., & Fullér, R., (1995). Multiple criteria decision making: The case for interdependence. *Computers & Operations Research*, *22*(3), 251–260.
9. Chatterjee, K., Majumdar, R., & Henzinger, T. A., (2006). Markov decision processes with multiple objectives. In: *STACS 2006: 23rd Annual Symposium on Theoretical Aspects of Computer Science, Marseille, France; Proceedings 23* (Vol. 3, pp. 325–336). Springer Berlin Heidelberg.
10. Colson, G., & De Bruyn, C., (1989). Models and methods in multiple objectives decision making. In: *Models and Methods in Multiple Criteria Decision Making* (Vol. 2, pp. 1201–1211). Pergamon
11. Dahooie, J. H., Zavadskas, E. K., Firoozfar, H. R., Vanaki, A. S., Mohammadi, N., & Brauers, W. K. M., (2019). An improved fuzzy MULTIMOORA approach for multi-criteria decision making based on objective weighting method (CCSD) and its application to technological forecasting method selection. *Engineering Applications of Artificial Intelligence*, *79*, 114–128.
12. Das, T. K., & Teng, B. S., (2001). Strategic risk behavior and its temporalities: Between risk propensity and decision context. *Journal of Management Studies*, *38*(4), 515–534.
13. Davydenko, M., & Peetz, J., (2020). Shopping less with shopping lists: Planning individual expenses ahead of time affects purchasing behavior when online grocery shopping. *Journal of Consumer Behavior*, *19*(3), 240–251.
14. Erol, I., & Ferrell, Jr. W. G., (2003). A methodology for selection problems with multiple, conflicting objectives and both qualitative and quantitative criteria. *International Journal of Production Economics*, *86*(3), 187–199.
15. Geers, S. A., (2010). Common sense and the fact finder without skill in the art: The role of objective evidence in achieving proper technology specificity. *Seton Hall L. Rev.*, *40*, 225.
16. Gorddard, R., Colloff, M. J., Wise, R. M., Ware, D., & Dunlop, M., (2016). Values, rules, and knowledge: Adaptation as change in the decision context. *Environmental Science & Policy*, *57*, 60–69.
17. Gregory, R., Ohlson, D., & Arvai, J., (2006). Deconstructing adaptive management: Criteria for applications to environmental management. *Ecological Applications*, *16*(6), 2411–2425.

18. Gu, S., Cheng, R., & Jin, Y., (2015). Multi-objective ensemble generation. *Wiley Interdisciplinary Reviews: Data Mining and Knowledge Discovery*, *5*(5), 234–245.
19. Hannan, M. A., Lipu, M. H., Akhtar, M., Begum, R. A., Al Mamun, M. A., Hussain, A., & Basri, H., (2020). Solid waste collection optimization objectives, constraints, modeling approaches, and their challenges toward achieving sustainable development goals. *Journal of Cleaner Production*, *277*, 123557.
20. Hwang, C. L., & Masud, A. S. M., (2012). *Multiple Objective Decision Making—Methods and Applications: A State-of-the-Art Survey* (Vol. 164, pp. 217–220). Springer Science & Business Media.
21. Ishibuchi, H., Akedo, N., & Nojima, Y., (2014). Behavior of multiobjective evolutionary algorithms on many-objective knapsack problems. *IEEE Transactions on Evolutionary Computation*, *19*(2), 264–283.
22. Janssen, R., (2012). *Multiobjective Decision Support for Environmental Management* (Vol. 2, pp. 258–260). Springer Science & Business Media.
23. Jozefowiez, N., Semet, F., & Talbi, E. G., (2008). Multi-objective vehicle routing problems. *European Journal of Operational Research*, *189*(2), 293–309.
24. Kaya, M., (2010). Autonomous classifiers with understandable rule using multi-objective genetic algorithms. *Expert Systems with Applications*, *37*(4), 3489–3494.
25. Khalili, N. R., & Duecker, S., (2013). Application of multi-criteria decision analysis in design of sustainable environmental management system framework. *Journal of Cleaner Production*, *47*, 188–198.
26. Kiker, G. A., Bridges, T. S., Varghese, A., Seager, T. P., & Linkov, I., (2005). Application of multicriteria decision analysis in environmental decision making. *Integrated Environmental Assessment and Management: An International Journal*, *1*(2), 95–108.
27. Kristina, T. N., Majoor, G. D., & Van, D. V. C. P., (2004). Defining generic objectives for community-based education in undergraduate medical programs. *Medical Education*, *38*(5), 510–521.
28. Lahdelma, R., Salminen, P., & Hokkanen, J., (2000). Using multicriteria methods in environmental planning and management. *Environmental Management*, *26*, 595–605.
29. Leung, K. N. F., (2008). A use of the complete squares method to solve and analyze a quadratic objective function with two decision variables exemplified via a deterministic inventory model with a mixture of backorders and lost sales. *International Journal of Production Economics*, *113*(1), 275–281.
30. Li, J., Mei, C., & Lv, Y., (2013). Incomplete decision contexts: Approximate concept construction, rule acquisition and knowledge reduction. *International Journal of Approximate Reasoning*, *54*(1), 149–165.
31. Linares, P., & Romero, C., (2000). A multiple criteria decision-making approach for electricity planning in Spain: Economic versus environmental objectives. *Journal of the Operational Research Society*, *51*, 736–743.
32. Lobo, L. O., & Arthur, J. D., (2005). An objectives-driven process for selecting methods to support requirements engineering activities. In: *29th Annual IEEE/NASA Software Engineering Workshop* (Vol.1, pp. 118–130). IEEE.

33. Logist, F., Houska, B., Diehl, M., & Van, I. J., (2010). Fast Pareto set generation for nonlinear optimal control problems with multiple objectives. *Structural and Multidisciplinary Optimization*, *42*, 591–603.

34. Loughlin, D. H., Ranjithan, S. R., Brill, Jr. E. D., & Baugh, Jr. J. W., (2001). Genetic algorithm approaches for addressing unmodeled objectives in optimization problems. *Engineering Optimization*, *33*(5), 549–569.

35. Mardani, A., Zavadskas, E. K., Khalifah, Z., Zakuan, N., Jusoh, A., Nor, K. M., & Khoshnoudi, M., (2017). A review of multi-criteria decision-making applications to solve energy management problems: Two decades from 1995 to 2015. *Renewable and Sustainable Energy Reviews*, *71*, 216–256.

36. Marler, R. T., & Arora, J. S., (2005). Function-transformation methods for multi-objective optimization. *Engineering Optimization*, *37*(6), 551–570.

37. Marttunen, M., Haag, F., Belton, V., Mustajoki, J., & Lienert, J., (2019). Methods to inform the development of concise objectives hierarchies in multi-criteria decision analysis. *European Journal of Operational Research*, *277*(2), 604–620.

38. Munda, G., Nijkamp, P., & Rietveld, P., (1994). Qualitative multicriteria evaluation for environmental management. *Ecological Economics*, *10*(2), 97–112.

39. Polasky, S., Carpenter, S. R., Folke, C., & Keeler, B., (2011). Decision-making under great uncertainty: Environmental management in an era of global change. *Trends in Ecology & Evolution*, *26*(8), 398–404.

40. Qu, B. Y., Zhu, Y. S., Jiao, Y. C., Wu, M. Y., Suganthan, P. N., & Liang, J. J., (2018). A survey on multi-objective evolutionary algorithms for the solution of the environmental/economic dispatch problems. *Swarm and Evolutionary Computation*, *38*, 1–11.

41. Roijers, D. M., Vamplew, P., Whiteson, S., & Dazeley, R., (2013). A survey of multi-objective sequential decision-making. *Journal of Artificial Intelligence Research*, *48*, 67–113.

42. Schaefer, J. L., Siluk, J. C. M., & De Carvalho, P. S., (2021). An MCDM-based approach to evaluate the performance objectives for strategic management and development of energy cloud. *Journal of Cleaner Production*, *320*, 128853.

43. Sharma, H. D., & Gupta, A. D., (1995). The objectives of waste management in India: A futures inquiry. *Technological Forecasting and Social Change*, *48*(3), 285–309.

44. Shepherd, N. G., & Rudd, J. M., (2014). The influence of context on the strategic decision-making process: A review of the literature. *International Journal of Management Reviews*, *16*(3), 340–364.

45. Shin, W. S., & Ravindran, A., (1991). Interactive multiple objective optimization: Survey I—Continuous case. *Computers & Operations Research*, *18*(1), 97–114.

46. Siebert, J., & Keeney, R. L., (2015). Creating more and better alternatives for decisions using objectives. *Operations Research*, *63*(5), 1144–1158.

47. Simon, M., & Houghton, S. M., (2002). The relationship among biases, misperceptions, and the introduction of pioneering products: Examining differences in venture decision contexts. *Entrepreneurship Theory and Practice*, *27*(2), 105–124.

48. Smith, C. M., & Shaw, D., (2019). The characteristics of problem structuring methods: A literature review. *European Journal of Operational Research*, *274*(2), 403–416.

49. Stewart, R. H., Palmer, T. S., & DuPont, B., (2021). A survey of multi-objective optimization methods and their applications for nuclear scientists and engineers. *Progress in Nuclear Energy*, *138*, 103830.

50. Tan, K., & Lim, C., (2019). A case study of TNB network solution & support (NSS) inventory information system: A quick printable and non-redundancy web-based application. *Int. J. Sup. Chain. Mgt.*, *8*(1), 740–745.

51. Wilke, N., Siegmann, B., Klingbeil, L., Burkart, A., Kraska, T., Muller, O., & Rascher, U., (2019). Quantifying lodging percentage and lodging severity using a UAV-based canopy height model combined with an objective threshold approach. *Remote Sensing*, *11*(5), 515.

52. Xu, L., & Yang, J. B., (2001). *Introduction to Multi-Criteria Decision Making and the Evidential Reasoning Approach* (Vol. 106, pp. 987–991). Manchester: Manchester School of Management.

CHAPTER 6

Decision Making Using Game Theory

LEARNING OBJECTIVES

After studying this chapter, you will be able to:

- Understand the strategic nuances involved in decision-making within games of skill.
- Explore the impact of randomness and probability in decision-making processes within games of chance.
- Analyze the complexities of sequential decision-making and cooperation in strategic games.
- Comprehend the dynamics of two-person zero-sum games and the implications of clear winners and losers.
- Navigate the intricacies of decision-making in two-person mixed-motive games, balancing cooperation and competition.
- Examine the influence of alliances, coalitions, and power structures on decision-making in multi-person games.

INTRODUCTORY EXAMPLE

Consider the workplace scenario of two colleagues, Sarah and Chris, vying for a coveted promotion, introducing us to the intricacies of two-person mixed-motive games of strategy. Both share a common objective of professional advancement (P), yet their paths diverge: Sarah emphasizes leadership skills, while Chris leans towards highlighting technical expertise. The crux of their strategic decision-making lies in whether to collaborate on a joint project or pursue individual endeavors. Collaboration holds the promise of synergy but risks overshadowing individual contributions, while independent projects showcase personal strengths but potentially sacrifice overall project success. In this nuanced example, the dynamics of shared objectives coupled with conflicting strategies exemplify the challenges inherent in mixed-motive games, where participants must navigate strategic complexities to achieve their goals.

UNIT INTRODUCTION

Game theory is the study of independent and collaborative decision-making. It is concerned with decision-making in organizations where the activities of two or more independent participants, one of which may be nature itself, and where no single decision-maker has complete control over the results. Game theory obviously covers games like chess and bridge, but it also covers a wide range of other social situations that are not usually thought of as games in the classic meaning of the word (Sanfey, 2007). Because classical models consider players as inanimate objects, they are incapable of handling interdependent decision-making. These cause-and-effect theories disregard the fact that individuals actively influence the decisions they make by taking into account the decisions of others. Conversely, a game theory model focuses on the strategic choices that players can make, with clearly defined and established desired outcomes (Lee, 2008). Let us consider the following scenario. Two cyclists are riding in opposite directions along a narrow lane. Both of them should strive to prevent the imminent collision. Each cyclist has three options: continue in the same direction, move to the left, or shift to the right. The decisions made by both cyclists and the precise alignment of their interests will determine the outcome. As this is a fully cooperative game, players must engage in communication with one another to formulate plans (Xiao et al., 2005). But occasionally, players' interests can be opposed to one another. Let's consider a scenario where multiple retail stores are competing for customers in a shared catchment region. Without knowledge of each other's choices, each store must independently decide whether to lower prices. Assuming that lower prices lead to increased turnover, some stores may experience gains or losses based on strategic combinations. However, if one retailer gains consumers, another must lose them. Therefore, unlike cooperative games, this is a zero-sum, non-cooperative game where participants must conceal their intentions from each other (Liang et al., 2016). Games that fall into a third category involve scenarios where players' interests are partially aligned and partially opposed. Assuming that parties act rationally and in their own best interests, game theory seeks optimal outcomes in conflict and cooperation scenarios like the ones described above. Sometimes a solution is found, while in other cases, formal attempts to address the issue may not be fruitful. However, the analytical synthesis process itself can provide valuable information about the issue. Overall, game theory offers an intriguing perspective on the nature of strategic decision-making in both ordinary and extraordinary circumstances (Palafox et al., 2020).

Games can be categorized into three distinct groups: strategic games, games of chance, and games of skill. Games of skill are solitary games characterized by the presence of a lone player with complete dominion over every conceivable outcome. Games of chance, on the other hand, involve a player pitted against the forces of nature. Strategic games, unlike skill-based games where the player wields absolute control over the outcome, do not always yield a predetermined result. These games involve two or more players, excluding nature, each possessing a certain degree of influence over the final outcome. In essence, strategy games are games of uncertainty, as players are unable to assign probabilities to each other's decisions (Zhang et al., 2018).

6.1. GAMES OF SKILL

Learning Objectives

- To understand the strategic principles involved in decision-making within games of skill.
- To apply analytical frameworks to evaluate and enhance decision-making strategies in skill-based games.

Single-player games are those that rely on skill. Since they do not involve other players, and when they do, it is only on the assumption of certainty, they are not genuinely regarded as legitimate games. In contrast to games of chance, nature does not truly function as a second player because its actions have no bearing on the choices made by the player. The lone player in a game of skill always knows exactly how every move will work out. The outcomes are entirely under the player's hands. While playing golf requires expertise because the player's decisions do not always result in the same outcome, doing a crossword puzzle does. A game of chance and uncertainty, golf is—despite what some may say—a moral endeavor! The degree to which nature affects the results relies on the player's talent; nevertheless, the probability of this is unknown (Fiedler & Rock, 2009).

Did you know?

The field of game theory has been honored with several Nobel Prizes in Economics. John Nash, whose life and work inspired the movie "A Beautiful Mind," received the Nobel Prize in Economic Sciences in 1994 for his contributions to game theory.

Games of skill fall under the purview of the mathematical discipline known as linear programming or optimization. In linear programming, the objective of the player is typically to maximize output or minimize input, as determined by a utility function, from a set of alternatives denoted as Ω, which is referred to as the constraint set. Furthermore, the player must establish criteria for assigning a concrete function to each possibility in order of preference:

$$f : \Omega \rightarrow R$$

So that $\omega \rightarrow \Omega$ can be chosen such the function f(ω) is either maximized or minimized, ω is referred to as the optimizer or maximizer in such cases. Optimization generally requires identifying the local maxima and minima of functions, which are commonly referred to as optima. In this context, differential calculus is frequently used as the preferred method for problem-solving (Pearce, 2004).

The derivative of a function *f(x)*, represented as *f'(x)*, quantifies the rate at which the dependent variable *(y)* changes with respect to the independent variable *(x)*. Graphically, *f'(x)* represents the slope of the tangent line to a curve at a specific position. Figures 6.1 and 6.2 demonstrate that the gradient of a tangent is zero at both maximum and minimum points. This provides us with a primary test for local optima (Dreef et al., 2004).

$$If\ a < p < b\ and\ f'(p) = 0, then;$$

$$If\ (a) > 0\ and\ f'(b) < 0, then\ p\ is\ a\ local\ maximum;$$

$$If\ f'(a)\langle 0\ and\ f'(b)\rangle 0, then\ p\ is\ a\ local\ minimum.$$

The second derivative yields the second derivative of a function, denoted as *f''(x)*. The rate of change is decreasing if the first derivative goes from being positive to zero to negative, signifying a local maximum. The rate of change of p increases if the first derivative changes from negative to zero to positive, signifying a local minimum. This gives us an evaluation of functions in the second order. It is faster than the first test mentioned above, but it is equivalent (Bachrach & Rosenschein, 2008).

$$If\ f''(p) < 0, then\ p\ is\ a\ local\ maximum;$$

$$If\ f''(p) > 0, then\ p\ is\ a\ local\ minimum.$$

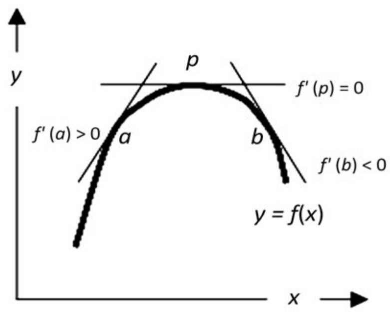

Figure 6.1. A function with a local maximum (Source: Anthony, Creative Commons License)

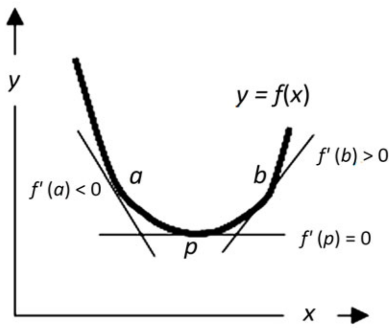

Figure 6.2. A function with a local minimum (Source: Anthony, Creative Commons License)

6.2. GAMES OF CHANCE

Learning Objectives

- To explore the role of randomness and probability in decision-making within games of chance.
- To develop strategies to navigate uncertainty and make informed decisions in scenarios influenced by chance.

Games of chance are individual endeavors in which the player competes against nature, without the ability to make decisions under conditions of certainty. Nature exerts an indeterminate influence on the consequences resulting from the player's choices. Games of chance can be categorized into two groups: risk-based games, where the reaction of nature is known, and uncertainty-based games, where the likelihood of nature's reaction is unknown (Morgensterm, 1949).

To fully grasp games involving risk, it is crucial to possess a certain level of knowledge of the fundamental principles of probability theory. While not technically necessary, it is certainly beneficial. For those seeking to enhance their understanding of the intricate aspects of gaming, there are numerous exceptional texts available on probability theory. However, for the average reader without specialized knowledge, the following description should sufficiently clarify the relationship between game theory and the probabilistic concepts of distribution function and expected value (Brandsen et al., 2022).

Now, let us delve into the principles of probability theory, which will serve as an introduction to the discussion of games with uncertain outcomes and potential risk.

Remember

Game theory is not only applied to human interactions but also extends to evolutionary biology. Evolutionary game theory helps explain strategic interactions and behaviors within species over time.

A probability space is the fundamental notion in probability theory. Let S be a collection of events known as the sample space,

$$S = \{S_1, S_2, S_3, \ldots.., S_{12}, \ldots., S_\pi\}$$

and P is a function that assigns to every subset S_i a real integer $p\{S_i\} = P_i, such that:$

$$0 \le p_i \le 1$$

then the ordered pair (S, P) is called the probability space and $p\{S_i\}$ is called the probability of S_i (see Figure 6.3).

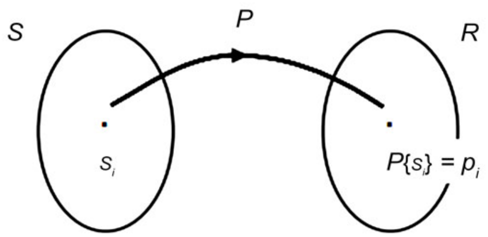

Figure 6.3. Diagram of sample space and probability of an event (Source: Gale, Creative Commons License)

The probability function, P(s), has the following six properties:

i. $p_i \geq 0, \forall i$

ii. $\sum p_i = 1, from\, i = 1\, to\, n$

iii. $If\ A \subset S, then\ P\{A\} = \sum p_i, for\ all\ events\ S_i \in A$

iv. $p\{\phi\} = 0$

v. $P\{S\} = 1$

vi. Only a subset of *S* is specified by P(s) if the sample space, *S*, is infinite (Niall, 2023).

Several other notions stem from the aforementioned ones, including the concept of a random variable and its distribution function.

A random variable, represented by X, is a mathematical function that maps a sample space *S* to the set of real numbers.

In general, X assigns a real number X(s) to an event s, where s ∈ S and X(s) ∈ R.

Occasionally, *Si* is a real number, while at other times it is not, in which case the random variable assigns a value of one to it. The distribution function of the random variable X is a mapping function, denoted as F(x), that assigns real values to themselves, following the rule:

$$F(x) = P(X), where\ X \leq x, \forall x \in R$$

Put simply, the distribution function is the mathematical procedure that converts random variables into probabilities. It is a fundamental idea that underlies many solutions in game theory (Dresher, 1951).

6.3. SEQUENTIAL DECISION-MAKING AND COOPERATIVE GAMES OF STRATEGY

Learning Objectives

- To analyze the complexities of sequential decision-making in strategic scenarios.
- To understand the dynamics of cooperation and apply strategic thinking in collaborative games.

Decision-making involves the selection of a certain course of action, whether it be in a game involving skill, chance, or strategy. Decisions can be made either concurrently or sequentially, regardless of the nature of the game. However, skill-based games are necessarily sequential as they feature a single player who has full control over all the outcomes. The process of making decisions at the same time is inherently uncomplicated, yet finding a solution to the resulting game may pose challenges. Sequential decision-making can be highly intricate, and specific approaches have been devised to depict the process (McKinsey, 1952).

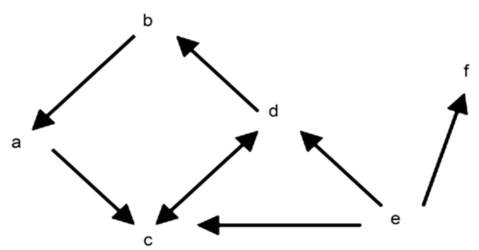

Figure 6.4. Illustration of a directed graph (Source: Guyer, Creative Commons License)

Typically, tree-like diagrams are used to show sequential decision-making. A directed graph, GD, is defined as an ordered pair (N, E), where N is a finite collection of nodes and E is a finite set of edges, each represented as an ordered pair of nodes (see Figure 6.4).

$$N = \{a, b, c, d, e, f\}$$

$$E = \{(a,b),(b,d),(d,c),(c,d),(c,a),(d,e),(c,e),(f,e)\}$$

In the context of any edge, $e = n_1, n_2$; n_1 is called the predecessor or parent of n_2, while n_2 is called the successor or child of n_1. In Figure 6.4, for example, d is the predecessor of both c and e (Van & De, 2021).

A path denoted as P, from node n_1 to node n_2 is a collection of edges that start at at n_1 and finish at n_2 as

$$P_{(n_1,n_2)} = \{(n_1,a),(a,b),(b,c),\ldots,(x,y),(y,z),(z,n_2)\}$$

In other words, the path joins n_1 and n_2 on the arrow diagram. n_1 is called the ancestor of n_2 and n_2 is called the descendent of n_1. On Figure 6.5, for example, the path Pdb is::

$$P_{db} = \{(d,c),(c,a),(a,b)\}$$

Inevitably, however, every path must reach a conclusion, as the collections of nodes and edges are inherently limited. These nodes are referred to as terminal nodes, specifically n_1, and can be identified as locations where edges enter, but do not exit. In Figure 6.4, node e is identified as a terminal node (Abele et al., 2004).

On the other hand, it is important to note that every set of decisions and, hence, every arrow diagram must possess an initial node, referred to as a root, denoted as r. This root node can be identified as the node that does not have any arrows pointing towards it. Edges emerge forth, but do not retract inward. Figure 6.5 has only one root, which is node f. Roots are significant characteristics of a specific kind of directed graphs, known as trees, which will be further explained later (Savikhin & Sheremeta, 2013).

Before tracing decision-making strategies chronologically from the outcome to the origin, it is important to note that for any directed graph, graph, G_D= there is another directed graph, G_{DB}=(N, E_B), known as the backward directed graph of G_D. The nodes in G_{DB} are the same as those in G_D, but the edges are reversed. The G_{DB} for the directed graph depicted in Figure 6.5 is as follows:

$$N = \{a, b, c, d, e, f\}$$

$$E = \{(b,a),(d,b),(c,d),(d,c),(a,c),(e,d),(e,c),(e,f)\}$$

and this can be seen on Figure 6.5.

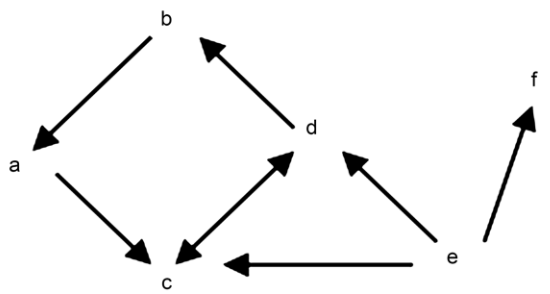

Figure 6.5. Illustration of a backward directed graph (Source: Guyer, Creative Commons License)

A specific sort of directed graph, called a tree, has a root and just one path for all other nodes (see Figure 6.6) (Katz, 1990).

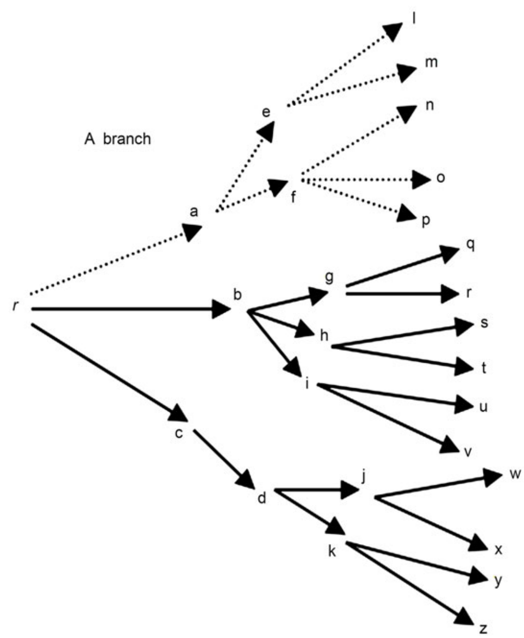

Figure 6.6. Representation of a tree showing a branch or sub-tree (Source: Guyer, Creative Commons License)

It is evident that in the case of trees, the root serves as a predecessor to every node, while every node is a successor of the root. Furthermore, no node can have multiple parents. Additionally, there are no reciprocal paths – if a road exists from n_1 to n_2, there is no corresponding path from n_2 to (Bayrak et al., 2021).

Trees can contain sub-trees or branches, as shown in Figure 6.7, under the following conditions:

i. A portion of the tree's nodes make up the branch's nodes.

ii. A subset of the tree's terminal nodes makes up the branch's terminal nodes.

iii. The edges that the branch's nodes form match the edges that the branch's nodes form in the tree.

iv. The branch's root and the tree's root are the same node.

6.4. TWO-PERSON ZERO-SUM GAMES OF STRATEGY

Learning Objectives

- To comprehend the strategic interactions and implications in two-person zero-sum games.
- To develop decision-making skills to optimize outcomes in scenarios.

A two-player zero-sum game is one in which all possible payoffs add up to zero. One player's gain is closely associated with the other player's loss in a strictly competitive dynamic. The game follows the conservation of utility value principle, which states that value is never created or destroyed but is instead transferred between participants. The interests of the two players are perpetually in direct opposition and characterized by competitiveness, devoid of any potential for, or advantage in, collaboration (Ribeiro et al., 2015).

Pareto-efficiency is a characteristic where one player's victory comes at the loss of the other player. In more exact terms, Pareto efficiency refers to a scenario where the well-being of one participant cannot be enhanced without causing a decline in the well-being of at least one other participant (Wray et al., 2018).

Game theory has many practical applications, especially in the analysis of zero-sum games, such as athletic competitions. In truth, the phrase "constant-sum games" would be more fitting since it appropriately captures the idea that there may be instances of unfairness in the game that prevent the payoffs from always adding up to zero. However, despite this common feature of these intensely competitive games, their sums are in fact constant. For convenience's sake, one will thus continue to use the term "zero-sum" in these situations (Washburn & Wood, 1995).

Finite and infinite are the two categories into which zero-sum games can be divided. In finite zero-sum games, there is a finite number of pure strategies available to both sides. In contrast, in infinite zero-sum games, there are an infinite number of pure tactics accessible for at least one player. Fortunately, these types of games are not very common. While all finite games have solutions, only a subset of infinite games do. To solve a zero-sum game, a clear specification of each player's best strategy is required. The value of the game is the payout that results from both participants meeting this requirement (Koller & Megiddo, 1992). Pay-off matrices are commonly used to represent zero-sum finite games between two players. However, Figure 6.7 presents the game as a tree to emphasize the relationship between decision-making and game trees (Satoh & Tanaka, 2019).

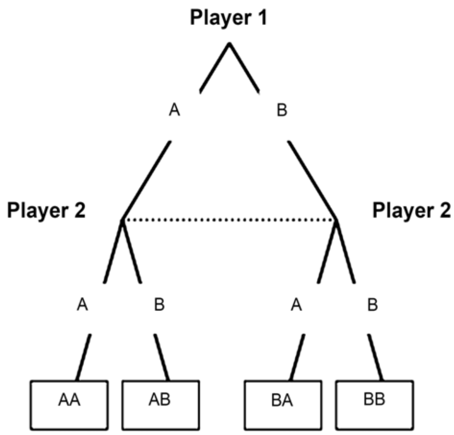

Figure 6.7. Diagram of the game-tree represents a two-player game with imperfect information and zero-sum outcomes (Source: Dixit, Creative Commons License)

The terminal nodes of the game tree reflect the outcomes of the game, while the linking nodes, which are indicated by a dotted line, constitute an information set. During gameplay, a player is unable to differentiate between nodes that belong to the same information set. Each participant in a game with imperfect information must independently make their decision without knowledge of past moves or the simultaneous decision of the other player. In a game with perfect information, the nodes on the game tree will only contain separate information sets (see Figure 6.8) (Raghavan, 1994).

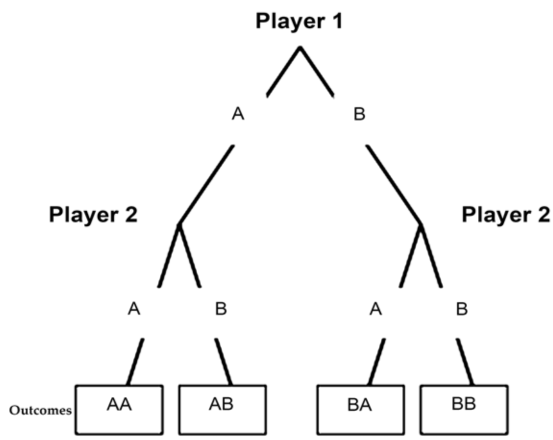

Figure 6.8. Diagram of game-tree for a two-person zero-sum game of perfect information (Source: Dixit, Creative Commons License)

Figure 6.9, commonly known as the normal form of the game, shows the pay-off matrix representation for the same game. Each row in the matrix represents a unique pure strategy for player 1, while each column represents a unique pure strategy for player 2. Traditionally, the payoffs to the row player are reflected in the matrix element at the intersection of a row and a column. The column player's payoffs will be the opposite of those shown in the matrix (Fox, 1972).

		Player 2	
	Strategy	Strategy A	Strategy B
Player 1	Strategy A	**AA**	**AB**
	Strategy B	**BA**	**BB**

Figure 6.9. A payoff matrix representation for a two-player zero sum game (Source: Bacon, Creative Commons License)

PRACTICE PROBLEM

1. Imagine two business partners, Alice and Bob, who own a small company together. They have to decide how to split their profits each month. If one partner feels unfairly treated, they can decide to dissolve the partnership, leading to the loss of the business. This scenario reflects a repeated dynamic game. Formulate the repeated dynamic game between Alice and Bob. Define the strategies, payoffs, and possible outcomes over several months. Consider the dynamics of cooperation, the temptation to defect, and the potential for building a trustworthy relationship.
2. Consider a scenario where three countries (A, B, and C) are negotiating a trade agreement. Each country has its own set of preferences regarding trade policies, and they must form coalitions to maximize their gains. This situation represents a multi-person coalitional game. Define the coalitional game between countries A, B, and C. Identify the possible coalitiwons, their bargaining power, and the outcomes they can achieve. Analyze how the distribution of power within coalitions influences the negotiation process.

SOLUTIONS TO PRACTICE PROBLEM (1)

In this scenario, the repeated dynamic game involves decisions on profit-sharing each month. Strategies for each player could be to "Cooperate" by sharing profits fairly or to "Defect" by taking a larger share for themselves. Payoffs may include monetary gains from a fair partnership, the cost of losing the business due to dissolution, and the emotional satisfaction from cooperation.

Over several months, Alice and Bob can develop a pattern of cooperation or defection. The solution involves finding a sub-game perfect equilibrium where both partners consistently choose cooperation, establishing trust and maximizing long-term gains.

Solutions to Practice Problem (2)

In this coalitional game, countries have the ability to form various coalitions, such as A and B, B and C, A and C, or all three together. Each coalition engages in negotiations based on its own preferences and strength. The solution to this problem involves calculating either the Shapley value or the nucleolus, which helps determine a fair distribution of gains for each country within a coalition.

Understanding the power dynamics within each coalition is of utmost importance. For instance, if country A possesses a stronger economy, it may wield more bargaining power. The key to solving this problem lies in identifying stable coalitions and achieving equitable outcomes that effectively balance the interests of all countries involved.

6.5. TWO-PERSON MIXED-MOTIVE GAMES OF STRATEGY

Learning Objectives

- To navigate the complexities of decision-making in two-person mixed-motive games.
- To strategically balance cooperation and competition to achieve optimal outcomes.

Cooperative games are those in which there is no conflict of interest, and both players receive the same rewards. On the other hand, zero-sum games are those in which the players' goals are completely opposite, so what benefits one person would harm the other. Mixed-motive games fall somewhere in the middle (Aplak et al., 2014).

Mixed-motive games are often referred to as variable-sum games because the payoffs change depending on the selected strategy. It is important to note that this statement is not entirely accurate, as cooperative games also have variable payoffs. Although they do not produce pure solutions, these situations are fascinating as they represent real-life scenarios and provide valuable insights into conflict resolution (Raghavan, 2002). Even the simplest mixed-motive games, depicted using two-by-two matrices, have multiple strategically distinct categories. There are a total of 12 unique symmetrical two-by-two mixed-motive games, of which eight have a single stable Nash equilibrium point, while the remaining four do not. Nash equilibrium points are classified based on their resemblance to one of these four fundamental patterns, making them essential in any classification of mixed-motive games. One of the four categories is the well-known prisoner's dilemma game, referred to as martyrdom games. Unlike the other three types, this game has a single Nash equilibrium but is paradoxical in nature (Liebrand, 1984). Mixed-motive games are depicted in a marginally distinct manner compared to cooperative and zero-sum games. The payoffs employed are consistently represented by basic ordinal values, with the numbers in the matrix solely indicating relative preference. The payoffs of both players are presented on the pay-off matrix, following the norm that the 'row' player is listed first in the coordinate pair (Colman & Stirk, 1998). To begin with, let's establish the precise definition of the games.

An instance of a two-player mixed-motive game is one in which the two participants have competing interests:

i. player 1 (row) has an infinite set of strategies $S_1 = \{ r_1, r_2, \ldots .. r_m \}$ where No. (S_1) = m;

ii. player 2 (column) has a finite set of strategies $S_2 = \{c_1, c_2, \dots c_n\}$ where No. (S_2) = n;

iii. the payoffs for the players are the utility functions u_1 and u_2 and the payoffs for player 1 of outcome (r, c) is denoted by u_1 (r, c) $\in S_1$ x S_2 (the cartesian product).

The notions of dominance and refusals can be refined using this new notation (see Figure 6.10). One of player 1's strategies, r_i, is said to outweigh another, r_j, if:

$$u_1(r_i, c) \geq u_1(r_j, c), \forall c \in S_2$$

Player 1's strategy r_j is now deemed inadmissible since they are unable to select it and still maintain their claim of acting logically (Gallo & McClintock, 1965).

		Player 2	
	Strategy	c_1	c_2
Player 1	r_1	$u_1(r_1, c_1), u_2(r_1, c_1)$	$u_1(r_1, c_2), u_2(r_1, c_2)$
	r_2	$u_1(r_2, c_1), u_2(r_2, c_1)$	$u_1(r_2, c_2), u_2(r_2, c_2)$

Figure 6.10. Representation of a mixed motive game with two players (Source: Bacon, Creative Commons License)

The dominance of r_i over r_j is said to be strict if:

$$u_1(r_i, c) > u_1(r_j, c), \forall c \in S_2$$

And weak if:

$$u_1(r_i, c) \geq u_1(r_j, c), \forall c \in S_2$$

Keyword

Coalitions: A coalition is a collection of people, organizations, or nations that come together with the intention of achieving a particular objective, usually a specific aim or result. In the framework of game theory, alliances frequently emerge to enhance the combined bargaining strength of the parties involved. Forming a coalition involves strategic decision-making, where parties collaborate to solve problems or achieve common goals. To comprehend the dynamics of cooperative interactions and negotiations, it is essential to understand the allocation of power and resources within coalitions.

6.6. MULTI-PERSON GAMES, COALITIONS AND POWER

Learning Objectives

- To examine the dynamics of decision-making in multi-person games.
- To develop strategic insights to navigate complex social interactions.

Games with three or more participants are referred to as multi-person games, and they are theoretically different from games for one or two players in that coalitions may be involved. When participants' interests align perfectly, eliminating the need for coalitions or making them unimportant, the games become pure coordination and resemble two-person cooperative games. In these situations, the only coalition that can exist is the grand coalition, which entails all parties operating in concert. Coordination is achieved through either explicit or implicit expectations (Gahagan & Tedeschi, 1969).

On the other hand, coalitions have a significant impact on zero-sum multi-player games because they create the prospect of cooperation in a game when none would otherwise exist. These multiplayer, non-cooperative games employ a strategy that builds upon the saddle/equilibrium point strategy (Byers, 1997).

Games with mixed motivations and partial cooperation fall in between strictly cooperative and zero-sum games. Although certain strategies may be obscure, solutions derived from somewhat cooperative and mixed-motive games are more realistic compared to those originating from totally non-cooperative games (Oskamp, 1971).

Decision-makers often need to independently select choices from a range of alternatives. Communication can be challenging or undesired, and forming a coalition may be unattainable. Coalitions can be forbidden by legal regulations or intentionally discouraged in specific circumstances, such as share support programs and price-fixing cartels (Maschler, 1963).

The equilibrium points of a multi-player non-cooperative game determine the formal solution when the decisions of other players are known. This outcome ensures that no player has any feelings of regret. In 1951, Nash extended the minimax theorem to prove that all finite multi-person games have at least one equilibrium point, which can be either pure or mixed strategies. Furthermore, every solution corresponds to a Nash equilibrium point. The original theorem proved that every finite strictly competitive game has a point of equilibrium where players use mixed strategies. Multiple solutions and, hence, multiple Nash equilibrium points often exist (Rapoport & Kahan, 1984).

In two-person zero-sum games, the equilibrium points are fungible, implying that any combination of strategies or Nash equilibria can be employed interchangeably. Moreover, their equilibrium points are identical as they yield identical payoffs. Unfortunately, because participants cannot agree on their preferences, equilibrium locations in two-person mixed-motive games do not have these desirable qualities. These issues worsen in multiplayer games. Identifying and classifying the numerous distinct and non-substitutable Nash equilibrium points that frequently occur is a difficult undertaking. Indeed, the result of a multi-player game may not always align with a Nash equilibrium point (Shubik, 1971).

6.7. A CRITIQUE OF GAME THEORY

Learning Objectives

- To critically assess the strengths and limitations of game theory in decision-making analysis.
- To develop a discerning perspective on the applicability of game theory.

Although game theory has been highly successful in enhancing our comprehension of how rational players make decisions in settings where their choices depend on each other, some of its fundamental assumptions have faced criticism. Certain individuals present challenges, but others have an excessive sense of self-importance. Among the former is the argument that the rational foundation of game theory is compromised because irrational players sometimes win games. It simply takes stating this to realize how ridiculous it is. In certain games, it is not irrationality per se that offers players an advantage, but rather the idea of irrationality and unpredictability. By purposefully creating that perception, they are acting rather logically as they try to use the same conscious or unconscious strategy to win the game (Dejenee, 2007).

The three most intriguing problems with game theory that have emerged in recent years are those related to rationality, indeterminacy, and consistency.

6.7.1. Rationality

The foundation of game theory is the assumption of rationality, which may initially seem idealistic. However, to support the argument that individuals make rational choices and complex judgments in the face of uncertainty, it is necessary to gather more experimental data. Furthermore, in games without a clear conclusion, players may need to employ some form of irrationality to gain an advantage (Rapoport & Rapoport, 1990).

There are several justifications for game theory's assumption of rationality. Firstly, there is evidence suggesting the presence of natural selection, which drives decision makers towards rationality. This is based on the notion that organizations that choose suboptimal tactics eventually succumb to competition. As a result, subsequent generations tend to make more rational judgments. However, it remains unclear to what extent this "competitive evolution" applies to all sectors, both commercial and non-profit (Hagen & Hammerstein, 2006).

Second, it can be shown that justification depends on the chosen definition of rationality. One such assumption is instrumental rationality, which posits that participants always act in their own best interests and can, to some extent, predict the outcomes of their decisions and rank them according to their desires. Therefore, if a player chooses something that appears illogical, it is because they are basing their decision on an unreasonable notion. While the choice itself may be irrational, the underlying belief is questionable when defining rationality based on outcomes. In the case of the prisoner's dilemma game, for instance, a player may achieve an optimal outcome by playing compassionately. Consequently, it may occasionally be counterproductive. In such situations, it seems that a different form of rationality, namely group rationality, is at play rather than irrationality (Naveed et al., 2021).

Based on the writings of Kant in the eighteenth century, there is another definition of rationality that is frequently debated in connection with game theory. According to Kant, rational behavior is that which complies with rules or categorical imperatives that specify a particular course of action that can only be taken based on reason. Given that everyone has the capacity for reason, rationality establishes actions that all people can agree upon, and everyone uses reason to create the same demands (Read & Read, 1970).

Because they are rational beings, rational players ought to act in accordance with the laws that they would like to see become universal. It is, by definition, irrational if no player may choose a particular course of action. Due to varying moral beliefs among players, judgments guided by Kant's moral imperative rather than self-interest can lead to divergent outcomes in game theoretic situations. This is because players may still be behaving in a logical and calculated manner, despite their decision to prioritize the well-being of others over their own interests. Hence, depending on the interpretation, it remains logical for participants in a prisoner's dilemma game to collaborate (Barrett, 2022).

6.7.2. Indeterminacy

The second main complaint leveled at game theoretic frameworks is their inability to consistently produce unique solutions. This is typically due to the existence of several equilibriums in the game. In these situations, the best course of action remains unknown, and decisions are typically based on players' anticipation of what other players will do. As a result, strategic selection is not always logical. It may focus on key elements of the game or focal points that influence decision-making. These prominent elements serve as markers for players to ensure balance in the outcome. Typically, they are not logical but rather cultural or experiential (Joosten, 2009). The issue of indeterminacy significantly impacts mixed strategy. Nash equilibrium arises when a player lacks motivation to choose a mixed strategy instead of a pure one, given their expectation that the opposing player will opt for a mixed strategy. To address this issue, certain authors have suggested that mixed-strategy probabilities should be based on players' subjective anticipations of other players' behaviors, rather than their observed behavior. This can be likened to the Harsanyi doctrine, which states that rational players will inevitably have the same opinions if they have access to the same information. However, it is also confronted by the reality that rational players do not consistently offer identical advice or reach identical conclusions (Roby, 1960).

6.7.3. Inconsistency

The third major criticism of game theory relates to the problem of inconsistency, specifically concerning the application of backward induction and the assumption of mutual knowledge of rationality in Bayesian sub-game perfect Nash equilibria. An example is an efficient approach to illustrate the critique (Kuechle, 2013).

The centipede game, named by its game tree's visual resemblance to a centipede, was originally created by Rosenthal (1981) based on Selten's work (1978). Over time, the game has been expanded to incorporate many modifications. In the initial rudimentary iteration, there are two participants, A and B, positioned opposite each other at a table. A referee places a £1 bill on the table. Player A is presented with the option to either accept the money and conclude the game, or decline it (Baltzell, 1982).

If Player A declines, the referee will add an additional £1 and offer Player B the same choice – to accept the £2 and complete the game or return it to the referee who will add another £1 and present the same choice to Player A once more. The monetary fund is permitted to increase in value until it reaches a predetermined threshold, such as £50, which is mutually recognized in advance by both participants (Wan, 1985).

According to the backward induction approach, a rational player A would accept the £49 pot at the penultimate node since player B must undoubtedly take the £50 at the final node. As a result, player B ought to take the money pot (£48) at the previous node, and so forth, all the way back to the starting node, when a sensible player A ought to take the first £1 and call a game. This is the ideal sub-game (Solum, 1987).

Such logic, however, contradicts the common knowledge assumption of rationality, which holds that a game of this kind should terminate at the first node and is predicated on the belief that all participants are rational. It is pointless to inquire as to what a player would do should a following node ever be reached. This reasoning should never lead to these nodes, hence any argument based on it is erroneous (Levinson, 2017).

These games continue for at least a few rounds after reaching the first node. The participants do better while acting in an "irrational" and selfish manner than when acting logically and selfishly. Without any prior agreement, some games have even been known to proceed straight to the final node, where players share the £50 in prize money (Krul & Krul, 2018).

The rationality of backward induction appears to be undermined in games such as the centipede game and repeated prisoner's dilemma games, where initial cooperation could potentially benefit both players through a form of implicit cooperative behavior and a sense of fairness. However, it is questionable how long such a cooperative attitude would persist if the initial reward money for the first move was exceedingly substantial (Munck, 2001).

The concept of common knowledge of rationality cannot be reconciled as it attempts to impose a false certainty onto a game that inherently involves uncertainty. For instance, in the centipede game, it assumes that no player will ever reject the monetary prize, even though it could be a viable decision. If player A acts unreasonably and refuses the prize money, player B will have concrete evidence that player A is irrational, and it will be unclear how the game will progress from that point (Guala, 2006).

In the hopes that Player A would not abruptly become rational and accept the pot, Player B may choose to hold out Player A for a time, knowing full well that the reward money will increase! Furthermore, from the perspective of Player A, it seems reasonable to act crazy at first, if only to fool Player B into thinking you're not. The presumption that everyone is aware of rationality, regardless of the game's conclusion or rules, is clearly false (Lindh, 1992).

There have been several attempts to overcome the challenges brought up by the requirement for some semblance of rational consistency. Selten (1975) proposes that if players make sporadic mistakes when playing games, it is one method to address this inconsistency. A player in the centipede game might decline the prize money without going against the assumption of rationality, thanks to the so-called trembling hand assumption. Binmore (1987) puts forth a more extreme proposal that redefines reason as procedural, necessitating the adoption of arbitrary halting rules by players. This model avoids scenarios where departures from sub-game perfection are at odds with rationality by merely defining various types of rationality in terms of alternative stopping rules (Pruitt & Kimmell, 1977).

SUMMARY

- This chapter delves into the analysis of decision-making techniques used in games of skill, revealing the complex tactics people use when skill plays a decisive role in determining the outcome.
- This chapter explores games of chance, examining how people make decisions, how randomness and probability function in decision-making, and how they maneuver through uncertain situations.
- This chapter provides an in-depth analysis of cooperative games of strategy and sequential decision-making, illuminating the intricacies involved in long-term and group-based strategic decisions.
- This chapter explores the dynamics of two-person zero-sum strategy games, in which the gains of each player are exactly equal to the losses of the other, leading to clearly defined victors and losers in strategic exchanges.
- This chapter's analysis delves into two-person mixed-motive strategy games, where competing goals introduce additional layers of complexity and necessitate a delicate balance between cooperation and competition in decision-making.
- Furthermore, this chapter explores power dynamics, coalitions, and multi-person games to illustrate how these factors influence decision-making in intricate social interactions.
- Moreover, this chapter takes a critical approach to game theory, offering a nuanced critique that highlights the limitations and potential inadequacies of this framework in understanding decision-making.
- Lastly, this chapter offers a comprehensive understanding of decision-making processes across various aspects such as skill, chance, cooperation, competition, and coalition building, by synthesizing concepts from numerous game theory applications. Within this chapter, a nuanced perspective is presented on decision-making strategies, recognizing the interplay of rationality, emotions, and social dynamics in shaping outcomes.

MULTIPLE CHOICE QUESTIONS

1. In games of skill, outcomes are primarily determined by:

a. Profit Luck

b. Random chance

c. Skill and strategy

d. External factors

2. What does "zero-sum" mean in two-person zero-sum games?

a. Outcomes are unpredictable

b. One player's gain is equivalent to the other's loss

c. Collaboration is encouraged

d. There are no winners or losers

3. In sequential decision-making games, players make decisions.?

a. Simultaneously

b. One after the other

c. Randomly

d. Based on chance

4. Mixed-motive games involve players with:

a. Shared objectives

b. Conflicting objectives

c. No clear strategy

d. Random decision-making

5. Coalitions in game theory refer to:

a. Individual players

b. Collaborative groups of players

c. Random outcomes

d. Chance-based decisions

REVIEW QUESTIONS

1. Certainly! Here are seven review questions related to game theory:
2. What distinguishes games of skill from games of chance? Provide an example for each category.
3. Explain the concept of sub-game perfection in the context of sequential decision-making games. Why is it important in analyzing strategic interactions?
4. In two-person zero-sum games, what does it mean for a game to be zero-sum? Provide an example and discuss the implications of zero-sum outcomes.
5. How do two-person mixed-motive games differ from two-person zero-sum games? Illustrate with a practical example and highlight the challenges associated with mixed-motive scenarios.
6. Define coalitions in game theory and discuss their significance in multi-person games. How does the concept of power relate to coalitions?
7. In the context of repeated games, explain the role of credibility in decision-making. How do threats contribute to cooperation, and what challenges may arise in maintaining a balance between threats and cooperation?
8. Choose a real-world scenario and analyze it using game theory concepts. Discuss the strategies employed by the involved parties, the potential outcomes, and the relevance of the chosen game theory principles.

Answers to Multiple Questions

1.I) 2. (b) 3. (b) 4. (b) 5. (b)

REFERENCES

1. Abele, S., Bless, H., & Ehrhart, K. M., (2004). Social information processing in strategic decision-making: Why timing matters. *Organizational Behavior and Human Decision Processes*, *93*(1), 28–46.
2. Aplak, H., Kabak, M., & Köse, E., (2014). A two person zero sum game oriented to integration of objectives. *Journal of Military Studies*, *5*(2), 65–85.
3. Bachrach, Y., & Rosenschein, J. S., (2008). Coalitional skill games. In: *Proceedings of the 7th International Joint Conference on Autonomous Agents and Multiagent Systems* (Vol. 2, pp. 1023–1030).
4. Baltzell, J. E., (1982). The application of game theory in collective behavior: A critique of 'erk's "gaming approach." *Sociological Focus*, *15*(3), 269–278.
5. Barrett, J., (2022). Ideology critique and game theory. *Canadian Journal of Philosophy*, *52*(7), 714–728.
6. Bayrak, A. E., McComb, C., Cagan, J., & Kotovsky, K., (2021). A strategic decision-making architecture toward hybrid teams for dynamic competitive problems. *Decision Support Systems*, *144*, 113490.
7. Binmore, K., (1988). Modeling rational players: Part II. *Economics & Philosophy*, *4*(1), 9–55.
8. Brandsen, S., Geng, I. J., & Gour, G., (2022). What is entropy? A perspective from games of chance. *Physical Review E*, *105*(2), 024117.
9. Bruin, B. D., (2005). Game theory in philosophy. *Topoi*, *24*(2), 197–208.
10. Byers, M., (1997). Taking the law out of international law: A critique of the iterative perspective. *Harv.' Int'l. LJ*, *38*, 201.
11. Castillo, L., & Dorao, C. A., (2012). Consensual decision-making model based on game theory for LNG processes. *Energy Conversion and Management*, *64*, 387–396.
12. Cobb, B. R., & Basuchoudhary, A., (2009). A decision analysis approach to solving the signaling game. *Decision Analysis*, *6*(4), 239–255.
13. Colman, A. M., & Stirk, J. A., (1998). Stackelberg reasoning in mixed-motive games: An experimental investigation. *Journal of Economic Psychology*, *19*(2), 279–293.
14. Cox, Jr. L. A., (2009). Game theory and risk analysis. *Risk Analysis: An International Journal*, *29*(8), 1062–1068.
15. Cudd, A. E., (1993). Game theory and the history of ideas about rationality: An introductory survey. *Economics & Philosophy*, *9*(1), 101–133.
16. Dejenee, A., (2007). *Three-Person Cooperative Game and its Application in Decision Making Process of Hierarchical Organizations* (Vol. 1, No. 1, pp. 1–20). Master of Science in Mathematics, Addis Ababa University.

17. Deng, X., Zheng, X., Su, X., Chan, F. T., Hu, Y., Sadiq, R., & Deng, Y., (2014). An evidential game theory framework in multi-criteria decision-making process. *Applied Mathematics and Computation*, *244*, 783–793.
18. Diamond, G. A., Rozanski, A., & Steuer, M., (1986). Playing doctor: Application of game theory to medical decision-making. *Journal of Chronic Diseases*, *39*(9), 669–677.
19. Dimand, M. A., & Dimand, R. W., (1996). *The History of Game Theory: From the Beginnings to 1945* (Vol. 1, pp. 1–20). Routledge.
20. Dreef, M., Borm, P., & Genugten, B. V. D., (2004). Measuring skill in games: Several approaches discussed. *Mathematical Methods of Operations Research*, *59*, 375–391.
21. Dresher, M., (1951). Games of strategy. *Mathematics Magazine*, *25*(2), 93–99.
22. Fang, F., Liu, S., Basak, A., Zhu, Q., Kiekintveld, C. D., & Kamhoua, C. A., (2021). Introduction to game theory. *Game Theory and Machine Learning for Cyber Security*, *1*(1), 21–46.
23. Fiedler, I. C., & Rock, J. P., (2009). Quantifying skill in games—Theory and empirical evidence for poker. *Gaming Law Review and Economics*, *13*(1), 50–57.
24. Földesi, P., & Böröcz, P., (2008). The application of the game theory onto the analysis of the decision theory of logistic packagings. *Acta Technica Jaurinensis*, *1*(2), 259–268.
25. Fox, J., (1972). The learning of strategies in a simple, two-person zero-sum game without saddlepoint. *Behavioral Science*, *17*(3), 300–308.
26. Gahagan, J., & Tedeschi, J., (1969). Shifts of power in a mixed-motive game. *Journal of Social Psychology*, *77*(2), 241.
27. Gallo, Jr. P. S., & McClintock, C. G., (1965). Cooperative and competitive behavior in mixed-motive games. *Journal of Conflict Resolution*, *9*(1), 68–78.
28. Guala, F., (2006). Has game theory been refuted? *The Journal of Philosophy*, *103*(5), 239–263.
29. Hagen, E. H., & Hammerstein, P., (2006). Game theory and human evolution: A critique of some recent interpretations of experimental games. *Theoretical Population Biology*, *69*(3), 339–348.
30. Huang, Y., & Zhu, Q., (2022). Game-theoretic frameworks for epidemic spreading and human decision-making: A review. *Dynamic Games and Applications*, *12*(1), 7–48.
31. Joosten, R., (2009). *Paul Samuelson's Critique and Equilibrium Concepts in Evolutionary Game Theory, 1*(1), 0916.
32. Katz, A., (1990). The strategic structure of offer and acceptance: Game theory and the law of contract formation. *Mich. L. Rev.*, *89*, 215.
33. Koller, D., & Megiddo, N., (1992). The complexity of two-person zero-sum games in extensive form. *Games and Economic Behavior*, *4*(4), 528–552.
34. Krul, M., & Krul, M., (2018). Players of the game: Rationality, choice, and indeterminacy. *The New Institutionalist Economic History of Douglass C. North: A Critical Interpretation*, *1*(1), 101–136.

35. Kuechle, G., (2013). The determinants of effective entrepreneurial behavior: An evolutionary game theory critique. *International Journal of Management*, *30*(2), 507.
36. Landa, D., & Meirowitz, A., (2009). Game theory, information, and deliberative democracy. *American Journal of Political Science*, *53*(2), 427–444.
37. Lee, D., (2008). Game theory and neural basis of social decision making. *Nature Neuroscience*, *11*(4), 404–409.
38. Levinson, D., (2017). The inevitability and indeterminacy of game-theoretic accounts of legal order. *Law & Social Inquiry*, *42*(1), 28–37.
39. Liang, X., Peng, Y., & Shen, G. Q., (2016). A game theory based analysis of decision making for green retrofit under different occupancy types. *Journal of Cleaner Production*, *137*, 1300–1312.
40. Liebrand, W. B., (1984). The effect of social motives, communication, and group size on behavior in an N-person multi-stage mixed-motive game. *European Journal of Social Psychology*, *14*(3), 239–264.
41. Lindh, T., (1992). The inconsistency of consistent conjectures: Coming back to Cournot. *Journal of Economic Behavior & Organization*, *18*(1), 69–90.
42. Madani, K., & Lund, J. R., (2011). A Monte-Carlo game theoretic approach for multi-criteria decision making under uncertainty. *Advances in Water Resources*, *34*(5), 607–616.
43. Maschler, M., (1963). The power of a coalition. *Management Science*, *10*(1), 8–29.
44. McKinsey, J. C. C., (1952). *Some Notions and Problems of Game Theory, 1*(1), 1–20.
45. Molinero, X., & Riquelme, F., (2021). Influence decision models: From cooperative game theory to social network analysis. *Computer Science Review*, *39*, 100343.
46. Morgenstern, O., (1949). The theory of games. *Scientific American*, *180*(5), 22–25.
47. Munck, G. L., (2001). Game theory and comparative politics: New perspectives and old concerns. *World Politics*, *53*(2), 173–204.
48. Naveed, R. T., Hussam Al, H. T. R., AlAbri, S., Fattah, F. A. M. A., & Uzir, M. U. H., (2021). Game theory: Historical overview and synthesizing critique. *International Journal of Social Sciences and Humanity Studies*, *13*(1), 127–151.
49. Niall, K. K., (2023). The theory of games of chance. In: *Johannes von Kries: Principles of the Probability Calculus: A Logical Investigation* (Vol. 1, No.1, pp. 31–46). Cham: Springer International Publishing.
50. Oskamp, S., (1971). Effects of programmed strategies on cooperation in the prisoner's dilemma and other mixed-motive games. *Journal of Conflict Resolution*, *15*(2), 225–259.
51. Palafox-Alcantar, P. G., Hunt, D. V. L., & Rogers, C. D. F., (2020). The complementary use of game theory for the circular economy: A review of waste management decision-making methods in civil engineering. *Waste Management*, *102*, 598–612.
52. Pearce, C., (2004). Towards a game theory of game. *First Person: New Media as Story, Performance, and Game*, *1*, 143–153.
53. Pruitt, D. G., & Kimmel, M. J., (1977). Twenty years of experimental gaming:

Critique, synthesis, and suggestions for the future. *Annual Review of Psychology*, *28*(1), 363–392.

54. Raghavan, T. E. S., (1994). Zero-sum two-person games. *Handbook of Game Theory with Economic Applications*, *2*, 735–768.
55. Raghavan, T. E. S., (2002). Non-zero-sum two-person games. *Handbook of Game Theory with Economic Applications*, *3*, 1687–1721.
56. Rapoport, A., & Kahan, J. P., (1984). Coalition formation in a five-person market game. *Management Science*, *30*(3), 326–343.
57. Rapoport, A., & Rapoport, A., (1990). Coalition formation in a five-person market game. *Experimental Studies of Interactive Decisions*, *1*(1), 295–316.
58. Read, D. W., & Read, C. E., (1970). A critique of Davenport's game theory analysis. *American Anthropologist*, *1*(1), 351–355.
59. Ribeiro, V. F., Weigang, L., Milea, V., Yamashita, Y., & Uden, L., (2015). Collaborative decision making in departure sequencing with an adapted Rubinstein protocol. *IEEE Transactions on Systems, Man, and Cybernetics: Systems*, *46*(2), 248–259.
60. Rizvi, S. A. T., (1994). Game theory to the rescue? *Contributions to Political Economy*, *13*(1), 1–28.
61. Roby, T. B., (1960). Critique and comment. *Behavioral Science*, *5*(3), 253–264.
62. Sanfey, A. G., (2007). Social decision-making: Insights from game theory and neuroscience. *Science*, *318*(5850), 598–602.
63. Satoh, A., & Tanaka, Y., (2019). Two person zero-sum game with two sets of strategic variables. *International Game Theory Review*, *21*(3), 1850014.
64. Savikhin, A. C., & Sheremeta, R. M., (2013). Simultaneous decision-making in competitive and cooperative environments. *Economic Inquiry*, *51*(2), 1311–1323.
65. Schmidt, C., (1990). Game theory and economics: An historical survey. *Rev'e D'économie Politique,1*(1), 589–618.
66. Schwalbe, U., & Walker, P., (2001). Zermelo and the early history of game theory. *Games and Economic Behavior*, *34*(1), 123–137.
67. Shubik, M., (1971). Games of status. *Behavioral Science*, *16*(2), 117–129.
68. Solum, L. B., (1987). On the indeterminacy crisis: Critiquing critical dogma. *U. Chi. L. Rev.*, *54*, 462.
69. Swedberg, R., (2001). Sociology and game theory: Contemporary and historical perspectives. *Theory and Society*, *30*(3), 301–335.
70. Van, B. J. H., & Marx, L. M., (2007). Exploring relations between decision analysis and game theory. *Decision Analysis*, *4*(1), 32–40.
71. Van, D. E., & De Dreu, C. K., (2021). Experimental games and social decision making. *Annual Review of Psychology*, *72*, 415–438.
72. Wan, Jr. H. Y., (1985). The new classical economics—A game-theoretic critique. In: *Issues in Contemporary Macroeconomics and Distribution* (Vol. 1, No. 1, pp. 235–257). London: Palgrave Macmillan UK.

73. Washburn, A., & Wood, K., (1995). Two-person zero-sum games for network interdiction. *Operations Research*, *43*(2), 243–251.

74. Wray, K., Kumar, A., & Zilberstein, S., (2018). Integrated cooperation and competition in multi-agent decision-making. In: *Proceedings of the AAAI Conference on Artificial Intelligence* (Vol. 32, No. 1, pp. 1–20).

75. Xiao, A., Zeng, S., Allen, J. K., Rosen, D. W., & Mistree, F., (2005). Collaborative multidisciplinary decision-making using game theory and design capability indices. *Research in Engineering Design*, *16*, 57–72.

76. Zhang, Z. X., Wang, L., & Wang, Y. M., (2018). An emergency decision making method for different situation response based on game theory and prospect theory. *Symmetry*, *10*(10), 476.

CHAPTER 7

Communicating with Decision Makers and Stakeholders

LEARNING OBJECTIVES

After studying this chapter, you will be able to:

- Understand the significance of determining clear communication objectives when engaging decision makers and stakeholders.
- Understand how to tailor communication approaches specifically for senior leaders, ensuring alignment with their perspectives and interests in decision-making processes.
- Understand effective techniques for communicating decision analysis results, with an emphasis on conveying key insights rather than overwhelming details.
- Understand best practices for presenting decision analysis results, both verbally and in written form.
- Understand the potency of illustrative examples in communication, using real-world applications to make complex concepts accessible and engaging.

INTRODUCTORY EXAMPLE

Consider a scenario where InnovateCorp International, a multinational corporation, finds itself at a crucial juncture, deliberating the launch of a new product line. As decision-makers and stakeholders convene to evaluate the strategic move, effective communication takes center stage. In the intricate landscape of decision analysis, the chapter on "Communicating with Decision Makers and Stakeholders" acts as a guiding beacon for InnovateCorp. Picture senior leaders navigating through intricate data, grappling with quantitative information, and deciphering complex analyses. The challenge isn't merely presenting these details but rather crafting a narrative that ensures these decision-makers grasp the essence—the key insights that will inform their strategic choices. This chapter becomes the compass for navigating this communication terrain for InnovateCorp, providing insights on determining objectives, tailoring messages for senior leaders, presenting decision analysis results, and employing illustrative examples to bridge the gap between intricate analyses and practical understanding.

UNIT INTRODUCTION

The approach of decision analysis is socio-technical. One of the utmost critical interpersonal abilities of a decision analyst is proficient communication. The transmitter, the communication, and the recipient are the three fundamental components of communication. It is imperative to recognize that the most efficient forms of communication involve transmitting, receiving, and providing the transmitter with feedback to confirm the receipt of the message. This diagram of fundamental communication is depicted in Figure 7.1. Both transmitting and receiving (listening) abilities are pivotal (Copp et al., 2021).

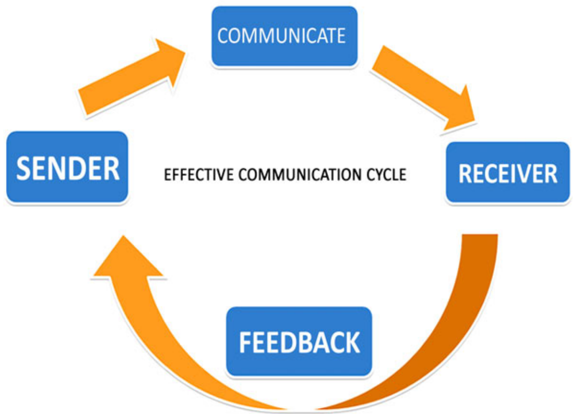

Figure 7.1. Diagram of communication (Source: Gregory, Creative Commons License)

The significance of listening is emphasized by one of the Seven Habits of Highly Effective People: "Seek first to understand, then to be understood." Furthermore, the message and the communication method are equally crucial. Different people have different preferred methods of learning: reading, listening, doing, telling tales, looking at pictures, and using charts and graphs (Johnson et al., 2020). When communicating with decision makers, stakeholders, and groups, the sender will be more successful if they are aware of and capitalize on the recipient's preferred learning style and employ a variety of communication modes.

The decision process, which emphasizes formal communication (dialog) between the decision analysis team and the decision team, will be discussed in this chapter. However, decision analysis communication involves several additional crucial communication channels (Treweek et al., 2013). The key participants and communication channels in decision analysis are illustrated in Figure 7.2. The study participants, including the study champion, internal stakeholder representatives, subject matter experts, and decision implementer representatives, the decision analysis team, consisting of the lead decision analyst and team members, the external decision makers, and the external stakeholders, are the main actors (Hutubessy et al., 2023).

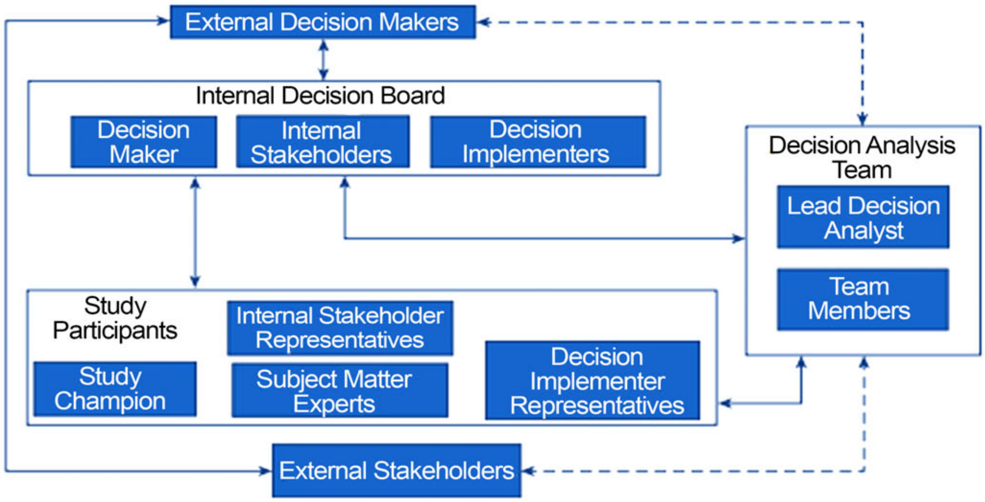

Figure 7.2. Flowchart of decision analysis participants and communication paths (Source: Greogry, Creative Commons License)

7.1. DETERMINING COMMUNICATION OBJECTIVES

Learning Objectives

- To understand the importance of defining clear and precise communication objectives for targeted and effective messaging.
- To understand the strategic alignment of communication objectives with broader organizational goals..

When preparing for a significant communication, the Decision Analysis Team (senders) must evaluate not only their own objectives but also those of the message recipients, which include Stakeholders (SHs), Decision Makers (DMs), and Subject Matter Experts (SMEs). A crucial component of effective communication is identifying communication objectives to include stakeholders and decision makers. The procedure entails figuring out the audience's particular needs, emphasizing the project's main messages and objectives, and developing concrete results that support the project's goals (Sato et al., 2020).

To guarantee an attentive and involved audience, establishing trust, responding to issues, and encouraging two-way contact are crucial elements of the communication objectives. Furthermore, the integration of quantifiable indicators streamlines the assessment of communication impact and offers a tactical method for effectively communicating information that is not only received but also understood and acted upon (Rogala et al., 2016).

Did you know?

Research indicates that the human brain has the capacity to make uncomplicated choices in as little as 0.1 seconds, demonstrating the extraordinary velocity at which our minds handle and react to information.

7.2. COMMUNICATING WITH SENIOR LEADERS

Learning Objectives

- To understand the importance of aligning communication with senior leaders' strategic perspectives for decision-making relevance.
- To acquire skills in tailoring communication specifically for senior leaders, considering their distinct roles and decision-making criteria.

Decision analysts must comprehend how senior leaders make decisions. Given their hectic schedules, senior leaders' time is one of their most valuable assets. They have gatekeepers that manage access to them and are difficult to meet. Developing the organization's vision and strategic goals is one of the main responsibilities of senior management. Senior executives always consider how a project aligns with their goals and vision. Therefore, it is crucial for the decision analyst to understand their objectives. Typically, we obtain this data through the stages of objective evaluation and conceptualization. If this knowledge is not easily accessible, the decision analysis champion serves as a useful secondary source. Finally, assigning resources to meet organizational goals is a key responsibility of senior leaders. This position often leads to the decision analyst interacting with the senior leader (Whitley & Chambers, 2009). Most of an analyst's academic and professional training is devoted to analytical methods. On the other hand, political factors, decision-making procedures, and organizational culture all play a role in the decision-making process.

An organization that has implemented a decision analysis process, such as the Dialog Decision Process, will have a significantly different decision analysis presentation compared to one that is utilizing decision analysis for the first time. Furthermore, decision makers are individuals who have their own experiences in decision-making, as well as knowledge of decision analysis techniques, information-learning preferences, and possibly emotional factors related to decision possibilities (Young & Post, 1993). For instance, a decision maker who has effectively utilized decision analysis for a significant decision will receive a markedly distinct presentation than one who is encountering a decision analysis presentation for the first time, or who has recently encountered an issue with another analytical technique. Decision analysts, in my estimation, must deliver robust analytical findings in a manner that aligns with the organizational, political, and personal knowledge and beliefs of the decision maker(s) involved. This objective is visually depicted in Figure 7.3 (Harris & Kim Barnes, 2006).

Diverse stakeholder groups that will be impacted by decisions differently are frequently brought together for decision assessments. In a perfect world, all parties' values could be elicited by the decision analyst in a fashion that results in consensus. Consensus is not always possible in the actual world; this is not because our methods of reaching consensus are ineffective, but rather because there might not be a motivation or an incentive to reach consensus.

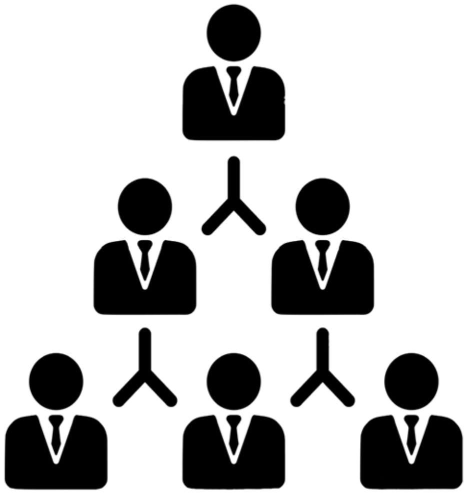

Figure 7.3. Diagram of communication tree with senior management (Source: Ian James Wright, Creative Commons License)

There is little reason to expect consensus when it comes to many problems when the values stakeholders appear to be at odds with one another. However, a choice that will undoubtedly annoy some parties must be taken. One of the most useful uses of decision analysis models is to pinpoint the areas of agreement and disagreement in both probability and core objectives, then use this information as a starting point for resolving conflicts. Decision analysis can help us focus on and explain the "real" issues by offering a rational, separate framework for discussion. Emotions have the potential to obscure the true nature of the debate and obstruct decision-making based on the decision rules. (Wang et al., 2023).

Remember

Visualization can have a significant impact on decision-making. Studies have shown that individuals who visualize the steps necessary to achieve a goal are more likely to succeed, thus emphasizing the cognitive influence of mental imagery.

7.3. COMMUNICATING DECISION ANALYSIS RESULTS

Learning Objectives

- To effectively convey key insights instead of overwhelming details when presenting decision analysis results.
- To develop strategies for communicating quantitative information clearly and succinctly.

Analysts often convey incorrect information. It is of utmost importance that decision maker(s) and other relevant stakeholders comprehend and appreciate the value of their message, even if their medium and communication styles are clear to them. While complex models such as influence diagrams, decision trees, NPV models, and MODA value hierarchies are often necessary for conducting thorough analysis, they may not always be the most effective means of communicating findings and insights to the intended audience (Politi et al., 2011).

7.3.1. Communicate only Key Insights

It is natural to want to draw attention to the specifics of the analysis that bolster the validity of the findings and ensure that the decision-maker goes through the entire process of analysis. When communicating with decision makers, it is important to highlight the most significant points instead of providing them with too many details. Because decision makers frequently have limited time, they need information that is clear and useful to make well-informed decisions. Using this method, complicated data is reduced to meaningful, actionable insights that are in line with strategic goals. Decision makers may quickly understand the implications by concentrating on the most important lessons, which enables them to act decisively and efficiently. This communication approach respects the time of decision makers and increases the possibility that important factors influencing the decision-making process will be well received and understood (Stevens, 2011).

Decision analysts often believe that once the analysis is completed, their work is essentially finished. They have gathered the necessary information to conduct a reliable and defensible analysis using the best methodologies, approaches, technologies, and tools, and they are ready to provide their recommendations to the decision-maker. However, this is where most analyzes fall short because the analyst fails to recognize that conveying the results is the most important and often flawed aspect of the analytical process. The primary author always reminds decision analysts that "when the analysis is finished, the job is 50% done" to emphasize this point. The results are in the analysts' hands, but it is their responsibility to identify the most significant takeaways and determine the best way to present them to stakeholders and decision-makers. One crucial soft skill is the ability to communicate the findings of the analysis. This is the stage in the process that poses the greatest challenge to some decision analysts (Choo, 1996).

7.3.2. Communicating Quantitative Information

It is important for decision analysts to use graphical excellence principles while communicating. The Edward Tufte book series is one of the greatest places to go for guidance on presenting quantitative data beautifully. Tufte defined graphical excellence as the intelligent amalgamation of substance, statistics, and design in the well-designed display of compelling facts. It consists of intricate concepts conveyed in an effective, precise, and clear manner (Gibson et al., 2013). The recipient can view the most concepts in the quickest amount of time using the least amount of ink in the smallest amount of space when there is graphic brilliance. Having a well-chosen format and design; combining text, numbers, and drawings; reflecting balance, proportion, and a sense of pertinent size are some fundamentals of visual quality. Exhibit a comprehensible level of detail; convey a tale; illustrate in a professional manner using meticulous replication; and stay away from "chartjunk," which obscures the content (Price et al., 2007).

Both bad and good examples of graphical presentations can be found throughout Tufte's works. Tufte is regarded as one of the world's leading authorities on the communication of quantitative information, although other aspects of his work—like his contempt for PowerPoint presentations—have generated controversy. Each decision analyst must determine for themselves what aspects of Tufte's philosophy appeal to them and should modify his or her suggestions for communications to fit their own needs and preferences (Longman et al., 2012).

7.3.3. Determining and Telling the Story

To effectively communicate decision analysis results, two steps must be taken. First, a clear and structured narrative should be defined to summarize the most important discoveries and insights. This narrative should reflect the priorities of decision-makers. Second, storytelling strategies should be employed to translate analytical results into an engaging and understandable style. Complex analyzes can be made easier to comprehend by utilizing logical flow, visual aids, and examples from everyday life. When the precision of decision analysis is combined with the skill of storytelling, communication becomes a powerful tool for influencing decisions and promoting a better understanding of complex analytical results (Soleimani & Khandan, 2013).

7.3.4. Best Practices for Presenting Decision Analysis Results

Following is a list of the communications lessons learned from years of professional practice:

i. Develop a communication plan
ii. Know the audience
iii. Review the decision frame

iv. Review the objectives of the decision team
v. Determine the story
vi. Develop the presentation
vii. Deliver the presentation (Marsh et al., 2016).

7.3.5. Best Practices for Written Decision Analysis Results

In addition to, or instead of, attending a formal presentation, some decision makers prefer to read a written report. In this case, we recommend that the decision analysis team prepare a written report of the decision analysis, following the best practices for presentations discussed in the previous section. Analysts should use a common structure for study reports, which is widely used in many businesses. Here are some guidelines for writing reports that are recommended (Thokala et al., 2016):

1. **Write an executive summary**: The executive summary should provide a concise overview of the report. It should cover the decision framework, objectives, alternatives, decision analysis technique, analysis, potential value addition, recommendation(s), and implementation strategy. The executive summary is arguably the most important section of the report, similar to the BLUF (Bottom Line Up Front) chart. Senior executives and key stakeholders are more likely to read the executive summary rather than the entire report, so it will have the greatest impact (Nishimura et al., 2014).

2. **Make the report readable to the audience**. The intended audience should be able to read the technical report. Definitions of technical words should be provided. For the busy reader who is unfamiliar with decision analysis words or domain jargon, a glossary can be of great assistance (Hrasky & Smith, 2008).
3. **Use appendices for technical details.** Appendices should typically contain technical information on the models, specific analysis results, and the complete results of the sensitivity analysis. This makes it simple for interested readers to obtain (Mauskopf et al., 2018).

PRACTICE PROBLEM

Imagine you are tasked with communicating the results of a complex financial analysis to both senior leaders and stakeholders. Define two specific communication objectives for each group, considering the unique needs and interests of senior leaders and stakeholders.

SOLUTIONS TO PRACTICE PROBLEM

Communication Objectives:

For Senior Leaders:

1. Clearly articulate the financial impact of the analysis on key performance indicators, focusing on profitability and return on investment.

   Tailor messages to highlight strategic implications and long-term financial benefits, aligning with the organization's overarching goals.

For Stakeholders:

1. Communicate the analysis in a clear and understandable manner, avoiding technical jargon, and highlighting the practical implications for the stakeholders.

   Address specific concerns and questions that stakeholders may have about the financial analysis, promoting transparency and fostering engagement.

7.4. COMMUNICATING INSIGHTS IN THE ILLUSTRATIVE EXAMPLES

Learning Objectives

- To effectively use illustrative examples for clearer communication of complex concepts.
- To effectively convey insights to stakeholders, it is important to understand the strategic application of real-world scenarios, such as the Roughneck North America Strategy and Geneptin.

A systematic approach is necessary to effectively communicate insights, particularly when utilizing instructive examples. These illustrations serve as powerful tools to clarify challenging concepts and enhance the accessibility of insights for a wider audience (Bromme et al., 2005). Carefully selecting examples that resonate with the audience is an integral part of the process to ensure relatability and relevance. Decision makers can grasp important insights through concise and straightforward storytelling, bridging the gap between complex analysis and practical comprehension. The use of illustrative examples makes communication both educational and engaging, thereby strengthening the connection between analytical findings and the decision-making process (Llewellyn & Harrison, 2006).

7.4.1. Roughneck North America Strategy

Several RNAS charts aided in illustrating the findings of a particular analysis. Here, we concentrate on the Tar Sands narrative. Opportunities for a intricate decision to be clearly presented in a decision tree. The analytic team endeavored to present the rationale behind their proposal to top stakeholders after they had discovered it. They determined that the decision regarding future scale-up and the oil price at the time should be communicated the most, and they created a simple decision tree that depicts this relationship (refer to Figure 7.4). The simulation's Tar Sands EV values were displayed, rounded to $10M. Inferred probabilities were derived from the simulation. Even in scenarios with favorable oil prices, the Full-Scale Plant's immediate construction failed because operating expenditure reductions from the pilot plant's experience were unavailable. Due to the fact that it generates an option to proceed only when the price of oil exceeds $60, the pilot plant option has a positive value (Lloyd et al., 2005).

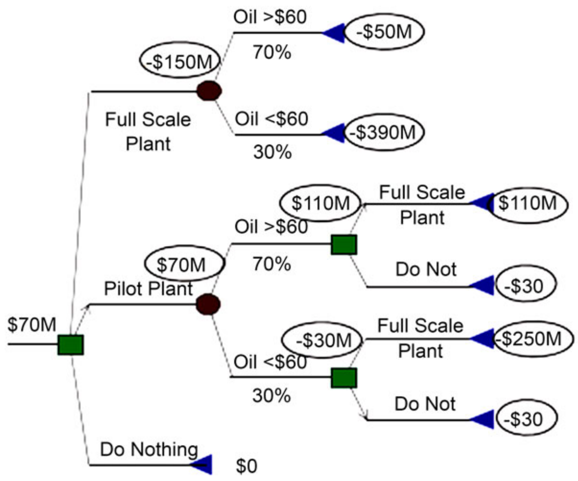

Figure 7.4. Illustration tar sands decision tree (Source: Terry, Creative Commons License)

7.4.2. Geneptin

Regarding those involved in the Geneptin case, the soaring bar chart (Figure 7.5) and the cascading chart (Figure 7.6) were the two most noteworthy visual aids. The soaring bar chart demonstrated that despite the personalized strategy's higher expected value and significantly greater potential for success compared to the conventional strategy, it carried the same level of risk.

The cascading chart elucidated the reasons behind this phenomenon: while the smaller patient population of the personalized strategy posed a challenge, it was more than compensated for by the segment's larger market share, extended patient treatment duration (attributable to longer life expectancies), and higher price (stemming from Geneptin's more compelling value propositions by exclusively targeting the HER2-positive patient segment) (Lingard et al., 2023).

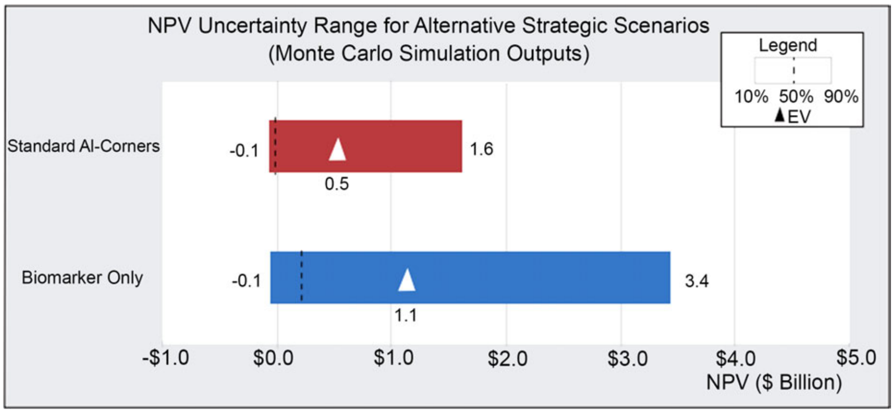

Figure 7.5. Representation of Geneptin flying bar chart (Source:Steven, Creative Commons License)

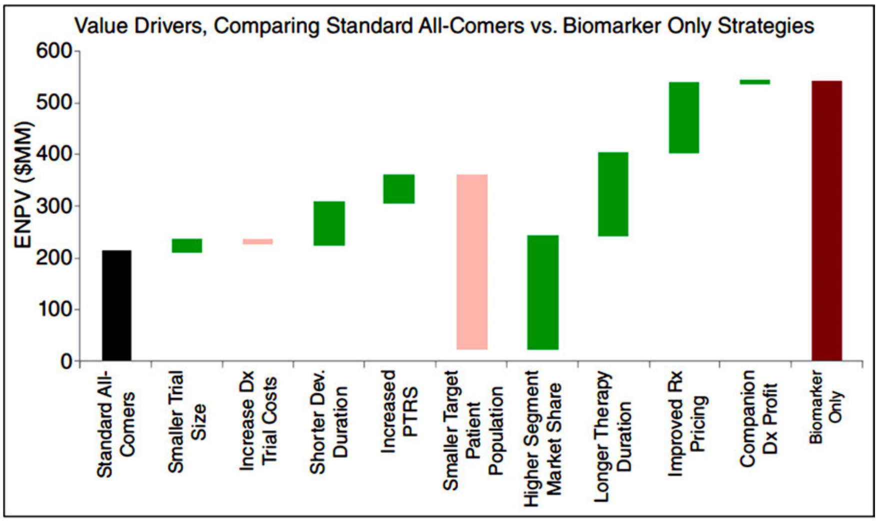

Figure 7.6. Representation of Geneptin waterfall chart (Source: Steven, Creative Commons License)

7.4.3. Data Center Location

The cost vs value plot in Figure 7.7 was the chart that best illustrated the analysis used to make the data center site selection (Bash & Forman, 2007). The decision makers were able to comprehend the value added for the increased cost of the dominant options by using a visualization of this data to immediately identify the dominated alternatives (Zhang & Liu, 2022). One can observe that Tennessee and Washington states outperform the other options in our data center challenge. Squares are used to indicate nondominated options and diamonds to indicate dominated alternatives in Figure 7.7. Using value component and waterfall charts, this chart concentrated decision makers on comparing the two non-dominated alternatives (Lei & Masanet, 2020).

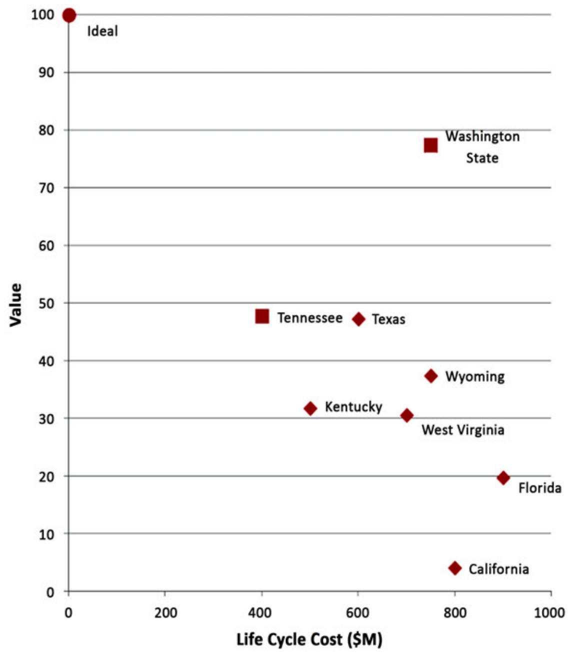

Figure 7.7. Illustration of data center cost versus value plot (Source: Steven, Creative Commons License)

Keyword

BLUF (Bottom Line Up Front): The BLUF chart is an early chart in a presentation that summarizes the story, the major analysis results, and recommendations.

SUMMARY

- This chapter aims to highlight the challenges involved in conveying the results of decision analyzes to decision makers and other stakeholders in the decision team, while also providing best practices in this area.
- Having knowledge of an organization's official and informal communication channels is crucial for decision analysts. The communication objectives of the decision analysis team typically change at each stage of the process when interacting with the decision maker, stakeholders, and subject matter experts.
- Due to time constraints, decision analysts face the difficult task of communicating with senior leaders. We believe that for a decision analyst to be successful, they must produce robust analytical findings that consider the political and organizational context, as well as the cognitive preferences of the decision maker(s).
- The inherent value of the decision model may lie in its ability to tell a story. Even an excellent analytical study may be doomed from the start if it overlooks a critical organizational or political issue. If the decision maker does not grasp a sound investigation, it is unlikely to succeed.
- Effective communication techniques in the context of decision analysis are the main focus of this chapter on Communicating with Decision Makers and Stakeholders. Establishing communication objectives is a crucial initial step in the process, as it ensures that communications are not only delivered but also understood and responded to.
- The chapter explores certain topics, such as communicating with senior executives, highlighting the necessity of customized strategies that take into account their viewpoints and areas of interest. It emphasizes that when communicating decision analysis results, it is crucial to focus on significant insights rather than excessive details.
- The chapter also examines methods for communicating numerical data and emphasizes the importance of selecting and presenting a compelling narrative to enhance comprehension. Additionally, it includes best practices for presenting and documenting decision analysis results.

MULTIPLE CHOICE QUESTIONS

1. What is the primary focus of determining communication objectives in decision analysis?

a. Presenting detailed information

b. Tailoring messages to audience needs

c. Highlighting project complexities

d. Offering subjective opinions

2. For the chapter section "Tell the Decision Maker the Key Insights and Not the Details," what is the recommended approach for communication?

a. Provide exhaustive details

b. Emphasize key insights

c. Focus on complex explanations

d. Avoid decision maker involvement

3. What does "Communicating Quantitative Information" in decision analysis entail?

a. Excluding numerical data

b. Emphasizing qualitative aspects

c. Effectively presenting numerical data

d. Avoiding data altogether

4. According to the chapter, what is the emphasis of "Determining and Telling the Story" in communicating decision analysis results?

a. Presenting raw data

b. Creating an engaging narrative

c. Ignoring analytical outcomes

d. Avoiding visual aids

5. What is highlighted in the "Best Practices for Presenting Decision Analysis Results" section of the chapter?

a. Omitting key findings

b Encouraging ambiguity

c. Following ineffective practices

d. Recommended practices for effective presentation

REVIEW QUESTIONS

1. How does determining communication objectives enhance communication with decision makers and stakeholders?
2. Why is emphasizing key insights, rather than details, crucial when communicating decision analysis results?
3. What strategies ensure effective presentation of quantitative information in decision analysis?
4. What elements are essential for creating an engaging narrative in "Determining and Telling the Story"?
5. Summarize key best practices for presenting decision analysis results.
6. Explore the significance of "Best Practices for Written Decision Analysis Results" and how it contributes to effective communication.

7. How does the use of illustrative examples contribute to effective communication of insights? Provide specific examples from the chapter?

Answers to Multiple Questions

1. (b) 2. (b) 3. (c) 4. (b) 5. (d)

REFERENCES

1. Bash, C., & Forman, G., (2007). Cool job allocation: Measuring the power savings of placing jobs at cooling-efficient locations in the data center. In: *USENIX Annual Technical Conference* (Vol. 138, p. 140).
2. Bromme, R., Jucks, R., & Runde, A., (2005). Barriers and biases in computer-mediated expert-layperson-communication: An overview and insights into the field of medical advice. *Barriers and Biases in Computer-Mediated Knowledge Communication: And How They May be Overcome, 10*(4), 89–118.
3. Choo, C. W., (1996). The knowing organization: How organizations use information to construct meaning, create knowledge and make decisions. *International Journal of Information Management*, *16*(5), 329–340.
4. Copp, G. H., Vilizzi, L., Wei, H., Li, S., Piria, M., Al-Faisal, A. J., & Mendoza, R., (2021). Speaking their language–development of a multilingual decision-support tool for communicating invasive species risks to decision makers and stakeholders. *Environmental Modeling & Software*, *135*, 104900.
5. Gibson, J. M., Rowe, A., Stone, E. R., & Bruine De, B. W., (2013). Communicating quantitative information about unexploded ordnance risks to the public. *Environmental Science & Technology*, *47*(9), 4004–4013.
6. Harris, J., & Kim, B. B., (2006). Inspirational leadership: Involving senior leaders in developing the next generation. *Industrial and Commercial Training*, *38*(4), 196–200.
7. Hrasky, S., & Smith, B., (2008). Concise corporate reporting: Communication or symbolism? *Corporate Communications: An International Journal*, *13*(4), 418–432.
8. Hutubessy, R., Lauer, J. A., Giersing, B., Sim, S. Y., Jit, M., Kaslow, D., & Botwright, S., (2023). The full value of vaccine assessments (FVVA): A framework for assessing and communicating the value of vaccines for investment and introduction decision-making. *BMC Medicine*, *21*(1), 229.
9. Johnson, J. A., Sutton, S. G., & Theis, J. C., (2020). Prioritizing sustainability issues: Insights from corporate managers about key decision-makers, reporting models, and stakeholder communications. *Accounting and the Public Interest*, *20*(1), 28–60.
10. Lei, N., & Masanet, E., (2020). Statistical analysis for predicting location-specific data center PUE and its improvement potential. *Energy*, *201*, 117556.
11. Lingard, L., Chandritilake, M., De Heer, M., Klasen, J., Maulina, F., Olmos-Vega, F., & St-Onge, C., (2023). Will ChatGPT's free language editing service level the playing field in science communication? Insights from a collaborative project with non-native English scholars. *Perspectives on Medical Education*, *12*(1), 565.

12. Llewellyn, N., & Harrison, A., (2006). Resisting corporate communications: Insights into folk linguistics. *Human Relations*, *59*(4), 567–596.

13. Lloyd, D., Van, N. P., & Boyd, W. E., (2005). Letting indigenous people talk about their country: A case study of cross-cultural (mis) communication in an environmental management planning process. *Geographical Research*, *43*(4), 406–416.

14. Longman, T., Turner, R. M., King, M., & McCaffery, K. J., (2012). The effects of communicating uncertainty in quantitative health risk estimates. *Patient Education and Counseling*, *89*(2), 252–259.

15. Marsh, K., IJzerman, M., Thokala, P., Baltussen, R., Boysen, M., Kaló, Z., & Devlin, N., (2016). Multiple criteria decision analysis for health care decision making—Emerging good practices: Report 2 of the ISPOR MCDA emerging good practices task force. *Value in Health*, *19*(2), 125–137.

16. Mauskopf, J., Standaert, B., Connolly, M. P., Culyer, A. J., Garrison, L. P., Hutubessy, R., & Severens, J. L., (2018). Economic analysis of vaccination programs: An ISPOR good practices for outcomes research task force report. *Value in Health*, *21*(10), 1133–1149.

17. Nishimura, R. A., Otto, C. M., Bonow, R. O., Carabello, B. A., Erwin, III. J. P., Guyton, R. A., & Thomas, J. D., (2014). 2014 AHA/ACC guideline for the management of patients with valvular heart disease: Executive summary: A report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines. *Circulation*, *129*(23), 2440–2492.

18. Politi, M. C., Clark, M. A., Ombao, H., Dizon, D., & Elwyn, G., (2011). Communicating uncertainty can lead to less decision satisfaction: A necessary cost of involving patients in shared decision making? *Health Expectations*, *14*(1), 84–91.

19. Price, M., Cameron, R., & Butow, P., (2007). Communicating risk information: The influence of graphical display format on quantitative information perception—Accuracy, comprehension, and preferences. *Patient Education and Counseling*, *69*(13), 121–128.

20. Rogala, A., Bialowas, S., Rogala, A., & Bialowas, S., (2016). Functions and objectives of internal communication. *Communication in Organizational Environments: Functions, Determinants and Areas of Influence*, *74*(3), 65–97.

21. Sato, A., Honda, K., Ono, K., Kanda, R., Hayashi, T. I., Takeda, Y., & Murakami, M., (2020). Reviews on common objectives and evaluation indicators for risk communication activities from 2011 to 2017. *PeerJ*, *8*, 9730.

22. Soleimani, H., & Khandan, M., (2013). The effect of telling short stories on learning grammar among EFL high school students in Iran. *International Journal of Language Learning and Applied Linguistics World*, *4*(2), 110–122.

23. Stevens, A., (2011). Telling policy stories: An ethnographic study of the use of evidence in policy-making in the UK. *Journal of Social Policy*, *40*(2), 237–255.

24. Thokala, P., Devlin, N., Marsh, K., Baltussen, R., Boysen, M., Kalo, Z., & Ijzerman, M., (2016). Multiple criteria decision analysis for health care decision making—An

introduction: Report 1 of the ISPOR MCDA emerging good practices task force. *Value in Health*, *19*(1), 1–13.

25. Treweek, S., Oxman, A. D., Alderson, P., Bossuyt, P. M., Brandt, L., Broćek, J., & Decide Consortium, (2013). Developing and evaluating communication strategies to support informed decisions and practice based on evidence (DECIDE): Protocol and preliminary results. *Implementation Science*, *8*, 1–12.
26. Wang, C., Cardon, P. W., Li, C. R., & Li, C. X., (2023). The influences of open communication by senior leaders and legitimacy judgments on effective open innovation. *International Journal of Business Communication*, *60*(3), 912–931.
27. Whitley, L. T., & Chambers, B. T., (2009). Strategic communications in a complex world: How senior executives successfully plan and communicate in global enterprises. *International Journal of Coaching Organizations*, *7*(2), 6–18.
28. Young, M., & Post, J. E., (1993). Managing to communicate, communicating to manage: How leading companies communicate with employees. *Organizational Dynamics*, *22*(1), 31–43.
29. Zhang, Y., & Liu, J., (2022). Prediction of overall energy consumption of data centers in different locations. *Sensors*, *22*(10), 3704.

CHAPTER

8 Decisions and Ethics

LEARNING OBJECTIVES

After studying this chapter, you will be able to:

- Explain the role of ethics in decision-making.
- Explain action-based vs consequence-based ethics.
- Classify actions as legal, prudential, and ethical.
- Explain positive vs negative injunctions.
- Explain the concept of building an ethical code..

INTRODUCTORY EXAMPLE

Ethically making decisions is vital in both the personal and professional spheres. It requires assessing the ethical ramifications of a choice and selecting the course of action that is consistent with one's values and beliefs. Making good ethical decisions in business can also improve the relationship with employees. Consider a company like Costco. Much of Costco's success comes from the high level of customer service offered by satisfied employees. One reason why Costco can attract high-quality employees is its willingness to pay higher-than-average wages. For example, Costco raised its base wage from $13 an hour to $14 an hour in 2018 and $15 per hour in 2019. Making ethical decisions is crucial for a variety of reasons. Establishing trust and credibility with stakeholders, such as consumers, employees, and investors, is an initial benefit. It fosters a sense of accountability and responsibility among employees and cultivates a positive work environment. Legal and financial hazards that may result from unethical conduct are also circumvented. All in all, the establishment of a just and equitable society that upholds the rights and dignity of every individual requires ethical decision-making.

UNIT INTRODUCTION

This chapter introduces ethical vocabulary and concepts that help guide decisions from an ethical perspective. Moral standards define what is right and wrong. The goal of this chapter is to provide enough background information to make decisions more ethically aware, rather than to give a comprehensive history and analysis of the discipline of ethics. Poor decision quality is frequently caused by a lack of awareness of ethical concerns (Stutchbury & Fox, 2009). It is advised that individuals judge their conduct based on this ethical discussion rather than the behavior of others. Pay attention to the introspection that can lead to awareness and ensuing transformation. As will be observed, this chapter does not advocate for a particular set of ethics; rather, it offers distinctions for comprehending and evaluating ethical situations, allowing readers to determine the role ethics should play in their decisions (Janvier et al., 2008).

8.1. THE ROLE OF ETHICS IN DECISION-MAKING

Learning Objectives

- Learn the essence of ethics in personal decision-making and navigate ethical dilemmas.

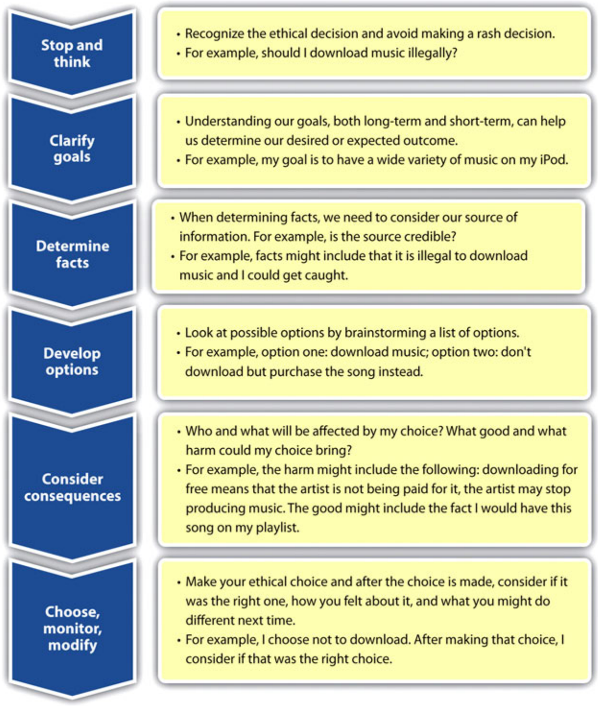

Figure 8.1. Representation of a decision-making model when dealing with an ethical situation of downloading music from share websites (Source: Lordbucket, Creative Commons License)

When teaching ethics, lecturers begin by having students recount instances in their private or professional lives where they have faced ethical challenges. Nearly everyone can share their experiences. For instance, one student reported seeing a man at a post office who had a stack of letters and stamps. Every letter was stamped by the man before being mailed. The student saw that the man left behind a stamp along with a letter at the place where he was previously working after he left the postal office. After mailing the letter, the student put a stamp on it. He wondered later if this was the man's intention to post this letter (Drumwright et al., 2015).

Another student described a challenge encountered while working for a software firm that was organizing a significant global product exhibition. In addition to creating a program that could solve prevalent issues twice as quickly as its rivals, the company also created a real-time demo in which equipment would run its own and its rivals' software concurrently to fix the same issue. The plan was for prospective clients to personally witness the benefits of the company's initiative. A problem that had little to do with the program arose shortly before our departure for the exposition, which unfortunately hindered the live demonstration (Green, 1997). However, we did have stored files from previous sessions that could create the illusion that the machine in the presentation was addressing the issue, when in reality it was simply following the predetermined files. Without disclosing that the machine was not executing the code in real time, the firm managers requested the student to proceed with the demo. Another student, employed by a business that guaranteed to deliver a product to a customer, discovered during initial testing that the device was not performing as effectively as promised in the contract. In an upcoming meeting, the managers requested that the student refrain from discussing these results with the client, assuring him that it would not make a difference since they would ensure that everything worked out in the end (Pasewark & Riley, 2010).

Nevertheless, the student had to make a choice. Students who bring up such incidents in class demonstrate their discomfort with past behaviors. The class provides them with an opportunity to reflect on how they would respond in similar circumstances or how they can avoid finding themselves in such situations in the future. When faced with a moral dilemma, it can be challenging to think effectively about one's ethical principles. Ethical dilemmas often involve a complex web of conflicting principles and can be emotionally taxing. Additionally, situations that require ethical sensitivity sometimes demand a prompt resolution (Kreie & Cronan, 1998).

8.2. ETHICAL DISTINCTIONS

Learning Objectives

- Classify acts into three major categories with examples.
- Incorporate these distinctions into the decision-making processes.

8.2.1. Classifying actions: Prudential, legal, Ethical

It is useful to categorize acts into three categories: prudential, legal, and ethical throughout the ethical talks. Prudent behavior is defined as acting in one's own best interests, which may or may not consider the impact on others or take legal or moral issues into account. For instance, most of us have a self-interest in ensuring our children's well-being. In either the short or long run, the action may be prudent (Childress, 1977). A few examples of prudential decisions that might not be morally or legally questionable are purchasing a stereo, upgrading one's educational background, or replacing the oil in the car. Prudent acts that are legally or morally delicate include keeping or terminating a pregnancy based on the gender of the fetus and keeping cash from a wallet that is dropped. If one believes that returning the money—even in secret—will inspire others to do the same for you in the future, then your choice to do so can even be seen as smart. The adage "Honesty is the best policy" may apply only in a prudential sense (Nucci et al., 1991).

Consider the situation where a parent steals food to provide for their child. This behavior, which would be termed as prudential, puts the ethical precept of avoiding theft in opposition to the prudential consideration for taking care of one's children (Slote, 2023). The book's presentation of decision analysis has primarily focused on prudential considerations thus far. The legality of an action depends on whether it is mandated or prohibited by law in the current location. The nature of the law is inherently coercive, as it implies the use of force against individuals or assets. By breaking the law, which includes the use of certain narcotics or committing assault, one exposes oneself to the risk of bodily harm or loss of property. Failure to file tax returns or report for military duty, if one breaks the law, may result in physical harm or the loss of valuable possessions (Schrag, 2005).

Whether or not a course of action is legal, it is ethical if it is morally right. It is feasible to follow the law exclusively as the morality of an individual. For instance, the Nuremberg trials were predicated on the differentiation between morally and legally acceptable behavior. While their society considered the actions of the people providing sanctuary to Anne Frank to be illegal, they believed that what they were doing was morally right. Similar, but less risky, circumstances exist for Americans who host illegal immigrants from Central America in their churches (Beauchamp, 1984). On the other hand, behavior could be lawful but unethical. For instance, deliberately misleading a stranger is not illegal even though it may be morally repugnant. Whether a particular action is intelligent or sagacious is the overall assessment one can make of it. When something is prohibited, even something otherwise clever (like selling wine in the US in Prohibition) may become foolish (Reader, 2006). Abortion is considered pragmatic, unethical, legal, and foolish by some. The same action could be reasonable, moral, unlawful, and wise in the eyes of others. Figure 8.2 assists in elucidating the distinction between the legal, prudential, and ethical positions. Whether or not a decision is prudential, legal, or ethical defines seven potential zones (Kass et al., 2013).

PRACTICE PROBLEM

As a leader, your decisions affect your company's culture, employees' motivation and productivity, and the effectiveness of business processes. With such a significant impact on your company's performance, here are seven ways to improve your ethical decision-making:

SOLUTION TO PRACTICE PROBLEM

i. Gain clarity around personal commitments
ii. Overcome biases: both explicit and implicit
iii. Reflect on past decisions
iv. Be compassionate and make decisions (like termination) empathetically by imagining yourselves in someone's shoes too
v. Be fair and just: Legitimate expectations, procedural fairness, and distributive fairness
vi. Take an individualized approach
vii. Accept feedbacks

8.2.2. Eliminating Alternatives from the Decision Tree

The distinctions between ethical, legal, and prudential principles can now be used in the decision-making processes. Assume, for instance, that one has chosen never to break the law and that one of the options is unlawful (Twala, 2009). This implies that one can eliminate any illegal acts from the list of options and that one would only consider legal acts. Additional instances, including those that occur in the corporate world, could include accepting or offering bribes. Receiving knowledge that is unlawful yet economically significant and relevant to decision-making scenarios, like insider trade information, could be another example (Mahjoobi & Etemad-Shahidi, 2008). If, as one has decided, he/she will not perform any criminal acts, then one will do away with all such decisions. Some circumstances are not as clear-cut. For instance, if one has moral concerns with the way the proprietors of that company conduct business, one might be able to combine with them. Even if the merger makes sense legally and prudently, one might still choose to rule out this alternative from the list of alternatives if it goes against moral principles (Awad & Fraihat, 2023).

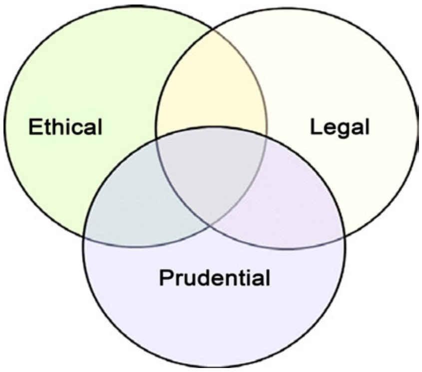

Figure 8.2. Classifying situations as ethical, legal, and prudential (Source: Ronald & Ali, Creative Commons License)

8.2.3. Classifying Ethical Theories

Ethical dilemmas can be classified according to two main ethical theories: Action-based ethics or ethical formalism, and consequence-based ethics or utilitarianism.

8.2.3.1. Action-Based Ethics

Formalism in ethics is action-oriented. According to this perspective, one's acts carry ethical weight regardless of the results. This notion states that attempting to commit murder would be the same as committing murder. The fact that the perpetrator's plans were foiled by fate does not release them from accountability. The creator of ethical formalism was Immanuel Kant. Kant argues that formalist ethics ought to apply to everyone. He promoted acting morally and in accordance with what one would want other people to do. For instance, one should only adhere to the ethic of "always tell the truth" if they want everyone else to do the same. This would entail expecting others to share their opinions with you rather than just what you want to hear. The question can be posed, "How many individuals in the classroom would like a complimentary fresh function for their car?" to illustrate this point. One will always hear what they would like to hear thanks to the unique instrument (Graf, 2011). The speedometer will always indicate that the individual is not going over the posted speed limit while they are approaching a traffic enforcement officer. Although nobody desires these instruments, those who claim to have them frequently lie to their friends out of concern for their feelings. In ethical formalism, excusing conditions, or exemptions, are permissible if they can be consistently universalized. An ethical formalist might, for instance, believe that murdering someone in self-defense is justified. Formalists might also believe that lying is appropriate in any circumstance where one is facing coercion or the possibility of coercion. They meet the requirements for reasonable justification as long as one can state that they want everybody to be allowed to act by these exceptions. Decision analysis is a useful tool for ethical formalists when making morally challenging choices. After ruling out the unethical options, they are left with just legally and prudentially sound options (Anderson et al., 2005).

8.2.3.2. Consequence-Based Ethics

Utilitarianism, the other primary ethical philosophy, is a consequence-based view. The consequences bear accountability, not the individual. This idea holds that even in cases when the criminal made efforts to prevent injury to others and had no intention of killing, the death caused by the crime is still considered murder. This perspective is supported by the offense of felony murder. Philosophers like Jeremy Bentham and John Stuart Mill, who held that behavior must be justified based on the measure of contentment and worldly pleasure, are the originators of utilitarianism (Royzman et al., 2020). "The end justifies the means" is a common characteristic of an ethic that is consequence-based. If you thought lying would result in a positive outcome, then it might be justified. The idea of "accomplishing the greatest benefit for the greatest number" is yet another utilitarian concept. Applying the rules as usual and employing their ethical preferences for prospects, utilitarians can use decision analysis to make their ethically mindful decisions. Because decision analysis offers a formal framework for expressing moral decisions—including those involving uncertainty—it helps to make ethical conversations more understandable. In ethical conversations, it is similarly helpful to draw the distinction that is essential to decision analysis between making a good decision and getting a good outcome. The structure applies to ethical formalists only after eliminating all unethical alternatives; it applies to utilitarians in its original form (Michaels et al., 2005).

Did you know?

In ethical philosophy, utilitarianism is a family of normative ethical theories that prescribe actions that maximize happiness and well-being for the affected individuals. In other words, utilitarian ideas encourage actions that ensure the greatest good for the greatest number.

8.2.4. Classifying Ethics: Positive vs. Negative Injunctions

Another important classification of ethical injunctions is whether they are negative or positive. Negative injunctions are prohibitions, such as "I will not." Following negative rules requires no energy. Most people follow the rule that they will not murder. It is insightful to investigate some of the teachings of different religions and classify them as either positive or negative (Tonry, 2014). For example, in the Ten Commandments, there are several negative injunctions, such as "Thou shalt not murder, commit adultery, bear false witness, steal, or covet." In contrast, positive injunctions are obligations, such as "I will." The challenge with positive injunctions is knowing where to draw the line. Including positive injunctions in an ethical code requires some circumspection. A milder way of expressing sentiment might be to say, "I have a positive regard for feeding the poor." One can then decide what actions are appropriate given their limited energy and resources. In some countries, taking positive action in certain situations is required by law (Burks & Krupka, 2012).

8.3. HARMING, STEALING, AND TRUTH-TELLING

Learning Objectives

- Understand how people use deception to convince without lying.
- Know how a positive ethic of 'telling complete truth' can resolve moral conflicts.
- Understand the consequences of telling the complete truth.

Which activities are the most morally dubious? The majority would rank killing or assaulting innocent individuals at the top of the list. Stealing to obtain another person's property would come next. Since both acts were common during the Nazi era, one could wonder why such evil could exist in a nation with such advanced technology and culture. These days, similar evils are not uncommon, therefore one needs to be aware of their possible role (Bloomquist, 2010).

The question of whether one would manufacture or market a product that is considered detrimental to other people is a classic instance of an ethical dilemma involving possible harm. Even if one may have a bad ethic and abstain from harmful acts, they still want to avoid using the legal system to forcibly impose it on other people (Cohen, 1998).

One might also adhere to an ethical stance that prescribes the use of force only when necessary to protect oneself or others. These ethics have an impact on every aspect of their life, including the initiatives they contribute to and the type of employment they pursue. A company can facilitate the ethical preferences of its staff by instituting a policy that grants employees the right to decline participation in projects they deem ethically objectionable. Editors who declined to collaborate on reports containing topics they deemed ethically reprehensible have been documented (Corntassel, 2009). This raises the inquiry into the degree of proximity one must have to an ethically reprehensible action to be held morally liable for it (Friesen & Gangadharan, 2013).

In the scenario of white lies and rhubarb pie, an engaged student encounters his prospective in-laws for the very first time. His prospective mother-in-law presents her signature dessert, a rhubarb pie, following a shared meal. She erroneously believes he enjoys rhubarb pie whereas, on the contrary, he abhors it. To improve his first impression, he nevertheless tells a "white lie." He declares himself a rhubarb pie enthusiast who desires a slice (Vredeveldt et al., 2014). After consuming it, he resolves to forget about the situation. Each time he visits his in-laws, his mother-in-law has baked rhubarb pie for years. On certain occasions, she makes special endeavors to procure the necessary ingredients to prepare her son-in-law's preferred pie, even when rhubarb is not in season. The student obediently ingests at least one piece of pie the first few times this occurs. Reminding himself that it is important to make a positive impression, he compares it to his first dinner. Nevertheless, the admission of the deception grows more humiliating as time passes. It is our understanding that rhubarb tarts continue to be prepared (Crosby & Lykes, 2011).

The true consequence of this deceit was the strain it placed on the relationship, not the sporadic requirement to consume rhubarb pie. His intention to have dinner and develop a stronger connection with his in-laws was diminished by the deceit. It is not difficult to envision a scenario in which a lack of openness in your interactions with in-laws might harm the marriage. From a prudential standpoint, deception is frequently more expensive to maintain than speaking what is true (Rejnö et al., 2017).

8.3.1. Deception

Deception creates the appearance of truthfulness when one does not utter a lie. Deceit can be easily achieved without resorting to lying, either through neglecting to rectify erroneous perceptions or by deliberately establishing a skewed belief. Certain activities or diversions, including acting, involve participants anticipating false statements. A skilled actor can portray a role that the viewer knows to be fake with convincing effects (Levine, 2022). There are no ethical concerns regarding the disclosure of the truth that results from these activities. It is not customary for an actor to confront the audience with the statement, "I am not Hamlet, Prince of Denmark." It is advisable to contemplate truth-telling ethics in a broader sense than mere non-lying or non-deceit. It is discovered that the positive ethic of "telling the whole truth" effortlessly resolves the majority of moral conflicts involving expression. One challenge associated with speaking the complete truth is that it requires considerable effort, as it requires introspection to identify the truth before expressing it (Smith et al., 2009).

8.3.2. Telling the Whole Truth

Let's illustrate the potential consequences of sharing the complete truth regarding "the rhubarb pie." The complete truth might have a sound.

"I appreciate your thoughtfulness in preparing the rhubarb pie. You are doing something so thoughtful for me and make me feel like an extended member of your family. Since I do not wish for our relationship to get off to a good start, this is difficult for me to state, but I do not enjoy rhubarb pie. I sincerely appreciate your considerate gesture and eagerly anticipate the opportunity to become a member of your family" (Weiskopf & Willmott, 2013).

Notably, the student was required to comprehend the source of his first temptation to deceive: Specifically, he desired to establish a favorable rapport with his prospective in-laws and held the belief that their new relationship would not tolerate the truth. Through confronting this apprehension, the student has elevated the status of his connection with his in-laws and can now anticipate the establishment of a robust bond founded upon integrity and confidence. In conclusion, the most significant ethical dilemma that students and colleagues encounter in business and daily life is the issue of telling the truth. Based on the above example and experience, the remedy is consistently to speak the truth (Tabak et al., 2013).

8.3.3. Euphemisms

Euphemisms constitute the final component of truth-telling. Euphemisms can be conceptualized as elusive language employed to evade ethical scrutiny of the subject matter being discussed. The Nazis extensively utilized euphemisms. The term "Special treatment" was reserved for executions, while individuals who were mentally retarded or deranged were regarded as "useless eaters" (Miyaji, 1993). Even today, "collateral damage" continues to refer to the unintentional deaths of innocent individuals. "Friendly fire" is a euphemism for the military taking the lives of our soldiers, not a log burned in a hearth. When a falsehood is exposed, politicians refer to it as "no longer operational" (Tuckett, 2006). Organizations that previously engaged in termination practices are now implementing "downsizing" or "rightsizing." One company even referred to this action as "returning resources to the economy." The prevalence of the expression "white lie" in private life suggests that minor deceits are tolerable, if not commendable. Euphemisms are, fundamentally, ethical warning signals. Ignoring them will result in a loss of ethical sensitivity (Sanney et al., 2020).

Did you know?

The word euphemism originated in the mid-17th century from the Greek word euphēmismos, which means "use auspicious words," with the prefix eu- meaning "good" or "well," and the word phēmē meaning "speech.""

8.4. ETHICAL CODES

Learning Objectives

- Construct an ethical code based on different ethical distinctions.
- Evaluate an ethical code based on the four tests.

An ethical code serves as a manifestation of one's innermost guidance. It guides us in situations where one feels disoriented or perplexed. The ethical distinctions furnish a structure upon which one can construct a code of ethics and examine a variety of ethical circumstances. When instructing ethics in the classroom, numerous ethical scenarios are scrutinized by employing these differentiations. By engaging in dialog and introspection, pupils discover ethical frameworks that resonate with them. Subsequently, they formulate individual ethical frameworks upon which they can depend in situations where ethical dilemmas arise (McKinney et al., 2010).

8.4.1. Foundation for the Ethical Code

The origin of an individual ethical code is unknown. What is the origin of it? Some would argue that ethical behavior consists solely of adhering to one's moral compass. Nevertheless, a notable consensus exists regarding the fundamental attributes that constitute an ethical code.

An illustration of this can be seen in an analysis of the fundamental tenets of Buddhism, Judaism, and Islam. While these faiths differ in religious beliefs, modes of worship, and dietary restrictions, they all adhere to the tenets of non-harm, non-theft, and non-deceit (Brooks, 2010).

The fundamental tenets of most legal systems—from the California criminals to the English common law—are non-harm and non-theft. For inspiration and direction, it could be beneficial to turn to others. Parents, role models, peers, and acquaintances all influence one's ethical inclinations. In essence, nevertheless, decision-making analysis is a philosophical stance that acknowledges the individuality of one's judgments, choices, and information, including ethical standards (Oladinrin & Ho, 2016).

8.4.2. Components of an Ethical Code

The most practical ethical codes address the most common ethical dilemmas that people encounter. This generally entails providing the truth. Additional factors that warrant contemplation comprise reproductive concerns (such as surrogacy, abortion, and custody), committing suicide, affiliations with organizations, animal welfare practices, and any specialized ethical considerations inherent to one's chosen career (Ruiz et al., 2015).

8.4.3. Tests of an Ethical Code

It is captivating to produce an exemplary ethical code that exudes high tones of praise; however, the objective should be to develop codes that are practical, rather than merely worthy of admiration. When evaluating a code, ensure that the following four conditions are met with "yes" responses (Leach & Oakland, 2007):

i. Reciprocity: Is someone subject to every rule, regardless of whether that individual is the one originating or obtaining the action?
ii. Universality: Can each rule be applied to all individuals?
iii. Consistency: Does the system of norms exhibit logical coherence?
iv. Actualization: Are behaviors guided by the rules?
v. After analyzing an important decision situation through the lens of your ethical code, you may wish to carry out some internal, individual checks on your code before taking action.
vi. Would you feel at ease confiding in individuals whose ethical discernment you hold in high regard regarding your actions?
vii. Do you anticipate having a positive self-perception upon waking in the morning?
viii. Do you wish for your children's moral convictions to be influenced by your conduct?
ix. Could you grant yourself the confidence that your actions would be covered by reputable press organizations?

Failure to pass any of these assessments signifies the necessity for a revision of your ethical code (Valentine & Barnett, 2003).

SUMMARY

- Upon careful examination of these numerous domains of ethical concern, it becomes evident that avoiding ethical dilemmas is considerably simpler than resolving them.
- Many ethical complications can be circumvented by adhering to the following three practices: Initially, abstain from affiliating with organizations whose ethical principles and conduct are inconsistent with your own. Secondly, refrain from engaging in morally objectionable activities. Lastly, treat everyone with the same regard one would like for their loved ones.
- Possessing a clearly defined ethical code is advisable in circumstances where ethical dilemmas are unavoidable. In the absence of an ethical code, one is compelled to sacrifice aspects of oneself to accept ethical compromises.
- Consequently, the study of ethics can be invigorating. It facilitates a more gratifying and comprehensive existence.

MULTIPLE CHOICE QUESTIONS

1. An employee is ______ likely to disobey orders from a boss to act unethically if the boss is not nearby, not seen very often, or is easy to challenge.

a. always

b. more

c. not

d. less

2. Which of the following actions is prudential?

a. Implementing risk management strategies to mitigate potential losses.

b. smoking cigarettes

c. driving under the influence of alcohol

d. skipping meals to lose weight

3. Utilitarianism dictates that actions are morally good

a. when they promote general happiness,

b. when they promote the actor's interests and well-being,

c. when they are performed by a virtuous person,

d. when they reflect the following of a just principle, regardless of the consequences.

4. Which of the following concepts says that 'one's acts carry ethical weight regardless of the results'?

a. Utilitarianism

b. formalism

c. euphemisms

d. deception

REVIEW QUESTIONS

1. Where do you classify yourself in terms of action-based versus consequence-based views?
2. Mention some areas where you have positive ethical obligations and others where you have negative ethical injunctions.
3. Do you expect your friends to lie for you?
4. You are new to a company. Your boss has asked you to spend time doing some personal things for himself rather than for the company. How would you react?
5. Is it acceptable to "oversell" oneself on a resume?

Answers to Multiple Questions

1. (b) 2. (a) 3. (a) 4. (b)

REFERENCES

1. Anderson, M., Anderson, S., & Armen, C., (2005). Towards machine ethics: Implementing two action-based ethical theories. In: *Proceedings of the AAAI 2005 Fall Symposium on Machine Ethics* (Vol. 2, pp. 1–7).
2. Awad, M., & Fraihat, S., (2023). Recursive feature elimination with cross-validation with decision tree: Feature selection method for machine learning-based intrusion detection systems. *Journal of Sensor and Actuator Networks*, *12*(5), 67.
3. Beauchamp, T. L., (1984). On eliminating the distinction between applied ethics and ethical theory. *The Monist*, *67*(4), 514–531.
4. Begley, A., & Blackwood, B., (2000). Truth-telling versus hope: A dilemma in practice. *International Journal of Nursing Practice*, *6*(1), 26–31.
5. Bloomquist, J., (2010). Lying, cheating, and stealing: A study of categorical misdeeds. *Journal of Pragmatics*, *42*(6), 1595–1605.
6. Bouilloud, J. P., Deslandes, G., & Mercier, G., (2019). The leader as chief truth officer: The ethical responsibility of "managing the truth" in organizations. *Journal of Business Ethics*, *157*, 1–13.
7. Brooks, R., (2010). The development of a code of ethics: An online classroom approach to making connections between ethical foundations and the challenges presented by information technology. *American Journal of Business Education (AJBE)*, *3*(10), 1–14.
8. Childress, J. F., (1977). The identification of ethical principles. *The Journal of Religious Ethics*, *4*(5), 39–66.
9. Choi, H. J., Park, H. S., & Oh, J. Y., (2011). Cultural differences in how individuals explain their lying and truth-telling tendencies. *International Journal of Intercultural Relations*, *35*(6), 749–766.

10. Clarke, C. A., & Knights, D., (2015). Careering through academia: Securing identities or engaging ethical subjectivities? *Human Relations*, *68*(12), 1865–1888.

11. Cohen, T. V., (1998). Three forms of jeopardy: Honor, pain, and truth-telling in a sixteenth-century Italian courtroom. *The Sixteenth Century Journal*, *10*(3), 975–998.

12. Corbera, E., Anguelovski, I., Honey-Rosés, J., & Ruiz-Mallén, I., (2020). Academia in the time of COVID-19: Towards an ethics of care. *Planning Theory & Practice*, *21*(2), 191–199.

13. Corntassel, J., (2009). Indigenous storytelling, truth-telling, and community approaches to reconciliation. *ESC: English Studies in Canada*, *35*(1), 137–159.

14. Crosby, A., & Lykes, M. B., (2011). Mayan women survivors speak: The gendered relations of truth telling in postwar Guatemala. *International Journal of Transitional Justice*, *5*(3), 456–476.

15. Davis, J. R., & Welton, R. E., (1991). Professional ethics: Business students' perceptions. *Journal of Business Ethics*, *10*, 451–463.

16. Dey, P., & Mason, C., (2018). Overcoming constraints of collective imagination: An inquiry into activist entrepreneuring, disruptive truth-telling and the creation of 'possible worlds.' *Journal of Business Venturing*, *33*(1), 84–99.

17. Drumwright, M. E., & Murphy, P. E., (2009). The current state of advertising ethics: Industry and academic perspectives. *Journal of Advertising*, *38*(1), 83–108.

18. Drumwright, M., Prentice, R., & Biasucci, C., (2015). Behavioral ethics and teaching ethical decision making. *Decision Sciences Journal of Innovative Education*, *13*(3), 431–458.

19. Ekman, S., (2017). A history of vocational ethics and professional identity: How organization scholars navigate academic value spheres. *Human Relations*, *70*(4), 461–487.

20. Friesen, L., & Gangadharan, L., (2013). Designing self-reporting regimes to encourage truth telling: An experimental study. *Journal of Economic Behavior & Organization*, *94*, 90–102.

21. Graf, K., (2011). Action-based jurisprudence: Praxeological legal theory in relation to economic theory, ethics, and legal practice. *Libertarian Papers*, *3*, 1–11.

22. Green, B. A., (1997). The role of personal values in professional decision-making. *Geo. J. Legal Ethics*, *11*, 19.

23. Greenwood, M. R., (2002). Ethics and HRM: A review and conceptual analysis. *Journal of Business Ethics*, *36*, 261–278.

24. Grover, S. L., (2005). The truth, the whole truth, and nothing but the truth: The causes and management of workplace lying. *Academy of Management Perspectives*, *19*(2), 148–157.

25. Hare, R. M., (1992). One philosopher's approach to business and professional ethics. *Business & Professional Ethics Journal*, 7, 3–19.

26. Hellwig, H. J., (2008). At the intersection of legal ethics and globalization: International conflicts of law in lawyer regulation. *Penn St. Int'l L. Rev.*, *27*, 395.

27. Janvier, A., Barrington, K. J., Aziz, K., & Lantos, J., (2008). Ethics ain't easy: Do we need simple rules for complicated ethical decisions? *Acta Paediatrica*, *97*(4), 402–406.
28. Kass, N. E., Faden, R. R., Goodman, S. N., Pronovost, P., Tunis, S., & Beauchamp, T. L., (2013). The research-treatment distinction: A problematic approach for determining which activities should have ethical oversight. *Hastings Center Report*, *43*(1), 4–15.
29. Kite, J. V., (2016). The fundamental ethical ambiguity of the analyst as person. *Journal of the American Psychoanalytic Association*, *64*(6), 1153–1171.
30. Kreie, J., & Cronan, T. P., (1998). How men and women view ethics. *Communications of the ACM*, *41*(9), 70–76.
31. Leach, M. M., & Oakland, T., (2007). Ethics standards impacting test development and use: A review of 31 ethics codes impacting practices in 35 countries. *International Journal of Testing*, *7*(1), 71–88.
32. Levine, E. E., (2022). Community standards of deception: Deception is perceived to be ethical when it prevents unnecessary harm. *Journal of Experimental Psychology: General*, *151*(2), 410.
33. Mahjoobi, J., & Etemad-Shahidi, A., (2008). An alternative approach for the prediction of significant wave heights based on classification and regression trees. *Applied Ocean Research*, *30*(3), 172–177.
34. McKinney, J. A., Emerson, T. L., & Neubert, M. J., (2010). The effects of ethical codes on ethical perceptions of actions toward stakeholders. *Journal of Business Ethics*, *97*, 505–516.
35. Michaels, C. A., Brown, F., & Mirabella, N., (2005). Personal paradigm shifts in PBS experts: Perceptions of treatment acceptability of decelerative consequence-based behavioral procedures. *Journal of Positive Behavior Interventions*, *7*(2), 93–108.
36. Miyaji, N. T., (1993). The power of compassion: Truth-telling among American doctors in the care of dying patients. *Social Science & Medicine*, *36*(3), 249–264.
37. Nucci, L., Guerra, N., & Lee, J., (1991). Adolescent judgments of the personal, prudential, and normative aspects of drug usage. *Developmental Psychology*, *27*(5), 841.
38. Oladinrin, O. T., & Ho, C. M. F., (2016). Enabling ethical code embeddedness in construction organizations: A review of process assessment approach. *Science and Engineering Ethics*, *22*, 1193–1215.
39. Pasewark, W. R., & Riley, M. E., (2010). It's a matter of principle: The role of personal values in investment decisions. *Journal of Business Ethics*, *93*, 237–253.
40. Radoilska, L., (2008). Truthfulness and business. *Journal of Business Ethics*, *79*, 21–28.
41. Raelin, J. A., (1989). Professional and business ethics: Bridging the gap. *Management Review*, *78*(11), 39.
42. Reader, B., (2006). Distinctions that matter: Ethical differences at large and small newspapers. *Journalism & Mass Communication Quarterly*, *83*(4), 851–864.

43. Rejnö, Å., Silfverberg, G., & Ternestedt, B. M., (2017). Reasoning about truth-telling in end-of-life care of patients with acute stroke. *Nursing Ethics*, *24*(1), 100–110.
44. Royzman, E. B., Cusimano, C., Metas, S., & Leeman, R. F., (2020). Is opposition to genetically modified food "morally absolutist"? A consequence-based perspective. *Perspectives on Psychological Science*, *15*(2), 250–272.
45. Ruiz, P., Martinez, R., Rodrigo, J., & Diaz, C., (2015). Level of coherence among ethics program components and its impact on ethical intent. *Journal of Business Ethics*, *128*, 725–742.
46. Sanney, K. J., Trautman, L. J., Yordy, E. D., Cowart, T. W., & Sewell, D. J., (2020). The importance of truth telling and trust. *Journal of Legal Studies Education*, *37*(1), 7–36.
47. Schauster, E., Ferrucci, P., Tandoc, E., & Walker, T., (2021). Advertising primed: How professional identity affects moral reasoning. *Journal of Business Ethics*, *171*, 175–187.
48. Schrag, B., (2005). Teaching research ethics: Can web-based instruction satisfy appropriate pedagogical objectives? *Science and Engineering Ethics*, *11*(3), 347–366.
49. Shafer, W. E., Morris, R. E., & Ketchand, A. A., (2001). Effects of personal values on auditors' ethical decisions. *Accounting, Auditing & Accountability Journal*, *14*(3), 254–277.
50. Shahidi, J., (2010). Not telling the truth: Circumstances leading to concealment of diagnosis and prognosis from cancer patients. *European Journal of Cancer Care*, *19*(5), 589–593.
51. Smetana, J. G., (1983). Social-cognitive development: Domain distinctions and coordinations. *Developmental Review*, *3*(2), 131–147.
52. Smith, N. C., Kimmel, A. J., & Klein, J. G., (2009). Social contract theory and the ethics of deception in consumer research. *Journal of Consumer Psychology*, *19*(3), 486–496.
53. Speer, S. A., & Hutchby, I., (2003). From ethics to analytics: Aspects of participants' orientations to the presence and relevance of recording devices. *Sociology*, *37*(2), 315–337.
54. Stutchbury, K., & Fox, A., (2009). Ethics in educational research: Introducing a methodological tool for effective ethical analysis. *Cambridge Journal of Education*, *39*(4), 489–504.
55. Tabak, N., Itzhaki, M., Sharon, D., & Barnoy, S., (2013). Intentions of nurses and nursing students to tell the whole truth to patients and family members. *Journal of Clinical Nursing*, *22*(9, 10), 1434–1441.
56. Tonry, M., (2014). Legal and ethical issues in the prediction of recidivism. *Federal Sentencing Reporter*, *26*(3), 167–176.
57. Twala, B., (2009). An empirical comparison of techniques for handling incomplete data using decision trees. *Applied Artificial Intelligence*, *23*(5), 373–405.

58. Valentine, S., & Barnett, T., (2003). Ethics code awareness, perceived ethical values, and organizational commitment. *Journal of Personal Selling & Sales Management*, *23*(4), 359–367.

59. Vredeveldt, A., Van, K. P. J., & Granhag, P. A., (2014). The inconsistent suspect: A systematic review of different types of consistency in truth tellers and liars. *Investigative Interviewing*, *4*(3), 183–207.

60. Wald, E., (2007). Lawyer mobility and legal ethics: Resolving the tension between confidentiality requirements and contemporary lawyers' career paths. *J. Legal Prof.*, *31*, 199.

61. Weiskopf, R., & Willmott, H., (2013). Ethics as critical practice: The "pentagon papers," deciding responsibly, truth-telling, and the unsettling of organizational morality. *Organization Studies*, *34*(4), 469–493.

62. White, J. E., (1996). Personal ethics versus professional ethics. *Airpower Journal*, *10*, 30–34.

63. Wilson, M., (2012). The flourishing analyst, responsibility, and psychoanalytic ethics: Commentary on Kirshner. *Journal of the American Psychoanalytic Association*, *60*(6), 1251–1258.

64. Wise, E. H., (2008). Competence and scope of practice: Ethics and professional development. *Journal of Clinical Psychology*, *64*(5), 626–637.

Index

Foundations of Decision Analysis

Decision analysis is a systematic and quantitative approach to decision-making that involves assessing and evaluating different alternatives to make informed choices. The foundations of decision analysis lie in the recognition that decision-making is often complex and involves uncertainty, multiple objectives, and conflicting priorities. Developed as an interdisciplinary field drawing from economics, mathematics, psychology, and management, decision analysis provides a structured framework to analyze decisions in a rational and logical manner. One key element is the identification of decision criteria and the quantification of uncertainties, allowing decision-makers to model and evaluate the potential outcomes of different choices. Decision trees, influence diagrams, and probability assessments are common tools used in decision analysis to represent and evaluate the possible consequences of decisions. By breaking down complex decisions into smaller, more manageable components, decision analysis enhances the decision-maker's ability to understand, compare, and ultimately choose the most favorable course of action.

This book, "Foundations of Decision Analysis," is divided into eight chapters, each focusing on a specific aspect of decision analysis. The simple format provides a straightforward way for readers to explore and understand the basics of this field. The first chapter describes the history of decision analysis, introducing the Five Rules and illustrating their real-world application. In the second chapter, the focus is on decision theory, addressing theoretical questions and processes. The chapter explores different decision models, such as sequential and non-sequential, covering concepts like deciding, valuing, and expected utility. Chapter three discusses effective problem identification and introduces taxonomies for decision analysis. Chapter four explores decision-making under uncertainty and risk, introducing tools like decision trees and influence diagrams. It provides practical insights into handling uncertain situations. Chapter five delves into the decision context, discussing objectives and criteria. The sixth chapter explores decision-making using game theory, covering various game scenarios, and providing a practical understanding of strategic interactions. Chapter seven focuses on effective communication strategies in decision-making. The final chapter discusses the role of ethics in decision-making, covering ethical distinctions and considerations in decision trees, offering insights into real-world ethical situations.

Designed with a focus on meeting the educational needs of students and scholars, this book aims to deliver comprehensive knowledge and foster a deep understanding of decision analysis. Our intention is for this book to serve as a valuable resource across various academic disciplines, providing clarity and insightful perspectives for readers seeking to navigate the complexities of decision-making scenarios.

About the Author

Mohamed Amine Hamdani, PhD in Finance and Econometrics, boasts over 12 years of experience in corporate finance. He has worked with various large companies and in academia, striving to bridge theoretical frameworks with practical applications through his diverse roles.

Mohamed Amine's international career has spanned North Africa, France, and Brazil, where he has honed his expertise in corporate finance and accounting. His academic journey includes a Master's degree from Ca' Foscari University of Venice and a DBA from the High Institute of Management and Planning in Algiers, Algeria. He has also participated in various research programs with the Aix-Marseille School of Economics in France, maintaining a strong connection with the latest technical updates in corporate finance.

TAP
Toronto Academic Press

ISBN 978-1-77956-700-0